BOOK OF ABSTRACTS

MCLS CONFERENCE 2023
5 to 8 JUNE 2023| Loughborough, UK

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PROGRAMME OVERVIEW

Monday 5th June

13:00 - 14:00	**Registration** *(Exhibition area)*		
	Pre-conference workshops		
14:00 - 17:30 (coffee break: 15:30-16:00)	**Data visualisation** *Krzysztof Cipora* *Room: CC021*	**Computing statistical power in R using simulations** *Hugues Lortie-Forgues* *Room: CC013*	**How to make a research lab accessible** *Erin Maloney & Fraulein Retanal* *Room: CC012*
18:00 - late	**Trainee Socia Event** *(Jam Garden)*		

Tuesday 6th June

Room	Room under the terrace	CC021	CC013	CC012	CC011
8:00 - 9.00	**Registration and Welcome** *(Exhibition area)*				
9:00 -10.15	Learning arithmetic and literacy: Common dynamics and cognitive underpinnings in typical and atypical samples *Chair: Chiara Banfi*	Design and delivery of mathematics intervention in schools *Chair: Sarah Powell*	Emotions, attitudes and beliefs in math learning: new insights from implicit and explicit measures *Chair: Maria Chiara Passolunghi*	Investigating home math environments: Looking beyond mothers' inputs in relation to children's math skills *Chair: Xiao Zhang*	ManyNumbers: A planned multi-lab investigation of the conceptual foundations of early number development *Chair: Melissa Libertus*
10:15 - 10.45	**Coffee Break** *(Exhibition area)*				
10:45 - 12.00	Using real-time data of mathematical thinking and learning processes as a basis for adaptive cognitive and affective support *Chair: Anselm Strohmaier*	More than nothing? Empirical insights into children and adults' conceptions of "zero" *Chair: Nicholas Vest*	Assessing advanced mathematical understanding *Chair: Ian Jones*	Nothing works in isolation: How Mathematics Anxiety Influences Children's Mathematics Achievement *Chair: Serena Rossi*	The impact of language experience on mathematical abilities: Evidence from deaf and hard of hearing children and adults *Chair: Stacee Santos*
12:00 - 13:.00	**Lunch** *(Exhibition area)* & **Mentoring Lunch** *(Room under the terrace)*				
13:00 - 14:00	**Poster Session 1** *(Exhibition area)*				
14:00 - 15:15	Big ideas for little kids: Early conceptual foundations in mathematics *Chair: Alexandria A. Viegut*	Numerical and mathematical cognition among neurodivergent children *Chair: Arcan Altinar*	How much and where: Conceptualizing and measuring different types of children's mathematical language *Chair: Lauren Westerberg*	Mathematical brain before school entry *Chair: Elizaveta Ivanova*	Look what you made me do: Registered reports on early mathematics interventions *Chair: David Purpura*
15:15 - 15:45	**Coffee Break** *(Exhibition area)*				
15:45 - 16:45	**Poster Session 2** *(Exhibition area)*				
16:45 - 18:00	Exploring the underlying mechanisms of number processing and math cognition *Chair: Xueying Ren*	Dyscalculia – early detection and prevention of neuromyths *Chair: Karin Kucian*	Mathematical explanations *Chair: Matthew Inglis*	Measurement and impact of parent-child interactions for mathematical learning in the home environment *Chair: Colette Duncan*	Equity-focused programs to measure and promote math learning and executive functioning *Chair: Geetha Ramani*
18:00	**Reception** *(Edward Herbert Building)*				

Wednesday 7th June

Room	Room under the terrace	CC021	CC013	CC012	CC011
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9:00 -10.15	How is numerical syntax complex, and why is it hard? *Chair: Michal Pinhas*	Early algebraic thinking *Chair: Ulises Xolocotzin*	Risk assessment for mathematics difficulties and disabilities *Chair: Patrick Ehrman*	Children's strategies in arithmetic *Chair: Catherine Thevenot & Jérôme Prado*	Beyond the surface: Which features of instructional materials help or hinder mathematical learning *Chair: Megan Foulkes & Suzanne Splinter*
10:15 - 10.45	**Coffee Break** *(Exhibition area)*				
			Open Submission talks		
10:45 - 12.00	Math attitude/anxiety & gender Enrica Donolato Michael Slipenkyj Maristella Lunardon Shuyuan Yu	Struggling learners & intervention Madison Cook Franz Wortha Syeda Sharjina Akther Lauren E. Anthony	Numerosity, perception & rational numbers Chuyan Qu Nathan T.T. Lau Isabella Starling-Alves Eva Redican	Early math skills & home envrionment Dominic Kelly Shirley Duong Alexa Ellis Tanya Paes	Arithmetic & strategies Nicolas Masson Joshua Jaffe Katarina Gvozdic Asya Istomina
12:00 - 13:.00	**Lunch & Board Meetings** *(Room under the teraace & CC21)*				
13:00 - 14:00	**Poster Session 3** *(Exhibition area)*				
14:00 - 15:15	Numerical development and applied mathematics – from kindergarten to primary school. *Chair: Yarden Gliksman*	Integrating perspectives on adults' and children's math anxiety *Chair: Carlo Tomasetto*	Evidencing the approximate system - findings from different research perspectives *Chair: Anita Lopez-Pedersen*	Parent Language Input, Math Attitudes, and Family Contexts in Children's Math Learning *Chair: Yu Zhang*	"Everything I know I learned after I was thirty.": the past, the present, and the future of Spatial-Numerical Associations *Chair: Krzysztof Cipora*
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15:45 - 16:45	**MCLS business meeting** *(CC011)*				
16:45 - 18:00	Foundational Number Skills and Early Assessment *Chair: Heather Douglas*	The multiple aspects of dyscalculia and calculation difficulties *Chair: Dror Dotan*	Algorithmic foundations of mathematical development *Chair: Joshua Rule*	Gesture's role in numerical development *Chair: Madeleine Oswald*	Numerical cognition in healthy and pathological aging *Chair: Hannah D. Loenneker*

Thursday 8th June

Room	Room under the terrace	CC021	CC013	CC012	CC011
9:00 -10.15	The role of perception in arithmetic cognition *Chair: Josh Medrano*	Mathematics attitudes and performance: importance of self-concept and self-efficacy *Chair: Ann Dowker*	Symbolic and non-symbolic number processing in dyscalculia *Chair: Michael Andres*	Data based individualization in mathematics for struggling learners *Chair: Stephanie Hopkins*	The role of inhibitory control in mathematics: Beyond correlations *Chair: Lucy Cragg*
10:15 - 10.45	**Coffee Break** *(Exhibition area)*				
10:45 - 12.00	Automatic number processing: Features, measurement, and links to individual characteristics *Chair: Lilly Roth*	Developmental pathways of mathematical abilities: Evidence from typical and atypically developing populations *Chair: Jo Van Herwegen*	Perspectives and influences on math engagement in early childhood: The role of family math *Chair: Mary DePascale*	Number games in the real world: Factors influencing play-based interventions at home and school *Chair: Francesco Sella*	Early math and motor skills: Evidence from around the world *Chair: Carolina Jiménez-Lira*
12:00 - 13:.00	**Lunch** *(Exhibition area)*				
13:00 - 14:00	**Poster session 4** *(Exhibition area)*				
14:00 - 15:15	Learning environments contributing to early numeracy and literacy skills *Chair: Jenni Salminen*	Post-stroke numerical deficit (Acalculia): Prevalence, impact, assessment and interventions *Chair: Yael Benn*	Word problems? No problem! School-based interventions for students with word-problem difficulty *Chair: Katherine Berry*	Cognitive, affective, and developmental factors in the spatial and ordinal understanding of numbers *Chair: Chang Xu*	Understanding the interplay of attention, executive function and mathematics by embracing complexity: From theory, to diversity, to intervention... and back to theory again *Chair: Gaia Scerif*
15:15 - 15:45	**Coffee Break & Closing** *(Exhibition area)*				

MONDAY 5 JUNE

Preconference Workshops, 2.00 pm – 5.30 pm

Data visualisation

Krzysztof Cipora (k.cipora@lboro.ac.uk)
Loughborough University

A picture says more than a thousand words – probably each of us has heard this cliché. In this workshop we will focus on how to make this picture so that it (1) tells the truth and nothing but the truth about the data; (2) says as many words as possible and does not overwhelm our audience too much; (3) looks nice; (4) can be seen and understood by as many people as possible (including individuals with colour vision problems, and those who look at our work in greyscales). In the first part we will focus on general principles of data visualisation, then we explore some out-of-the-box solutions implemented in open source JASP software. The third, and the most extensive part will cover data visualisation in ggplot2 environment in R.

Prior knowledge of R may be useful but is by no means necessary to participate in the workshop. It is recommended that the participants bring their laptops with necessary (free) software installed. Before the workshop go to https://osf.io/46ez5/ In the "Wiki" section you will find the information on what to download and install on your computer.

Computing statistical power in R using simulations

Hugues Lortie-Forgues (h.lortie-forgues@lboro.ac.uk)
Loughborough University

In this session, we will introduce how to conduct simulations in R to compute statistical power. Our goal is to utilize a minimal number of packages, ensuring a clear understanding of the underlying concepts. We will demonstrate power analysis techniques through simulations for basic tests, such as t-tests, ANOVA, and regression, as well as more complex cases involving interactions. Using simulation is a versatile approach to computing power, which can easily be adapted to a wide range of research designs and assumptions. This workshop will also serve as a valuable opportunity to review fundamental statistical concepts.

Participants are encouraged to bring their own laptops to actively engage in running and modifying the code. Alternatively, you can follow along with the pdf document provided closer to the workshop date.

How to make a research lab accessible

Erin Maloney (erin.maloney@uottawa.ca) & Fraulein Retanal (freta059@uottawa.ca)
University of Ottawa

In this workshop, we will discuss accessibility in research, both with respect to making research more accessible to those with exceptionalities, and with respect to knowledge mobilization in general. Participants will learn, for example, strategies for increasing the readability of their presentations for those with visual impairments and specific reading difficulties, how to ensure that screen-reading technology can read their text, and how to use live closed captioning within their presentations. Participants will also be taught how to easily and quickly create infographics to communicate their research to broader audiences while meeting accessibility standards.

Participants are encouraged to bring a device compatible with Canva (e.g., laptop, tablet), to have registered for a free Canva account (https://www.canva.com), and to have a piece of research in mind for which they would like to create an infographic.

TUESDAY 6 JUNE

Symposia 9.00 am – 10.15 am

Learning arithmetic and literacy: Common dynamics and cognitive underpinnings in typical and atypical samples

Chair: Chiara Banfi
Institute of Psychology, University of Graz

Reading, spelling and arithmetic are the cornerstones of early school attainment and foster the acquisition of higher-level competences. Although they are three clearly distinct ability domains, there is overlap among them. The three skills are indeed correlated: Children with higher literacy skills also show high achievement in arithmetic and vice versa. Learning disorders in these domains co-occur more often than what would be expected based on individual prevalence rates. What factors explain the association among reading, spelling and arithmetic? This symposium aims to answer this question by showing recent findings from typical and atypical developmental samples and across different study designs and languages. The first contribution by Banfi et al. is based on a cross-sectional study that investigated common dynamics and cognitive underpinnings of orthographic and arithmetic learning in German- and Italian-speaking 2nd and 3rd graders. The second and third presentations are based on longitudinal designs in different languages. Jöbstl et al. present results from German- and English-speaking children followed from Grade 1 to Grade 3. They addressed the contribution of domain-general as compared to domain-specific predictors of reading and arithmetic. Koponen et al. present findings from a large longitudinal study that followed Finnish children from Kindergarten to adolescence. They identified cognitive and parental dimensions that predict reading and arithmetic dysfluency deficits later on. Nardacchione et al. investigated Italian 5th graders with and without reading and arithmetic deficits. They tested the hypothesis that a global factor related to slow performance underlies both reading and math difficulties.

Presentation 1: Cognitive dimensions of acquisition and retrieval of orthographic and arithmetic knowledge in primary school children: Insights from German and Italian

Chiara Banfi*[1], Chiara Valeria Marinelli[2], Pierluigi Zoccolotti[3], Karin Landerl[1]
[1] Institute of Psychology, University of Graz [2] University of Salento [3] University of Rome

Introduction: Reading, spelling and arithmetic are distinct abilities. Yet, they are correlated and share neurocognitive mechanisms. They also undergo similar skill acquisition steps, progressing from slow, serial procedures toward fast, parallel retrieval of acquired memory traces. This study aims to shed light on the shared mechanisms underlying this overlap by addressing the relation between acquisition and retrieval of new verbal facts in German- and Italian-speaking children. We further tested the contribution of executive functions to verbal learning. Methods: The sample comprised 2nd and 3rd graders. The German-speaking sample (n=40) underwent trainings with additions and multiplications. The Italian-speaking sample (n=36) learnt pseudowords by repeated spelling to dictation. Retrieval was tested with recognition tasks. Executive functions were measured by a listening span task (working

memory) and by different inhibition tasks. Results: Working memory contributed significantly to acquisition of arithmetic and orthographic facts. Recognition accuracy was largely explained by performance during the learning phase. Working memory made no significant contribution to recognition, with the exception of addition recognition. Inhibition did not significantly predict acquisition or retrieval. Discussion: The contribution of working memory to learning highlights the role of active manipulation during acquisition of new verbal facts. Active manipulation is no longer needed once associations are available in memory. The role of working memory in recognition was indeed negligible, with the exception of addition recognition, a particularly demanding task for young children. The fact that inhibition did not predict verbal learning is unexpected and warrants further investigation related to its operationalization.

Presentation 2: 1-two-3: Associations and dissociations of reading and arithmetic

Viktoria Jöbstl[1]*, Silke M. Göbel[2], Karin Landerl[1]
[1] Institute of Psychology, University of Graz [2] University of York

Reading and arithmetic are core domains of formal education, foundational for the development of other academic domains and affecting later socioeconomic status. Despite being highly correlated throughout development, predictors were mostly identified in studies investigating each skill in isolation. The current study addresses which predictors of reading and arithmetic are domain-specific and which predictors account for associations. We followed 166 German- (M_{age} = 7;2 years) and 191 English-speaking children (M_{age} = 6;2 years) from first to third grade. Predictors of reading (phonological awareness, RAN), arithmetic (counting, number knowledge, magnitude comparison), as well as domain-general predictors (nonverbal intelligence, working memory) were assessed in Grade 1, reading (fluency) and arithmetic (fluency & accuracy) in Grades 1, 2, and 3. In hierarchical regression models, we investigated whether domain-general skills (step 1) explain unique variance independently of domain-specific contributions (step 2). The second learning domain was introduced in a third and last step (i.e., arithmetic for reading as dependent variable and vice versa), testing which predictors account for unique, domain-specific variance. Predictors accounting for reading-arithmetic covariance were identified by partialling out their contribution to the reading-arithmetic correlation. Nonverbal intelligence predicted arithmetic accuracy and working memory predicted reading and arithmetic. Phonological awareness and RAN explained variance specific to reading, magnitude comparison and number knowledge variance specific to arithmetic (Grades 1-3). Both domain-general and domain-specific predictors accounted for covariance. This evidence can be explained in terms of overlaps in developing neurocognitive networks of reading and arithmetic.

Presentation 3: Identification of adolescent arithmetic and reading dysfluency – when and how?

Tuire Koponen*[1], Kenneth Eklund[2], Kaisa Aunola[2], Marja-Kristiina Lerkkanen[3], Pekka Niemi[4], Anna-Maija Poikkeus[3], Minna Torppa[3]
[1] Department of Education, University of Jyväskylä [2] Department of Psychology, University of Jyväskylä [3] Department of Teacher Education, University of Jyväskylä [4] University of Turku

Background: Long-term negative consequences of learning difficulties in arithmetic and reading are well known but very little is yet known about how and when to identify students in increased risk to fluency difficulties in adolescence. Aims: To examine how early, to what

extent and by which constellation of parental and child related factors could we detect adolescent difficulties in arithmetic and/or reading fluency? Methods. Children (N=941) were followed from Kindergarten (Age 6) to adolescence (Age 13-16). Children's cognitive skills were assessed in Kindergarten, their arithmetic and reading fluency were assessed in grades 2, 4, 6, 7, and 9, and their parents reported about their own arithmetic and reading difficulties as well as their educational levels. Scoring at both grades 7 and 9 below the 16th percentile was considered as a fluency difficulty either in reading (N=87, 9.2%) or arithmetic (N=84, 8.9%). Results: Although adolescent difficulties could be moderately predicted by parental measures and Kindergarten cognitive skills alone, specificity of these models remained low. Adding school-age fluency measures increased both the AUC-value and specificity of the models. However, parents' learning difficulties in reading and kindergarten skills in both skills remained significant even after including school-age fluency measures. Conclusions: Although kindergarten skills showed their relevance with unique predictive value and importance of cumulative information, our findings highlight the necessity for monitoring reading and arithmetic fluency development during the primary school years when predicting adolescent fluency difficulties.

Presentation 4: The role of the global factor in developmental dyslexia and dyscalculia

Giuliana Nardacchione[1], Pierluigi Zoccolotti[2], Gloria Di Filippo[2], Giulia Piergiovanni[2], Paola Angelelli[3], Francesca Vizzi[3], Chiara Valeria Marinelli[3]
[1] Learning Sciences Hub, University of Foggia [2] University of Rome [3] Uniersity of Salento

The study examined whether developmental dyslexia and dyscalculia could be expressed in terms of global factors by reference to the rate and amount (RAM) and difference engine (DEM) models. We explored the existence of a global factor for numerical abilities, producing slower performances for more difficult tasks, as previously reported for reading in dyslexic children. Moreover, we aimed to examine if math tests underlie the same global factor affecting reading.5th grade typically developing children and children with dyslexia and dyscalculia in association and dissociation were examined with several judgment tasks. Reading was tested with a lexical decision task, examining the effect of lexicality, frequency, and length. We tested numerical and computation skills by: -Arithmetic facts tests (judge the correctness of multiplication tables and additions below ten), - Numerical knowledge (identify the largest number between pairs of numbers or judge whether two numbers are adjacent or not in the number line) - Computation skills (judging the correctness of addictions and multiplication beyond ten). Results confirmed the presence of a global factor in reading and a sizeable length effect among impaired children. Also, math performance was accounted for by a single global factor responsible for the slowness of children with a learning disorder. When controlling for this global factor, multiplications were the most impaired performance in children with a learning disorder. We will discuss the results focusing on the difference between isolated or comorbidity deficits.

Design and delivery of mathematics intervention in schools

Chair: Sarah Powell
The University of Texas at Austin

Researchers have studied how students develop mathematical knowledge and learn mathematics for decades. A significant challenge, however, is the translation of research, collected in clinics or with small samples, into school-based interventions that have promise of impacting hundreds or thousands of students and teachers. In this symposium, our primary objective is to show how to take what is known about mathematical cognition (i.e., research) and translate that research into action within schools through the design and delivery of mathematics intervention (i.e., practice). Across four presentations, we will provide examples of translating research into practice. In the first presentation, we present research on the importance of learning mathematics vocabulary and provide an overview of an 11-session intervention on how to teach fraction mathematics vocabulary to Grade 4 students. In the second presentation, we review research related to cognitive science, then describe how that research was incorporated into a school-based fraction intervention. In the third presentation, we describe research-based practices for the teaching of mathematics and how these practices were translated into professional learning and coaching sessions for teachers. In a fourth presentation, we focus on research in preschools and how to develop materials for very young children and test these materials through a series of iterative studies. Across all four presentations, the student sample of interest is students who experience mathematics difficulty (MD) and may require targeted mathematics intervention efforts. At the end of the presentation, our discussant will highlight how to design and effectively deliver school-based mathematics interventions.

Presentation 1: Iterative development of numeracy and literacy supports for preschoolers

Michelle Luna[1]*, Connor O'Rear[2], Alcides Algueta[1], Tery Cobb[1], Jill Pentimonti[1], Nicole McNeil[1]
[1] University of Notre Dame [2] Purdue University

Children from higher socioeconomic (SES) backgrounds often have greater access to educational opportunities than do children from lower SES backgrounds. These opportunity gaps lead to differences in children's early kindergarten readiness and subsequent achievement and life outcomes (Duncan et al., 2007; Campbell et al., 2002; Gray-Lobe et al., 2021). Given that high-quality tutoring is one of the most effective ways to reduce academic opportunity gaps (Fryer, 2017; Nickow et al., 2020), we have been working with partners in our community to increase access to evidence-based tutoring in math and literacy for children in PK-9. Granted, most people do not think of preschoolers when they think of tutoring, but children of all ages can benefit from time spent 1:1 with a caring adult who has knowledge of cognitive science and experience applying it to support children's learning. Our work at the PK level is guided by research showing benefits of learning plans and materials designed to help preschoolers construct print awareness (Justice & Ezell, 2002) and early number knowledge (Gibson et al., 2020; Jordan et al., 2010; Mix et al., 2012; O'Rear et al., 2019; Purpura et al., 2017). In this talk, we will describe the basic research that informs our PK approach and how we are using it to iteratively design, implement, and evaluate our tutoring program for children

in Head Start during the school day. We will highlight the impact on children's print awareness and numeracy, on tutors' knowledge and career aspirations, and on university-community relationships.

Presentation 2: Design and delivery of a fraction vocabulary intervention

Xin Lin*
University of Macau

A growing body of research suggests students' knowledge of mathematics vocabulary is critical for developing mathematics skills (Powell & Nelson, 2017; Purpura et al., 2021). However, mathematics vocabulary acquisition remains difficult, especially for students experiencing MD (Forsyth & Powell, 2017; Lin et al., 2021). Examining the impact of a mathematics vocabulary intervention on the mathematics knowledge of students with MD is necessary to better understand how improvements to mathematics vocabulary knowledge relate to gains in mathematics performance.We discuss a fraction vocabulary intervention in which we used an adapted graphic organizer paired with explicit instruction and multiple exposures to teach fraction terms to Grade 4 students with MD. Each intervention lesson included three activities: (1) Read and Match, to review and solidify knowledge of previously introduced fraction vocabulary terms; (2) Vocabulary Grid Instruction that included definitions, examples and non-examples, and practice problems; and (3) Vocabulary Log Review in which students received immediate affirmative or corrective feedback.In this quasi-experimental study, we assigned students to either the (a) intervention (n = 16) or (b) business-as-usual (n = 17) condition. Intervention sessions occurred for 25 minutes, three times per week for four weeks (i.e., 11 sessions). Results indicated the impact of the fraction vocabulary intervention was significant for fraction vocabulary (ES = 0.67) and fraction arithmetic (ES = 0.39) posttests. These data affirm (a) that students with MD can successfully learn fraction vocabulary from participation in a brief intervention and (b) improved fraction vocabulary knowledge may positively affect their fraction competencies.

Presentation 3: From cognitive science to school-based intervention

Lynn Fuchs[1,2]*, Doug Fuchs[1,2], Pamela Seethaler[1]
[1] Vanderbilt University [2] American Institutes for Research

We discuss Super Solvers, a fractions intervention at Grades 3-5 (SS_INT) based on principles derived from cognitive science. We outline and explain these design principles as contextualized within SS_INT. We then describe a recent randomized controlled trial that isolated the effects of interleaved instruction within the SS_INT's calculations segment. Students with MD were randomly assigned one of three conditions: (1) the conceptual and calculations components of SS_INT with blocked calculations instruction (SS_INT_B); (2) the conceptual and calculations components of SS_INT with interleaved calculations instruction (SS_INT_I); or (3) control. On a mix of proximal and transfer conceptual and calculations outcomes, SS_INT across conditions produced strong, significant effects over control at posttest. At 1-year follow-up, SS_INT effect sizes were weaker but remained significant on calculations: g = 1.22. On other conceptual measures, follow-up g was 0.39–0.58. The effect of SS_INT_I over SS_INT_B, although not significant at posttest (g = 0.28), was significant and large at follow-up (g = 0.65). These findings align with research in cognitive science showing long-term advantages for interleaved instruction. We discuss the translation of this small-group SS_INT, originally designed for small-group intervention for students with MD,

to a class-wide platform designed to improve fractions performance for students with and without MD at Grades 4 and 5.

Presentation 4: School-based research with teachers: Implementation of evidence-based practices

Sarah Powell*, Tasia Brafford, Sarah King
The University of Texas at Austin

Researchers have determined several strategies for the teaching and learning of mathematics that have a strong evidence base (Fuchs et al., 2021). Some of these include (a) modeling, practice, and feedback (Stockard et al., 2018); (b) multiple representations (Peltier et al., 2019); (c) building fluency (Powell et al., 2020); and (d) using an attack strategy and schemas for word-problem solving (Kong et al., 2021; Jitendra et al., 2020). We discuss a teacher-focused intervention (SPIRAL: SPecialized Instruction to Reach All Learners) in which we worked with teachers of students with MD in Grades 4 and 5. In this study, we recruited 20 Grades 4 and 5 teachers of students who did not meet a minimum level of proficiency on the previous grade's end-of-year mathematics test. These teachers provided small-group mathematics intervention to students in groups of 3. We employed a professional learning with embedded coaching model to provide teachers with information about how to use research-based practices in their small-group instruction. We measured teacher understanding and frequency of use at pretest and posttest. In a series of paired sample comparisons, we identified that, at posttest, teachers significantly increased their understanding of research-based instructional practices ($g = .48$) and word-problem practices ($g = 1.27$) from pretest. We describe how we implemented professional learning sessions with the teachers and later provided follow-up coaching in their classrooms to continue discussions about their use of research-based practices.

Emotions, attitudes, and beliefs in math learning: new insights from implicit and explicit measures

Chair: Maria Chiara Passolunghi
Department of Life Sciences, University of Trieste

Emotions, attitudes and beliefs are important prerequisites, mediators, and outcomes of students' math learning and achievement. Affective variables also impact several decisions individuals make regarding their engagement with math-related activities, including how parents support their children in the home learning environment. However, research continues to be rather fragmented, and most studies have focused on data from self-reported measures. The proposed symposium brings together four studies that, employing different perspectives, approaches and methods (e.g., explicit and implicit measures of emotions), will further our understanding of the role and mechanisms of affective factors in mathematics from preschool children to adults. In particular, the first presentation will discuss findings on the emotional perception of math-related words using the physiological measure of pupil dilation. The second talk will examine the relation between math anxiety, implicit attentional processes and math performance. The third talk will describe the construct validity and reliability of different explicit measures of math anxiety, confidence and interest and explore the relation between them. Lastly, the fourth contribution will consider the relevant role of parental math emotions

and attitudes in child's home learning environment and home numeracy. The findings described in this symposium provide converging evidence and novel insight into the relation between attitudes toward math and learning outcomes, and point to the need to advance mixed-method paradigms to better probe the emotion-achievement relation.

Presentation 1: Mathematical and negative information are similarly processed: Pupil dilation as an indicator

Lilach Layzer Yavin*, Adi Shechter, Orly Rubinsten
Department of Learning Disabilities, Faculty of Education and Edmond J. Safra Brain Research Center for the Study of Learning Disabilities, University of Haifa

The emotional perception of math-related information can affect achievements in math during the school years and career choices later in life. Moreover, negative emotions about math can lead to avoid mathematics and STEM fields altogether. To investigate the physiological aspect, we compared the processing of math-related words, neutral words and word with negative valence using pupil dilation measurement as an indicator of cognitive effort including emotional effort, on a random sample of 30 adults. Pupillary responses were found as sensitive to emotional information, and specifically exposure to math-related information led to increased pupil dilation, similar to negative affective information. The study illustrates the physiological aspects of emotional and cognitive effort in exposure to math-related information. The conclusion highlights the emotional and semantic load a typical individual may deal with in mathematical situations. Understanding the cognitive and emotional effort should attract the attention of policymakers and educators which aim to increase the appeal of STEM professions.

Presentation 2: The relationship between math anxiety, attentional processes, and math performance: evidence from a developmental sample

Alessandro Cuder*, Sandra Pellizzoni, Eleonora Doz, Maria Chiara Passolunghi
Department of Life Sciences, University of Trieste

Math anxiety (MA) is a negative attitude toward mathematics that may influence individuals' attentional processes, causing them to avoid threatening math stimuli and learning activities. According to literature, individuals with MA frequently exhibit attentional bias and avoidance behaviors when presented with arithmetic-related stimuli. However, especially when taking into account developmental samples, attentional processes associated with MA and their connection to self-reported anxiety and math performance are understudied. For this reason, the aim of the present study was to assess MA using an attentional paradigm (i.e., dot-probe task; Rubinsten et al., 2015) and to evaluate its relationship with self-reported MA and math performance in fifth and sixth grade students (Mmonths =132.6; SDmonths =11.5), while controlling for age and fluid intelligence. In the dot-probe task, a math-related or neutral prime word appeared on one side of the screen. Then, a probe appeared in the same location or on the opposite side of the screen, and children had to quickly discriminate its identity. When the probe appeared in the same position as a math-word stimulus, regression analyses revealed that math anxious children took longer to identify it, indicating an avoidance attitude of the threatening math word. Children that showed this behavioral pattern also had a lower math performance. Overall, our results indicated that attentional processes and MA interact in

developmental samples, offering new insight on how math-related stimuli could affect avoidant behaviors in anxious children.

Presentation 3: Measuring and correlating math anxiety, interest, and confidence in primary school children

Colleen M. Ganley[1], Zahra Sharif1*, Nandrea Burrell[1], Rachel A. Conlon[1], Elyssa A. Geer[2], Connie Barroso[3]
[1] Florida State University [2] University of Oregon [3] Texas A&M University

Though there have been recent efforts to develop math anxiety scales for use with young children, there has been less work with math interest or confidence scales. In this study of approximately 2,400 kindergarten through third-grade students in the United States (ages 5-10), we report on the reliability of scales for math anxiety, interest, and confidence as well as factor analyses assessing how similar or different scale items from the three constructs are and whether they separate into the three scales. We then assess relations between these variables and whether those relations differ by child age. Children were given the 14-item Math Anxiety Scale for Young Children-Second Revision (Harari et al., 2013, Ganley & McGraw, 2016), and 5-item math confidence and math interest scales that were based on Fredricks and Eccles (2002). Results show that the three constructs are separable, but one confidence item fit better with the interest scale items and was therefore removed from the confidence scale. The interest and anxiety scales showed good reliability at all grade levels (.82<Cronbach's alphas<.89). The reliabilities for the confidence scale were a bit lower (.64<Cronbach's alphas<.74). All three constructs were significantly correlated with one another, with the highest correlation being between confidence and interest (r=.51), compared to confidence and math anxiety (r=-.36) and anxiety and interest (r=-.28). We found that as students got older, the relations between variables generally got stronger, though there were some comparisons that were not statistically significant.

Presentation 4: Does parents' maths anxiety play a role in home numeracy activities?

Mariuche Gomides, Flavia H. Santos*
University College Dublin, School of Psychology, UCD Music and Math Cognition Lab

Parental attitudes, beliefs, and support in formal and informal maths activities in the home learning environment impact children's academic achievement. However, these associations depend on factors hindering or enhancing maths learning opportunities, for instance, parents' educational attainment. The present study examined whether parents' maths anxiety and attitudes towards maths are associated with the frequency of home numeracy activities. We included 75 parents' responses (39.5% low to intermediate educational attainment) to an online survey of children who were enrolled in third and fourth grades (56% girls) in Ireland. Three findings were explored: First, parents' maths anxiety was significantly predicted by their attitudes towards maths and educational attainment. The beta weights indicated that more positive attitudes towards maths were associated with lower levels of maths anxiety. Second, parents with lower educational attainment showed higher levels of maths anxiety than parents with higher educational attainment. Third, home numeracy practices depend on parents' maths anxiety. The more highly maths-anxious parents engage in home numeracy activities, the worse their children's performance in arithmetic calculation. In conclusion, parents' maths anxiety and negative attitudes towards maths at home affect home numeracy activities and are mediated by parents' schooling.

Investigating home math environments: Looking beyond mothers' inputs in relation to children's math skills

Chair: Xiao Zhang
Faculty of Education, The University of Hong Kong

Home math environments serve as an important context for children's math learning. Over the past decade, there is a growing body of research on the relation between home math environments and young children's math development (Zhang et al., 2020; Skwarchuk et al., 2014). The existing models of and research on home math learning have typically restricted children's math learning outcomes within knowing and applying math concepts and procedures and have rarely included such math learning outcomes as children's disposition (e.g., attitude, motivation, and self-efficacy) towards math. Moreover, most research has assessed the unidirectional role of home math environments in children's math development, and there has been a lack of research on the impact of children's math skills and disposition on home math environments (Deng et al., 2015). Moreover, most previous studies have not distinguished between mothers' and fathers' numeracy activities or have focused solely on mothers' activities (LeFevre et al., 2009; Zou et al., 2022). This symposium aims to bring together researchers from Hong Kong and the United States to share their investigations of home math environments that go beyond the existing home math models.

Presentation 1: Relations between parents' beliefs and attitudes about mathematics, use of sustained shared thinking strategies, and young children's mathematical outcomes

Sum Kwing Cheung*, Yuk Hin Yiu, Pui Lam Ho, Hei Ching Kum
The Education University of Hong Kong

Home mathematical environment – including parents' mathematics-related beliefs, attitudes, and practices – plays a crucial role in early mathematical development (Cheung et al., 2021). To date, there is limited understanding of the predictors and benefits of parents' use of sustained shared thinking strategies, though teachers' use of such strategies has been substantially studied among the literature (e.g., Siraj-Blatchford et al., 2002). The present study thus examined whether parents' beliefs about the nature of mathematics and anxiety towards mathematics contributed to their use of sustained shared thinking strategies during parent-child joint mathematical activities, and how parents' use of such strategies were related with young children's mathematical interest and competence. Three hundred and forty-eight parents completed a questionnaire about their beliefs, attitudes and mathematics teaching behaviors, whereas their young children were individually tested on their numeration knowledge, mental computation, and applied problem-solving. Structural equation modelling showed that parents' use of sustained thinking strategies was predicted by their dynamic belief about mathematics and mathematics anxiety, but not static belief about mathematics. After controlling for children's age, parents' use of sustained thinking strategies was positively associated with children's mathematical competence through children's mathematical interest. Parents' static belief about mathematics had a direct negative link with children's mathematical competence. Our study demonstrates that early childhood educators should pay attention to parents' beliefs and attitudes about mathematics as they would affect parents' home mathematical practices. Moreover, it is essential to help parents understand how they can use conversations to

Presentation 2: The interrelations between home numeracy activities, children's mathematics affective attitude, and their mathematics achievement

Xiangzi Ouyang[1], Wai-Lan Winnie Chan[2]
[1] The University of Hong Kong [2] The Education University of Hong Kong

Children's early mathematical development is important for their future career success and quality of life. Drawing on Bandura's (1986) triadic reciprocal model of children's cognitive development, this study examined the cross-lagged relations among children's mathematics achievement, mathematics attitudes, and home numeracy activities in a sample of 248 preschool children (123 boys; mean age = 52.43 months, SD = 4.65) and their parents in Hong Kong. This study assessed the children and their parents at three time points with intervals of four months: the beginning of the second preschool year (Time 1), the end of the second preschool year (Time 2), and the beginning of the third preschool year (Time 3). The results showed that children's attitudes toward mathematics at Time 1 predicted their parents' engagement in operational, mapping, and informal numeracy activities at Time 2. However, only operational activities at Time 2 had a significant effect on children's mathematics achievement at Time 3. Additionally, a bidirectional relation was found between children's mathematics attitudes and mathematics achievement (i.e., children's attitudes at Time 1 predicted their mathematics achievement at Time 2, which in turn predicted their attitudes at Time 3). These findings highlight young children's active role in shaping the home numeracy environment and building their mathematical competence.

Presentation 3: Mothers' and fathers' math activities uniquely predict toddlers' math skills

Alex Silver[1]*, Nandini Rastogi[1], Mackenzie Swirbul[2], Natasha Cabrera[3], Catherine Tamis-LeMonda[2], Melissa Libertus[1]
[1] University of Pittsburgh [2] New York University [3] University of Maryland

From a young age, children differ in their math performance, and parental math engagement predicts these variations in performance (Daucourt et al., 2020; Dunst et al., 2017). However, most prior work has examined primarily mothers' math engagement with their preschool- and school-aged children. Here, we test associations between mothers' and fathers' engagement in math activities with their two- to three-year-old toddlers and children's math performance. Toddlers (N=221) completed assessments of their number knowledge and spatial skills, via the Give-N task, where they were asked to produce sets of objects, and the Point-to-X, Point-to-Spatial Relations, and Point-to-Shape tasks, where they were shown two images and asked to point to the image containing a set of a particular size, the image containing objects in a particular spatial relationship, or the image containing a particular shape, respectively. Additionally, parents reported children's math language skills and their frequency of engaging in math activities. We found that mothers and fathers did not differ in their frequency of math activities, and their math engagement was related to some of toddlers' math skills. Fathers' math activities were associated with toddlers' number and math language skills, but not their spatial skills. Mothers' math activities were only associated with toddlers' math language skills. Critically, these associations were domain-specific, as parents' literacy engagement was unrelated to all measures of math performance. Mothers' and fathers' math activities may uniquely relate to some of toddlers' developing math skills, although future work teasing apart the nuances of these associations is needed.

Presentation 4: Cross-lagged associations between father-child numeracy activities and children's number competence during the transition to kindergarten

Xiao Zhang[1], Xinzhuo Zou[1], Weiyi Xie[1], Nan Xiao[2]
[1] The University of Hong Kong [2] The Ohio State University

Based on a longitudinal sample of 109 young Chinese children who were navigating the transition from nursery to kindergarten, this study examined the bidirectional associations between father-child numeracy activities and children's number competence using cross-lagged modeling. Children were tested individually on their number competence first at the end of their nursery programs (mean age = 38.01 months, SD = 2.68 months; Time 1 [T1]) and then at the beginning of their kindergarten programs (Time 2 [T2]). At both T1 and T2, the children's fathers completed a questionnaire that measured the frequency of their father-child numeracy activities. At T1, the children were also tested individually on their receptive vocabulary, and their mothers reported the frequency of mother-child numeracy activities and their demographic backgrounds. The results showed that the children's number competence at T1 negatively predicted the frequency of father-child number skill and book activities at T2, but these predictions were only significant among girls. The frequency of father-child game and application activities at T1 positively predicted the children's number competence at T2, but these predictions were only significant among boys. All of the predictive relations, except for the relation from T1 father-child game activities to boys' T2 number competence, persisted after adding mother-child numeracy activities, demographic factors, and children's receptive vocabulary as control variables. The findings highlight the significance of father-child number application activities for boys' math learning. They also underscore the possibility of fathers' engagement in number skill and book activities to remedy their girls' poor number competence.

ManyNumbers: A planned multi-lab investigation of the conceptual foundations of early number development

Chair: Melissa Libertus
Department of Psychology, University of Pittsburgh

Preschool numeracy is a crucial foundation for STEM learning and long-term academic success. Previous research suggests that the development of strong numeracy skills depends on a combination of perceptual, cognitive, and language skills. However, most past studies have focused on relatively small and homogenous groups of children in Western countries, often in urban areas of the United States. As a result, our current understanding of early numeracy may not generalize to diverse groups of learners, because home language background, socio-economic status, and geographic and cross-cultural differences could also influence numeracy development. In addition, the relatively small samples that are typical of most laboratory studies preclude more nuanced analyses of children's developing numeracy. To address these issues, and to probe what factors drive early numeracy across a broader sample of children, the ManyNumbers project will investigate how toddlers and preschool-aged children perceive, reason, and talk about numbers by uniting an international network of 130+ labs to investigate the conceptual foundations of early numeracy. The purpose of this symposium is to present the plans for the two foundational studies of ManyNumbers on: the conceptual foundations of number word learning in preschoolers (Presentation 1), the nature and development of small set representations in toddlers (Presentation 2), and the logistics of participation and

possibilities to engage in exploratory studies as part of this multi-lab investigation (Presentation 3). Finally, the three presenters will facilitate a discussion with the attendees about the implementation of ManyNumbers, and will answer questions about how to get involved.

Presentation 1: ManyNumbers 1: Conceptual foundations of number word learning in preschoolers

Elizabeth Gunderson[1]*, David Barner[2], Pierina Cheung[3], Sara Cordes[4], Lisa Feigenson[5], Daniel Hyde[6], Veronique Izard[7], Melissa Kibbe[8], Melissa Libertus[9], Jessica Sullivan[10], Kristy vanMarle[11]
[1]Temple University [2] University of California [3] Nanyang Technological University [4] Boston College [5] Johns Hopkins University [6] University of Illinois - Urbana-Champaign [7] Université Paris Cite [8] Boston University [9] University of Pittsburgh [10] Skidmore College [11] University of Missouri

Children learn small number words like "one", "two", and "three" before learning to construct larger sets via counting - a key transition related to later educational outcomes (e.g., Wynn, 1990, 1992; Geary et al., 2018). However, debate surrounds which conceptual resources support these earliest stages of number word learning. According to some researchers, the fact that number word learning is initially limited to small numbers suggests that it must depend on the capacity-limited object-tracking system (OTS; e.g., Le Corre et al. 2007; Carey & Barner, 2019). Others argue that approximate number representations provided by the analog magnitude system (AMS) best explain children's number word learning, since the AMS exhibits greater precision for small numbers that declines for larger magnitudes, explaining why small number words are easier to learn (e.g., Wagner & Johnson, 2011). Foundation 1 will take a collaborative, multi-lab approach to assess 2.5- to 5-year-old children's (N=~3,600 across ~150 labs from 27 countries) number word knowledge (Give-a-Number task), counting skill (highest count task), and AMS acuity (dot comparison task). This study aims to 1) provide a well-powered test of whether early number word meanings are supported by the AMS or OTS, 2) test whether number word learning is associated with changes in the precision of children's AMS acuity, as predicted by the AMS account, 3) characterize variability in number word learning and AMS acuity across labs, countries, language groups, and socioeconomic status, and 4) catalyze exploratory studies to test new questions of interest to the field.

Presentation 2: ManyNumbers 2: The nature and development of small set number representation in toddlers

Daniel Hyde[1]*, David Barner[2], Pierina Cheung[3], Sara Cordes[4], Lisa Feigenson[5], Elizabeth Gunderson[6], Veronique Izard[7], Melissa Kibbe[8], Melissa Libertus[9], Jessica Sullivan[10], Kristy vanMarle[11]
[1] University of Illinois - Urbana-Champaign [2] University of California [3] Nanyang Technological University [4] Boston College [5] Johns Hopkins University [6]Temple University [7] Université Paris Cite [8] Boston University [9] University of Pittsburgh [10] Skidmore College [11] University of Missouri

ManyNumbers Foundation 2 studies will investigate how toddlers track and numerically compare small sets, abilities thought to be foundational for later numerical thinking. Existing evidence suggests that 12-month-old infants can successfully compare sets of 1 vs. 2 and 1 vs. 3 objects, but surprisingly fail to compare 1 vs. 4 or 2 vs. 4 (see Feigenson et al., 2004). These findings are thought to reflect engagement of an object tracking system (OTS), with a capacity limit of 3 objects. However, prior research has been limited to only a few laboratories using

small, relatively homogeneous participant samples, leaving open the question of whether these results generalize to broader populations. Furthermore, at some point children overcome these capacity limits, but the trajectory of this development remains largely unknown. To address these gaps, we will conduct a larger-scale (N=~250+) multi-lab replication of capacity limits in early small set representation in toddlers from 20-29 months of age. Through this study we aim to 1) establish robust effect size estimates of small set comparison in a diverse sample of children, 2) establish the developmental trajectory of small set comparison and the factors related to individuals' differences (including number word knowledge), 3) diversify participation by training new labs, and 4) catalyze exploratory studies to test new questions of interest to the field. Given the scope, this study has the potential to provide a field-wide benchmark for understanding and conducting future studies on the development of numerical cognition with small sets.

Presentation 3: ManyNumbers: Getting involved and opportunities beyond the two foundational studies

Melissa Libertus[1]*, David Barner[2], Pierina Cheung[3], Sara Cordes[4], Lisa Feigenson[5], Elizabeth Gunderson[6], Daniel Hyde[7], Veronique Izard[8], Melissa Kibbe[9], Jessica Sullivan[10], Kristy vanMarle[11]
[1] University of Pittsburgh [2] University of California [3] Nanyang Technological University [4] Boston College [5] Johns Hopkins University [6]Temple University [7] University of Illinois - Urbana-Champaign [8] Université Paris Cite [9] Boston University [10] Skidmore College [11] University of Missouri

A major goal of ManyNumbers is to collaborate broadly to collect data in support of our two foundational studies, and to conduct new, exploratory research in numerical cognition. In this presentation, we will describe the opportunities for researchers to participate in the ManyNumbers project both within the scope of the foundational studies, and by creating and/or collaborating on exploratory projects. We will also describe the planned timeline and logistics for participation. The ManyNumbers project is led by nine Principal Investigators in the US and several international advisors who are currently working on registered reports of the two foundational studies. To date, more than 130 labs around the world have agreed to be part of ManyNumbers by collecting data for one or both of the foundational studies. Participating labs will have an opportunity to weigh in on the registered reports before they are submitted. Once the registered reports are accepted, participating labs will receive training on the experiment procedures via live virtual workshops, on-site training sessions, and webinars. Webinars will be recorded and shared with the wider community via a public-facing Youtube channel, resulting in the widespread availability of these materials to the research community at large. In addition, the PIs will create the infrastructure via mailing lists and online workspaces to encourage participating labs to collaborate on smaller exploratory spin-off projects that use data from the broader network while also adding new measures that are specific to their own labs, thereby generating new collaborative projects.

Discussants

Elizabeth Gunderson[1], Daniel Hyde[2], Melissa Libertus[3]
[1]Temple University [2]University of Illinois - Urbana-Champaign [3] University of Pittsburgh

Symposia 10.45 am – 12.00 pm

Using real-time data of mathematical thinking and learning processes as a basis for adaptive cognitive and affective support

Chair: Anselm Strohmaier
School of Social Sciences and Technology, Technical University of Munich

Education increasingly appreciates the diversity and heterogeneity of learners. Optimal learning environments are not one-size-fits-all, but adapt to the specific needs of each learner as quickly and efficiently as possible (e.g., Cronbach & Snow, 1977). Achieving such adaptation requires observing and understanding learning processes in real time and making appropriate decisions based on detailed observations. This includes both cognitive and affective aspects of learning. However, collecting more data does not necessarily lead to more knowledge about learning processes, and providing helpful and appropriate adaptive support is challenging: An important prerequisite is to have a clear theoretical rationale for interpreting such data and relating it to learning, and how amenable the underlying processed are through adaptive support. This symposium includes four presentations that cover different challenges of using real-time data for adaptive support, ranging from cognitive to affective processes, from secondary to post-secondary students, and from logfile data to physiological data. The presentations share the vision of making use of these data to provide students with the best, individualized and adaptive support during learning mathematics. The objective of the symposium is to initiate a dialogue about the potential and prerequisites of using such data in adaptive learning environments by bringing together experts both from a mathematics education, psychological, and data science perspective. Moreover, presenting authors are expected to refer to joint theoretical frameworks, methodological approaches, and starting points for symbiotic cooperation. Cronbach, L. & Snow, R. (1977). Aptitudes and Instructional Methods: A Handbook for Research on Interactions. New York: Irvington.

Presentation 1: Adaptive prompting in simulation-based learning: Designing rationales for real-time adaptation

Stefan Ufer*, Stephanie Kron
Chair of Mathematics Education, Department of Mathematics, LMU Munich

Simulations are promising to foster teachers' diagnostic competence (Grossman et al., 2009), which allows to address their students' understanding during teaching. However, pre-service teachers, themselves, form a heterogeneous group regarding their learning prerequisites. To support their learning tailored to their individual needs, adaptive prompting can be a beneficial add-on in simulations (Plass & Pawar, 2020). Conceptualizing this adaptivity requires not only a strong theoretical basis about potentially differential effects of prompting, but also concrete rationales for automated adaptation decisions. We report how we designed a rationale for adaptive prompting with two types of prompts in a simulation-based learning environment for pre-service mathematics teachers' diagnostic competence regarding decimal fractions: (i) knowledge activation prompts provide knowledge to make sense of the observed student solutions and (ii) reflection support prompts aim to support the diagnostic process. The adaptation rationale was designed using data from a prior study with N = 120 participants. It is

based on performance indicators drawn from the simulation's logfiles, which predicted learning gain in the prior study. The resulting rationale is currently used in an intervention study comparing adaptive prompting to constant and no prompting. We will also discuss designs for targeted calibration studies extending the proposed approach to generate adaptation rationales.

Grossman, P., Compton, C., Igra, D., Ronfeldt, M., Shahan, E., & Williamson, P. (2009). Teaching Practice: A Cross-Professional Perspective. Teachers College Record, 111(9). Plass, J., & Pawar, S. (2020). Toward a taxonomy of adaptivity for learning. Journal of Research on Technology in Education, 52, 275-300.

Presentation 2: Effects of feedback and time-on-task during web-based practice on fraction and decimal arithmetic

Parvaneh Babari*[1], Frank Reinhold[2], Lennart Schalk[1]
[1] Schwyz University of Teacher Education [2] University of Education Freiburg

Digital learning environments allow for combining tasks with automated feedback. Although digital environments are being increasingly developed and used, research evidence is inconsistent with regard to the effects of feedback and time-on-task for learning outcomes. Particularly, these effects are less well understood for digital environments which provide tasks in typically predefined orders of practice such as blocking or interleaving sequences. To gain a better understanding of how feedback and time-on-task affect learning in blocking and interleaving sequences, we re-analysed data from two previous experiments. In both experiments, participants (N=160 sixth graders) practised 98 fraction and decimal arithmetic tasks within a digital environment. Both experiments lasted 13 sessions, 45 minutes each, including practice and assessments. Participants were randomly assigned to practice sequences (blocked and interleaved). For example, in a blocked sequence, participants practised arithmetic tasks separately (i.e., first addition, then subtraction, etc.), while for an interleaved sequence, arithmetic operations were mixed (i.e., addition and multiplication tasks were practised together or tasks for all the four arithmetic operations were randomly mixed). Learning gains were assessed with pre-, post- and delayed posttests. In the original analyses of the experiments, we did not find significant differences for learning outcomes in posttests between different sequences. However, large interindividual differences within sequences called for additional analyses of learning processes. The present re-analyses trace the emergence of these differences to feedback processing and time-on-tasks. The results help to better understand individual progressions in digital learning environments.

Presentation 3: Real-time assessment of mathematics state anxiety: Implications for measurement and adaptive support

Christian Schons*[1], Hanna Weiers[2], Megan Foulkes[2]
[1] Technische Universität München [2] Loughborough University

Mathematics anxiety (MA) is a multidimensional construct which has been found to have a substantial impact on mathematics performance. Recent research has made a distinction between a trait (how anxious one generally feels) and state component of MA (how anxious one feels in a specific situation), which might have implications for measurement. While MA is often assessed using self-report measures, this might be more suitable for trait MA, as it is considered stable over time. The experiences associated with state MA may be better captured using physiological measures, which allow for real-time assessment without interrupting the

situation. This trait-state distinction also has implications for implementing interventions, as state MA is potentially amenable through adaptive support. We assess state MA using a combination of both self-report and physiological measures. Specifically, we will investigate 1) the relation of different physiological measures for state MA (EDA, Facial-Recognition, Eye-Tracking) to each other and to self-reports and 2) the relation of different physiological measures and self-reports to mathematics performance, while controlling for general anxiety, test anxiety, trait MA and mathematics self-concept. Measurements will be obtained from adults whilst solving arithmetic tasks with varying levels of difficulty, as well as a non-mathematical control task to check the validity of the measures used (N=100, data collection February 2023). We will report findings providing an initial step for evaluating the validity of different physiological measures for assessing state MA in real-time, and offer considerations on when adaptive support could help students regulate state MA in anxiety-provoking situations.

Presentation 4: Motivational and emotional engagement mediates the effect of features of educational technology in mathematics classrooms

Maria-Martine Oppmann*, Frank Reinhold
University of Education Freiburg

Potentials of digital tools in mathematics education include interactivity, adaptive task difficulty, and feedback—but the underlying cause and effect mechanism is not yet fully explained. We argue that experiencing an adaptive learning environment may result in higher motivational-emotional engagement (e.g., situational interest and motivation, perceived competence and autonomy support, perceived demand), leading to higher behavioral and cognitive engagement, resulting in higher learning outcomes. We tested this hypothesized mediation model in a RCT with N = 300 students from sixth-grade classrooms on the topic of ‘equivalence of fractions’ (i.e., expanding and reducing fractions). In an experimental group, students developed the ‘equivalence of fractions’-concept in a digital learning environment with interactivity, adaptive task difficulty, feedback, and self-regulated prompts of hints; in a control group, students worked with the same material paper-based. We assessed students’ knowledge of the ‘equivalence of fractions’-concept before and after the intervention and their motivational-emotional engagement via self-reports after the lesson. We operationalized cognitive and behavioral engagement with process data from the digital and paper-based learning environment (number of tasks solved during the practice phase, task level achieved), and additional data from the digital environment only (problem solving and feedback time, number of hints counted). In line with our hypothesis, we found higher motivational-emotional engagement and higher learning gains in the experimental group. We currently code the process data from each student, which we expect to reflect our hypotheses as well. Afterwards, a two-step mediation model will be estimated to underpin the above-described cause and effect mechanism.

More than nothing? Empirical insights into children and adults' conceptions of "zero"

Chair: Nicholas Vest

Department of Psychology, University of Wisconsin–Madison

Children often hold vague conceptions of zero such as "zero is nothing". Between childhood and adulthood, it is possible that people acquire more complex and sophisticated conceptions of zero. How can researchers measure understanding of this abstract concept? And what are the characteristics of more advanced conceptions of zero? There are several different ways that students might conceive of zero, for example, as the quality of nothingness ("null"), as the smallest number, or as the symmetry point between positive and negative numbers. It is unclear whether children hold these conceptions and how their understanding changes with development. This symposium will present current research about children and adults' understanding of zero. The symposium will consider dimensions of knowledge about zero (operational knowledge, linguistic knowledge, and meta-knowledge), consider how context may influence conceptions of zero, and consider whether magnitude comparisons that involve zero are processed in the same way as comparisons that involve positive and negative numbers. The symposium as a whole raises questions about how to measure conceptions of zero and their implications for mathematical reasoning.

Presentation 1: Understanding zero in preschoolers and adults

Attila Krajcsi*[1], Petia Kojouharova[2], Gábor Lengyel[3]
[1] Cognitive Psychology Department, Institute of Psychology, ELTE Eötvös Loránd University [2] Institute of Cognitive Neuroscience and Psychology, Research Centre for Natural Sciences, Budapest [3] Department of Brain and Cognitive Sciences, University of Rochester

In two studies, we investigated how preschoolers and adults handle zero in simple numerical tasks. First, we found that preschoolers can handle empty sets in numerical tasks (as measured with comparison, addition, and subtraction tasks) as soon as they can handle positive numbers. Some also know that these sets are labelled as "zero." However, preschoolers are unsure whether zero is a number. These results identify three components of knowledge about zero: operational knowledge, linguistic knowledge, and meta-knowledge. We propose that preschoolers may understand numbers as the properties of items or objects in a set. In this view, zero is not regarded as a number because an empty set does not include any items, and missing items cannot have any properties; therefore, they cannot have the number property either. Second, we found that, in adults and 8-years-old children, the performance of single-digit comparison cannot be predicted by the ratio of the values, but they can be accounted for by the sum of the distances and frequencies of the values. These results mean that symbolic zero is not processed by the approximate number system but more probably by the discrete semantic system (a network of nodes similar to conceptual or linguistic networks). Overall, both preschoolers, older children, and adults handle zero on representations that are used for handling positive integers. Our interpretation of these findings also highlights that different representations can be used for conceptual understanding and more mechanistic handling of numbers.

Presentation 2: The processing of empty sets as zero depends on the homogeneity of the stimuli features

Rut Zaks-Ohayon[1,2], Joseph Tzelgov[1,3], Michal Pinhas*[4]
[1] Department of Psychology, Achva Academic College, Arugot [2] Mental Health Institute of Beer Sheva [3] Department of Psychology, Zlotowski Center for Neuroscience, and Department of Cognitive and Brain Sciences, Ben-Gurion University of the Negev [4] Department of Psychology, Ariel University

Distance and end effects are indicators of the notion that numbers are represented on a magnitude system, ordered by the quantity they represent. While an empty set represents a lack of a quantity, previous research revealed distance and end effects also for comparisons to an empty set, indicating that it was processed as a numerical entity. In this study, we examined whether the perception of an empty set as a numerical entity is reliant on the homogeneity of the stimuli features. In two experiments, participants performed magnitude comparisons of empty versus non-empty sets, and comparisons between non-empty sets. Furthermore, we manipulated the homogeneity of the stimuli backgrounds (Experiment 1) and frames (Experiment 2). The results revealed distance and end effects for comparisons to empty sets under background-homogeneous, but not heterogeneous conditions. In contrast, distance and end effects for comparisons to empty sets emerged in both frame-homogeneous and heterogeneous conditions. These findings indicate that the representation of empty sets as numerical entities is reliant upon the context in which it is presented. Such context could be manipulated by changing stimuli features or surroundings in a way which could determine whether an empty set will be perceived as 'zero' or as 'nothing'.

Presentation 3: Conceptions of zero and the semantic congruency effect: Evidence from children and adults

Nicholas Vest*, Martha Alibali
Department of Psychology, University of Wisconsin-Madison

Integers extend positive numbers with negatives and zero. It is unclear how negatives and zero are represented cognitively, and whether these representations change with development. It is possible that negatives and zero are represented with reference to positives (e.g., using polarity and positive number magnitude). Alternatively, people may restructure their understanding to reflect discrete conceptions of positives, negatives, and zero. One way to test this is to examine behaviors during symbolic number comparisons (e.g., 3 vs. 7). One specific behavior pattern that is exhibited in positive comparisons is the semantic congruence effect (SCE), which is the phenomenon that reaction times are quicker when people make greater judgments (i.e., "which is greater?") with two larger numbers than with two smaller numbers. In two experiments, we tested whether SCEs occur when comparisons include negatives and zero. In Experiment 1, adults displayed a traditional SCE for positives. However, they displayed inverse SCEs for negative, mixed, and zero comparisons. In an exploratory analysis, these effects were moderated by their conception of zero (e.g., "zero is the reflection point between positives and negatives"). In Experiment 2, children in 5th through 7th grade did not exhibit SCEs for any comparisons, and children's conceptions of zero did not moderate SCEs. These findings replicate past work by Varma & Schwartz (2011) and provide evidence that adults may represent negatives and zero differently from positives, and that conceptions of zero may relate to these representations. Moreover, children between 5th and 7th grade hold less sophisticated number conceptions than adults.

Discussant

Francesco Sella
Centre for Mathematical Cognition and Centre for Early Mathematics Learning, Department of Mathematics Education, Loughborough University

Assessing advanced mathematical understanding

Chair: Ian Jones
Department of Mathematics Education, Loughborough University

The symposium will focus on mathematics topics taught at university level, and specifically the assessment of undergraduate understanding. This is a growing area of interest, as evidenced by the recent identification and publication of a research agenda for assessing advanced mathematical understanding in technology-based contexts (Kinnear et al., 2022). The need for such research arises because while it is relatively trivial to assess undergraduates' knowledge of facts and procedures using traditional exam-style questions, it is less straightforward to assess other forms of knowledge such as proof comprehension or conceptual understanding. The objective of the symposium is to showcase ongoing research that addresses research questions identified by Kinnear et al. (see https://maths.github.io/e-assessment-research-agenda/questions/), the answers to which would advance our understanding of undergraduates' mathematical understanding and its assessment. Davies presents an investigation of how comparative judgement can be used to assess proof comprehension via undergraduates producing summaries of presented proofs. Evans and Jeong demonstrate how concept mapping can be used to assess undergraduates' conceptual understanding and, crucially, how producing concept maps can support undergraduates' perseverance and effort when learning advanced mathematical topics. Finally, Kinnear et al. compared undergraduates' performance in e-assessment and paper-based conditions, and report that the poorer performance in e-assessments seemed to arise from less sophisticated example-generation strategies. Kinnear, G. et al. (2022). A collaboratively-derived research agenda for e-assessment in undergraduate mathematics. International Journal of Research in Undergraduate Mathematics Education, 1–31. https://doi.org/10.1007/s40753-022-00189-6

Presentation 1: Proof summaries, comparative judgement, and the dimensionality of proof comprehension

Ben Davies*
University of Southampton

Productive engagement with written proofs is a pivotal skill for any professional or apprentice mathematician. However, we seldom write out a formal mathematical argument from axiomatic foundations. Rather, we expect that proofs written by students or research mathematicians will rely on shared understandings to abbreviate their arguments, expanding upon only the most salient and intricate points. Hence, I claim that summarising is strongly

embedded in mathematical practice and has substantial potential to offer a novel assessment practice, and a productive research tool for understanding different aspects of proof comprehension. In this session, I present a project using comparative judgement (CJ) to evaluate a series of proof summaries written by students from an undergraduate class on Proofs and Problem Solving. Twenty students summarised (a subset of) nine proofs each, assessed via pairwise comparisons performed by expert judges. I present analysis addressing reliability and validity using standard measures from the CJ literature. I then turn to the open question of the dimensionality of proof comprehension, and illustrate how the combination of proof summaries and comparative judgement can offer an elegant insights with limited resource investment. The findings add to the growing body of literature demonstrating the merits of this assessment as a measure of undergraduates' proof comprehension. Moreover, these findings are consistent, even when judging summaries of multiple proofs in the same session. The latter support conjectures in the literature on variations of the difficulty of proof comprehension in different settings, and the dimensionality of proof comprehension as a singular construct.

Presentation 2: Concept maps as assessment for learning in university mathematics

Tanya Evans*, Inae Jeong
University of Auckland

A concept map is a visualisation of a group of related concepts with their relationships identified by directed arrows. Concept maps have become popular learning tools in various educational settings. However, the existing research has not fully explored the effectiveness of concept mapping as a learning tool nor analysed its utility as an assessment tool in mathematics. This presentation reports on implementing and evaluating a novel assessment, concept mapping, in a university mathematics course (N = 219). We investigated relationships between concept mapping performance and two major variables: academic achievement and assessment self-efficacy (a two-factor measure comprising Comprehension and Execution and Emotional Regulation). Hierarchical multiple regression showed that concept mapping performance explains a statistically significant amount of variance in both the final exam scores and the Emotional Regulation factor of assessment self-efficacy after accounting for other conventional coursework assessments. This suggests that concept mapping used as an assessment tool can detect and evaluate learners' distinct capabilities that are not discerned by conventional assessments. Hence, concept mapping's potential to assess conceptual understanding warrants further investigations. Moreover, the association with the emotional regulation efficacy measure suggests that concept mapping as a learning activity involves more positivity about the ability to succeed in facing challenges than a typical assignment. This potentially indicates more perseverance and effortful learning while actively engaged in meaning-making and the type of relational reasoning elicited by concept mapping. Evans, T. & Jeong, I. (2023). Concept maps as assessment for learning in university mathematics. Educational Studies in Mathematics (in press).

Presentation 3: Student approaches to generating mathematical examples: comparing e-assessment and paper-based tasks

George Kinnear*[1], Paola Iannone[2], Ben Davies[3]
[1] University of Edinburgh [2] Loughborough University [3] University of Southampton

Asking students to generate examples of mathematical objects has been suggested as an effective way to develop their understanding of mathematical concepts. Using e-assessment makes it possible to give students feedback on their examples, in a way that might be infeasible for paper-based tasks due to the effort involved in checking examples from large numbers of students. However, translating paper-based tasks to e-assessment may change their nature, and the way that students approach them. We will report on data from two cohorts of students completing the same sequence of tasks on paper (N = 333) and through e-assessment (N = 322). We found that the students completing the e-assessment version of the tasks scored significantly lower than students completing the tasks on paper, and gave different types of answers. Task-based interviews with 19 further students completing the same task sequence (11 on paper and 8 through e-assessment) reflected a similar pattern. Our analysis of the students' solution strategies offers a possible explanation: the students completing the e-assessment tasks used less sophisticated example-generation strategies than the students completing the tasks on paper. We will discuss the implications of these results for the use of e-assessment.

Discussant

Ian Jones
Department of Mathematics Education, Loughborough University

Nothing works in isolation: How mathematics anxiety influences children's mathematics achievement

Chair: Serena Rossi
Department of Mathematics Education, Loughborough University

Studies have demonstrated a negative association between Mathematics Anxiety (MA) and mathematics performance. Several factors may influence this relationship, such as environmental, e.g., parental influences, and cognitive, e.g., Executive Functions (EFs). It is crucial to understand how these factors influence mathematics performance concurrently, especially in young children who are in the process of learning mathematics. Research so far has been contradictory and inconclusive; this symposium introduces new methodological approaches and novel insights into the mechanisms via which MA influences children's mathematics performance. Specifically, how MA affects children's EFs and the role that children's parents play. The symposium is organised by S. Rossi (PhD student, Loughborough University, UK) and I. Xenidou-Dervou (Senior Lecturer, Loughborough University, UK). The speakers are: a) Eleonora Doz (PhD student, University of Trieste, Italy), who explored the relationship between children's MA, ego-resiliency, verbal and visuospatial WM and mathematics performance, b) Serena Rossi (PhD student, Loughborough University, UK), who

examined the causal mechanism via which MA and verbal WM affect children's arithmetic performance using a dual-task design, c) Jimena Cosso (Assistant Professor, Pennsylvania State University, US), who examined the association between the home numeracy environment, parental MA and their perception of their children's numerical skills in Latine families, and finally, d) Sylvia Gattas (PhD student, University of Oxford, UK) who triangulated parental reports and children's mathematics attitudes, EFs and mathematics performance. This symposium will shed light on the concurrent effect of cognitive, environmental, and individual factors on children's mathematics performance.

Presentation 1: Exploring the role of different components of WM in the relationship between ego-resiliency, math anxiety, and math performance

Eleonora Doz*, Alessandro Cuder, Sandra Pellizzoni, Maria Chiara Passolunghi
Department of Life Sciences, University of Trieste

Several studies evidenced that math achievement is influenced by cognitive and emotional aspects. According to the Processing Efficiency Theory, math anxiety (MA) would interfere with working memory (WM) leading to poor math performance. However, findings in school-aged children are still unclear and a limited number of studies considered simultaneously different components of WM (i.e., visuo-spatial and verbal WM) in the MA-math performance link. Furthermore, although some investigations demonstrated the protective role of personal assets such as ego-resiliency in math learning and anxiety development, the underlying mechanisms are largely unexplored. This study aimed to investigate the relation between primary school children's ego-resiliency, MA, verbal and visuo-spatial WM and performance on two different math tasks (i.e., calculation and word problem-solving task), after controlling for general anxiety and age. The study involved 185 children from grades 3 to 5. Mediational analysis revealed that MA mediated the relationship between ego-resiliency and math performance on both tasks. Visuo-spatial WM, but not verbal WM, played a significant role in the relationship between ego-resiliency, MA and math achievement on both tasks. Moreover, verbal WM had a significant direct effect only on word problem-solving performance. These findings shed light on the mechanisms by which MA may interfere with primary school children's math achievement and highlight the importance to consider different components of WM when studying the MA-math performance relationship. Additionally, results suggest the significance of ego-resiliency as a salient personal asset in math learning. The implications in the educational setting will be discussed.

Presentation 2: The impact of mathematics anxiety on children's working memory while undertaking an arithmetic task: A dual-task study

Serena Rossi*[1], Krzysztof Cipora[1], Sara Caviola[2], Irene Cristina Mammarella[2], Iro Xenidou-Dervou[1]
[1] Centre for Mathematical Cognition, Loughborough University [2] Department of Developmental and Social Psychology, University of Padova

It has been suggested that Mathematics Anxiety (MA) influences mathematics performance by affecting cognitive processes such as Working Memory (WM) and attentional control (Eysenck & Calvo, 1992; Eysenck et al., 2007). Specifically, MA may activate intrusive thoughts and attentional bias on threat-related stimuli that could reduce WM resources necessary for solving

the task at hand, thus resulting in poorer performance. However, this mechanism has not been fully proven in primary school children. This study investigated the interplay of MA and WM in children's arithmetic by implementing a dual-task design in a large sample of 4th and 5th graders (9-10 years old; N = 428). First, we assessed the children's MA. Then, they were administered: an arithmetic (primary task) and a word recall (secondary task) task presented in a stand-alone condition, and a dual-task, where the primary and secondary tasks were presented concurrently. To examine whether children with elevated MA have a specific attentional bias toward threat-related stimuli, we manipulated the type of words that children had to recall in the secondary task, namely they were presented with: Neutral, Mathematics-related, or Emotional words. As expected, results demonstrated that the phonological loop component of WM is necessary for arithmetic. WM load impacted children's performance, and this was further amplified in high MA children. However, we only found a limited effect of MA based on the type of words presented in the trials. These findings introduce methodological and theoretical considerations on the interplay of MA, WM, and arithmetic performance.

Presentation 3: The Role of parents' math anxiety in the home numeracy environment of Latine families

Jimena Cosso*[1], David Purpura[2]
[1] The Pennsylvania State University [2] Purdue University

A growing body of research shows that both parents' math anxiety - MA (e.g., Maloney et al., 2015; Soni & Kumari, 2017) and parent-child engagement in mathematics related activities at home are associated to children's mathematics skills (e.g., Purpura et al., 2020; Skwarchuk et al., 2014). Evidence suggests that parents' MA moderates the association between the home numeracy environment (HNE) and children's early mathematics skills (Cosso et al., 2023). Previous studies tested this relation with moderately racially and ethnically diverse samples. Thus, the purpose of this study was to examine the association and interaction between the HNE and parents' MA related to parents' perception of their children's numeracy skills with a sample of Latine families. Participants were 340 parent-child dyads. Mothers (62.94%) primarily answered the survey. Children ranged in age from 2 to 6 (M = 2;9 years, SD = 0.7 months). Results from hierarchical multiple regression models demonstrated when parents' MA and HNE were included as separate predictors of children's mathematics skills only HNE was positive and statistically significant (parents' MA: B = -0.05, p =.543; HNE: B = 0.22, p =.005). However, the interaction between HNE and parents' MA was statistically significant (B = -.14, p = .041), showing that parents' MA negatively affects the previous positive association between HNE and children's numeracy skills. Results from this study highlight that when exploring the HNE it is important to account for parents' MA given that it could significantly affect how parents interact with their children at home.

Presentation 4: The role of children's attitudes and affect in guiding attention to maths

Sylvia Gattas*, Alex Fraser, Imanie Robinson, Ariana Minea, Katie Hurman, Mihaela Duta, Gaia Scerif
Department of Experimental Psychology, University of Oxford

Children's attitudes strongly influence their interest in learning (Dowker et al., 2019). Early negative attitudes result in further deterioration in attitudes and in an increase in anxiety towards maths, as children get older (Ramirez et al., 2013). Furthermore, attitudes may influence the deployment of foundational processes for maths ability, Executive Functions

(EF), defined as the abilities which allow children to attend to and use specific information during learning. However, the understanding of early presentation of attitudes to maths, and their role in modifying how EF is deployed in function of maths is limited in young children. Here, we addressed both current limitations by studying these mechanisms in 6-year-old children and developed new methodological approaches to address multiple components of attitudes to maths and their influence on EF. We leveraged a newly designed gaze-scoring pipeline to examine attention guidance when children engaged in a mathematical task within a pressure-free environment, and again within a pressure-induced numeracy task. Gaze indices throughout the task were assessed as predictors of children's EF and numeracy performance. Finally, we triangulated these measures against child and parental reports of attitudes. We hypothesised that children's EF guidance to numbers will predict their performance within both the pressure-free and the pressure-induced numeracy tasks and that their attitudes will moderate this relationship. Our new methodologies deepen our understanding of how children might develop foundational EF mechanisms at the early stages of maths education, which might help to better equip their future maths learning experiences.

The impact of language experience on mathematical abilities: Evidence from deaf and hard of hearing children and adults

Chair: Stacee Santos
Department of Psychology and Neuroscience, Boston College

The relationship between language and the emergence of early numerical concepts has been well established in the literature. However, how language experience, defined here as the timing of language access (from birth or later) and modality of language (spoken or signed), impacts numerical cognition is less understood. Here, we present four talks focusing the mathematical abilities of a unique population with varying experience with language access from birth: Deaf and Hard of Hearing (DHH) children and adults. This symposium aims to 1) highlight the importance of early language access for the emergence of early numerical concepts; 2) discuss the impacts of language modality (spoken or signed) on symbolic (counting and problem solving) and nonsymbolic (object tracking and numerical discrimination) numerical abilities; 3) shed light on the neural mechanisms recruited in arithmetic processing in DHH adults; and 4) provide evidence for game-based interventions designed to improve numerical abilities in DHH children. Together, our talks will present evidence from DHH children and adults to show the impact of the timing and modality of language experience on mathematical abilities as well as provide evidence for game-based interventions to promote math learning in older DHH children with math difficulties.

Presentation 1: Does language experience and number knowledge predict children's abilities to track both small and large sets of quantities?

Madeline Quam*, Marie Coppola
Language Creation Lab, Department of Psychological Sciences, University of Connecticut

It has been hypothesized that language is not necessary to exactly represent or track small quantities, but this has not been studied in populations in which linguistic and cognitive development can be disentangled, such as deaf and hard-of-hearing (DHH) children, whose

language experiences are highly variable. Participants were 177 children (ages 3;1-7;6, mean: 5;1) categorized by timing of first access to language: the Early-Language group comprised 96 hearing or DHH children exposed to ASL or English from birth and the Later-Language group comprised 81 DHH children who had hearing parents and who began acquiring English (via hearing technology) and/or ASL at some point after birth. Participants completed (1) Give-a-Number to assess cardinal principle (CP) knowledge and (2) an object tracking game with small (2-3) and large (4-7) sets.On large-set trials, older children in the Early-Language group performed better. In the Early-Language group only, older CP-knowers performed better. For the small-set trials, Early-Language children were 2.58 times more likely to get both small-set trials correct; CP-knowers were 5.8 times more likely to get both trials correct.Timing of a child's first exposure to accessible language and CP knowledge are important for tracking both small and large sets. Thus, language may influence the development of object tracking skills, but hearing children's language experiences likely exceed the required threshold, thus obscuring its contribution. We conclude that early access to language (in any modality) is essential to guarantee age-typical development of numerical cognition.

Presentation 2: Role of language experience in the development of the approximate number system

Stacee Santos*[1], Marie Coppola[2]
[1] Department of Psychology and Neuroscience, Boston College [2] Departments of Psychological Sciences and Linguistics, University of Connecticut

The approximate number system (ANS) underlies our ability to estimate and track quantity without the use of symbols or counting (Feigenson et al., 2004) which has been linked to the development of formal, symbolic math abilities (e.g., Starr at el., 2013). However, unlike formal, symbolic mathematics, which rely heavily on icons and language, the ANS operates independent of language. Despite this, language may be influential in shaping and refining this seemingly non-linguistic numerical system. In this talk, we present evidence from the Study of Language and Math (SLaM), a large-scale study of deaf and hard of hearing (DHH) children based at the University of Connecticut exploring the role of language experience: 1) timing of language access: from birth or later; and 2) modality of language: spoken or signed. We look at the timing and modality of language as well as the vocabulary scores and ANS acuity of 200 DHH and hearing children between the ages of 3 – 7 years. Our results suggest ANS development may be tied to linguistic experience: children with access to language from birth (both hearing and DHH) outperformed DHH children with later access to language. Surprisingly, the ANS acuity for English speakers was higher than ASL signers. Taken together, these results highlight the potential impact of language experience on ANS development.

Presentation 3: Investigating the role of language modality and time of language acquisition on the neural networks supporting arithmetic processing.

Sarah Kimbley*[1], Casey Spelman[1], SaraBeth Sullivan[2], Ilaria Berteletti[1]
[1] Numeracy and Educational Neuroscience Laboratory, Gallaudet University, Washington D.C. 2 National Aeronautics and Space Administration

The role of language modality has been overlooked in the field of numerical cognition, but language plays a prominent role in arithmetic. Sign languages recruit the same left-lateralized perisylvian areas as spoken languages with additional visuospatial and premotor processes.

Two questions remain understudied: are the areas supporting proficiency in arithmetic language modality specific? What is the impact of language delay, as experienced by deaf children lacking accessible language during critical language development periods, on the neural networks supporting arithmetic processing? We will first present data showing that early signers show similar neurocognitive attentional markers distinguishing operation type (Berteletti et al., 2022) and that early signers also rely on language areas for solving multiplication problems (Sullivan, 2022). Because preliminary analyses have shown a relationship between the engagement of language areas with proficiency in sign language, in a third study, we investigate the impact of language delay and variability. Finally, we will present data on the recruitment of visuospatial-numerical processes in early signers to understand how a visual language might modify the reliance on the other central cognitive process supporting arithmetic proficiency. So far, our studies suggest that a similar dissociation exists between language modalities for different operation types and that language proficiency supports proficient multiplication processing. This study is the first to show the functional role of sign language proficiency in supporting arithmetic problem-solving. These results will be discussed within the current theories of arithmetic processing and in the context of educational policies for the Deaf signing community.

Presentation 4: Counting and non-counting arithmetical strategies using a video game intervention among 4th- to 9th-graders with special needs

Lilia Marcelino*[1], Conceição Costa[1], Carlos Santos[2]
[1] CICANT, Lusofona University of Lisbon [2] ISEL-IPL and CEMAPRE, University of Lisbon

Improving numeracy will induce better individual perspectives and substantially impact society, especially with lower-achieving learners, such as children with special needs. Using a video game as a game-based intervention may significantly and positively influence several areas of cognition, such as mathematics. The paper reports a six-week mathematics game-based intervention for middle schoolers with special needs. In the video game, the player must add or remove particles to create a resource to build a space base using arithmetical strategies and mathematical knowledge. The study aims to analyse children's mathematics behaviour in solving additive and subtractive tasks up to 40, using counting and non-counting arithmetical strategies. Fifteen 5th- to 9th-graders and a deaf child with home-schooling participated in the study - seven girls and eight boys, aged between 10 and 14, five deaf and ten hearing students with different special needs (dyscalculia, cognitive deficits, autism spectrum disorder, deafness and Asperger syndrome), including a twenty-two-year-old girl diagnosed with Dravet Syndrome. Students played the video game in game sessions using Zoom video conference software in 10-12 sessions during the COVID-19 pandemic lockdown. The results show that the videogame was able to identify fundamental numerical deficits in deaf and hearing children with special educational needs, such as the difficulty of counting by zero or identifying numbers on a number line. Children without numerical deficits improve mental arithmetic, as rounding up to the nearest ten) and compensation strategy for 2-digit addition and subtraction.

Poster session 1 (1.00 pm – 2.00 pm)

1. Parental mathematical talk in the home environment in the UK and Mexico

Abbie Cahoon*[1], Carolina Jiménez Lira[2], Elia Verónica Benavides Pando[2], Daniela Susana Paz García[2], Victoria Simms[1]
[1] School of Psychology, Ulster University [2] Universidad Autònoma de Chihuahua

Given the importance of parent-child interactions for their children's mathematical development, the current study investigates the stimulation that children receive at home as a source of variation in early mathematical development. The purpose of this study was to use the Learning Environment Analysis (LENA) recording device to examine conversations between parents and their preschool children during daily mealtimes and storybook reading in the UK and Mexico (currently N = 25 within each country, with a target of N = 40; age range 36-60 months). LENA was used to collect data regarding the amount (e.g., number of words), type of language (e.g., vocabulary, complexity) and the content of the language parents use when talking to their children. LENA also offers descriptive data of interactions (e.g., adult word count, child vocalisation) which will be compared and contrasted by household. The aim is to compare the amount of mathematical talk that preschool children hear to the frequency of numeracy activities (measured by the Pre-school Home Mathematical Questionnaire; PHMQ) that occur in the home across both countries. This study aims to understand the precursors for mathematical development that may bolster children's early mathematical learning while investigating the similarities and differences in parent-child interactions between the UK and Mexico. The results from both countries offer a deeper understanding of parent-child interactions in the home.

2. Spatial language in bilingual families across three activities

Fernanda Ahumada*
Institute of Education, University College London

Caregivers influence their children's spatial abilities through the amount and type of spatial language they use during everyday interactions. Those who offer enriched explanations relating to spatial concepts and encouraged their young children to use spatial language and concepts may benefit their children's later math skills. This exploratory research describes the pragmatic and spatial language (talk and gestures) used by young children and caregivers from two low-income, bilingual, Latina families across three situations: sharing a wordless picture book, setting a table for a birthday party, and cleaning up the objects used in the party. Similar to previous studies, spatial language varies according to the type of activity and materials available. Specifically, the results of this study show that through gestures and verbal expressions, dyads refer considerably to the location of objects and/or individuals in the space. Frequently, children did not always express spatial utterances to accompany the gestures. Gestures may reflect implicit knowledge and provide a foundation for geometric reasoning. In terms of the pragmatic nature, when caregivers are trying to direct behavior or attention, children used less spatial talk. In contrast, when the purpose of the interactions was providing and eliciting knowledge, behavior, and/or language, children produced more spatial talk. This study is part of an ongoing research project that involved 75 families.

3. A month-long parent-led spatial intervention

Jing Tian*, Grace Bennett-Pierre, Nadia Tavassolie, Xinhe Zhang, Emily D'Antonio, Lexi Sylverne, Nora Newcombe, Marsha Weinraub, Annemarie Hindeman, Kristie Newton, Elizabeth Gunderson
Temple University

Spatial skills are a major predictor of success in STEM (Atit et al., 2021), and the frequency of home learning activities (e.g., playing with puzzles and building with blocks) correlates with young children's spatial skills (Levine et al., 2012). However, causal evidence on the effect of home learning activities on children's spatial skills is limited. We addressed this issue through a parent intervention. Parents of 4- and 5-year-old children received messages about the importance and malleability of spatial or control (i.e., verbal) skills and then engaged their children in spatial or verbal activities provided by the researchers. Before and after the intervention, parents completed questionnaires about their current home learning environment and motivational beliefs; and children completed measures of spatial skills during a Zoom session. Pre-registration: https://osf.io/u7qrx. Preliminary results (N = 78) suggest that children in the spatial condition did not have stronger mental rotation skills or spatial vocabulary than children in the control condition at posttest, after controlling for pretest performance, child age, and child gender. Parents' motivational beliefs about their children did not change after the intervention. Child age, gender, pretest performance, and parent education did not moderate the intervention effects on mental rotation or spatial vocabulary. These results suggest limitations of parent-led home learning interventions. We are exploring parent interaction videos to better understand these null results.

4. Early numeracy and mathematics development: A longitudinal meta-analysis on the prediction nature of early numeracy

Yuting Liu*, Peng Peng
Special Education, College of Education, University of Texas, Austin

Based on 58 longitudinal studies, the present meta-analysis examined the predictive nature of early numeracy for later mathematics performance. Results showed that early numeracy measured at or before the first year of formal schooling significantly predicted mathematics measured at least six months later, r = .47, 95% CI [.44 .51]. After controlling for all moderators in a model, we found (a) different early numeracy skills including numbering, relations, and arithmetic operations did not differ in their predictions of later mathematics in general. Yet, when it comes to specific types of mathematics, numbering was more closely related to later algebra and word problems, while arithmetic operations were more closely related to later word problems, (b) early numeracy as a whole was more predictive of later advanced mathematics, such as word problems and algebra, than later fundamental mathematics such as fact fluency and calculation, (c) the prediction of early numeracy on later mathematics was non-linear, with longer prediction intervals associated with the stronger prediction. These findings, taken together, suggest that early numeracy may be a unitary and diverse construct, depending upon what types of mathematics as the prediction outcomes. More importantly, early numeracy is not just a stepping-stone for foundational mathematics but more likely to serve as a snowballing effect trigger for mathematics development overall. That is, the effect of early numeracy on mathematics development may be accumulative over time. Implications on assessment and instruction of early numeracy were also discussed.

5. Math anxiety predicts aversion to social comparison in classroom mathematical contexts

Raeanne Martell*[1], Ian Lyons[1], Pierpaolo Dondio[2]
[1] Department of Psychology, Georgetown University [2] School of Computer Science, Technological University Dublin

To date, the vast majority of research on math anxiety has focused on its performance-related and affective aspects. Only recently have researchers begun to explore the potential social aspects of math anxiety. Of these social aspects, one topic which remains relatively uninvestigated is how math anxiety relates to social comparison, or one's assessment of themselves as compared to someone else. The current study investigates how math anxiety relates to preference for or aversion to aspects of social comparison experienced within classroom mathematical contexts. Here, we used the leaderboard of a novel digital math game, a feature which publicly ranks students' game performance in comparison to their peers', as our specific example of concrete social comparison in the classroom. Results of a logistic regression revealed a significant positive relationship between math anxiety and players' aversion towards the leaderboard, such that players with higher math anxiety reported a greater disliking for the leaderboard than their peers with lower math anxiety. This result held even when we controlled for players' performance and reported level of preference for social engagement in the context of this digital math game. Overall, the results provide evidence of a social dimension to math anxiety. This suggests that, in addition to performance and emotions, we should also consider how math anxiety relates to social factors, like social comparison, particularly in the context of classroom settings.

6. Building word-problem solving and working memory capacity: A randomized controlled trial

Lynn Fuchs, Douglas Fuchs*, Marcia Barnes
Vanderbilt University

This study's purpose was to investigate effects of 3 intervention approaches for building working memory (WM) and improving word-problem solving (WPS). Children with mathematics difficulties (n = 240; 7.51 years [SD = 0.33]) were randomized to 4 conditions: a control group, general WM training with contiguous math practice, WPS intervention without WM training, and WPS intervention with domain-specific WM training. WM, WPS, and arithmetic were assessed before and 1-3 weeks after intervention; delayed WPS and arithmetic posttesting occurred 4-6 weeks later. Multilevel modeling of main effects and mediation effects were employed. Compared to control, general WM training with contiguous math practice and WPS intervention without WM training increased WM and WPS. The 3rd training condition, WPS intervention with domain-specific WM training, which minimized WM training time, improved WPS but without effects on WM. Both WPS intervention conditions outperformed general WM training on WPS. Conclusions are as follows. (1) General WM training with contiguous math practice improves WM and WPS. (2) WM training is not a substitute for WPS intervention when the goal is to strengthen WPS. (3) WPS intervention without WM training improves WM but is not a substitute for WM training when the goal is to strengthen WM. (4) For WM effects to accrue, WM training needs to occur with sufficient intensity. (5) WM plays a causal role in WPS, but not in arithmetic. Implications are drawn for research and practice, including assessing instructional supports in future research to build cognitive-academic bidirectionality.

7. A synthesis of pre-algebraic reasoning interventions for middle-school students with mathematics difficulty

Danielle O. Lariviere*, Syeda Sharjina Akther
The University of Texas at Austin

Proficiency in algebra is a gatekeeper not only to success in secondary-level mathematics, but also to postsecondary studies and numerous career paths. The foundation of success in algebra is pre-algebraic reasoning ability, which centers on content such as linear equations and functions. In the United States, pre-algebraic reasoning is a primary instructional focus in the middle-school grades (i.e., at ages 11–14). Yet despite this instructional emphasis, middle-school students often encounter difficulty developing pre-algebraic reasoning skills (National Center for Education Statistics, 2022). Moreover, limited synthesized research on interventions is available in this area (Powell et al., 2021). This poster details a synthesis of 10 pre-algebraic reasoning intervention studies at the middle-school level. Studies were identified using systematic search and screening procedures, including database, table of contents, and forward and backward searching. Results indicated positive proximal effects across studies, with primarily positive maintenance effects and mixed transfer effects. Manipulative-based instruction and explicit instruction were the two most common approaches used across studies. Implications include encouraged use of these approaches, as well as increased instruction in applied problem solving to facilitate transfer of skills. ReferencesPowell, S. R., Mason, E. N., Bos, S. E., Hirt, S., Ketterlin-Geller, L. R., & Lembke, E. S. (2021). A systematic review of mathematics interventions for middle-school students experiencing mathematics difficulty. Learning Disabilities Research & Practice. 0(0), 1–35. https://doi.org/10.1111/ldrp.12263National Center for Education Statistics. (2022). The nation's report card. U.S. Department of Education, Institute of Education Sciences. https://www.nationsreportcard.gov/

8. Neural substrates for fast numerical and non-numerical magnitude averaging

Chenxi He*, Daniel Ansari, Blake Butler
Department of Psychology, University of Western Ontario

Humans show a remarkable ability to quickly average both groups of symbolic numbers and physical properties of objects (e.g., size). Additionally, distribution characteristics like skewness may bias these judgments. However, little is known about the neural basis of fast averaging for either numerical or non-numerical magnitudes. In this pre-registered fMRI study with data collection still ongoing, participants quickly estimated and compared the mathematical averages of two sets of 8 numbers or the average sizes of two sets of 8 dots, one set presented after the other. Neural activities were then compared to those elicited when participants compared the magnitudes of 2 single numbers or the sizes of 2 single dots, each embedded within 7 'XX' symbols to control for visual properties. Moreover, number and dot distributions were manipulated to contain no-skew, low-skew or high-skew. Preliminary results with 18 participants showed that at $p<0.001$, GRF-corrected level, number groups > single numbers activated right lingual gyrus, whereas dot groups > single dots activated right lateral occipital cortex. A significant interaction in right postcentral gyrus showed greater activations for dot groups relative to single dots, but no difference between number groups and single numbers. Multivariate pattern analysis further revealed bilateral precentral gyri, middle frontal gyri, medial superior frontal areas and anterior cingulate for number groups vs. single numbers,

but not for dot groups vs. single dots. Lastly, the medial orbital frontal area decoded patterns of skewness for dot groups. The results suggest divergent neural activity profiles associated with fast numerical and non-numerical averaging.

9. Classroom peer effects on preschool children's mathematics learning

Can Carkoglu*[1], Robert J. Duncan[1], Sarah H. Eason[1], David J. Purpura[1], Sara Schmitt[2]
[1] Purdue University [2] University of Oregon

Social learning theory suggests that children can learn by observing people in their learning environment. Math, literacy, EF skills co-develop in early childhood (Cameron et al., 2019) and predict future academic success (Duncan et al., 2007). Classroom peers' math, literacy, and EF skills at fall positively relate to gains in children's skills (Choi et al., 2018; Korucu et al, under revision). However, prior studies examining peer effects on preschoolers' skills have not addressed whether associations are due to overall classroom levels and/or changes in classroom levels across time. This study is a secondary data analysis of existing data from children's fall and spring semesters of preschool. The sample for this analysis consisted of 577 preschoolers (3-5 years) from 105 classrooms containing three or more children. Classrooms' overall ability levels were calculated by averaging scores from both semesters. Changes in classroom abilities were calculated by subtracting fall scores from spring scores. A multilevel regression analysis predicting children's gains in math skills was run with a host of sociodemographic variables; children's fall math scores and their overall and change in literacy and EF scores; classroom overall math; classroom overall levels and change in EF and literacy scores. Children's fall math skills, overall and change in literacy and EF skills as well as peers' overall math skills were positively related to gains in math skills. These findings challenge previous findings because classroom level EF skills were not related to the outcome when including classroom level math skills.

10. Fraction interventions for secondary students with mathematics difficulty: A research synthesis

Jessica Mao*
The University of Texas at Austin

Students with mathematics difficulty (MD) often experience challenges with fractions. Researchers have determined that learning fractions requires prerequisite conceptual understanding of partitioning and sharing as well as the continual conceptual development of fraction magnitudes and properties (Siegler et al., 2010). Furthermore, fraction performance becomes more disparate between students with and without MD as students age (Tian & Siegler, 2017). According to previous syntheses, researchers identified six intervention components embedded in fraction interventions: Explicit instruction, concrete and visual representations, range and sequence, strategy instruction, student verbalization, and contextual problems (Shin & Bryant, 2015; Roesslein & Codding, 2019). Given that the Roesslein and Codding's (2019) fraction intervention review included studies that also covered Grade 6 students and that their last study reviewed was published in 2016, this synthesis extends previous syntheses by expanding the inclusion years from 2016 to 2022 and evaluating fraction intervention effects for secondary students with MD between Grades 6 and 12. After searching electronic databases using relevant search terms, de-duplicating, title and abstract screening, and full text screening, I identified 15 articles to be included in this synthesis. Between now and April, 2023, I will code the studies and analyze effects. During this poster, I will present

whether studies included the previously-identified six intervention components, whether I identified additional efficacious intervention components, and provide recommendations for the design and delivery of fractions-focused interventions for students in MD in Grades 6-12.

11. Using books to improve mental rotation skills in 4- and 5-year-old children

Nadia Tavassolie*, Lexi Sylverne, Nora Newcombe, Marsha Weinraub, Elizabeth Gunderson
Department of Psychology and Neuroscience, Temple University

Mental rotation skills predict later achievement in STEM (Wai et al., 2009). Prior research has shown that children's mental rotation skills improve after training (Uttal et al., 2013; Hawes et al., 2022). However, almost all studies have used dynamic stimuli where children see objects rotating (Hawes et al., 2022). We hypothesized that reading books designed to practice mental rotation, with only static images, could improve 4- and 5-year-olds' mental rotation skills.

We preregistered a pretest-training-posttest design with 4- and 5-year-olds (current N=39, target sample size of 80). Children completed a mental rotation assessment at pretest, then completed 4-6 reading days with an experimenter over the course of two weeks in one of two randomly-assigned conditions (Mental Rotation Book Condition versus Control Book Condition), and finally completed the mental rotation assessment at posttest. In both conditions, trained experimenters read researcher-designed books in one-on-one sessions with the children. The Mental Rotation Books involved mental rotation practice and the Control Books were matched for length but did not involve mental rotation. Consistent with our hypothesis, condition was a significant predictor of posttest mental rotation accuracy, $F(1,34)=4.61$, $p=.039$, $\eta p2= 0.119$, controlling for age and pretest mental rotation accuracy. Children in the Mental Rotation Book condition significantly improved from pretest (M=.59, SD=.24) to posttest (M=.73, SD=.24) ($p=.007$), whereas those in the control group did not. Book-reading may be a scalable method for improving mental rotation skills in early childhood, and warrants further intervention studies using book-reading at home or in schools to improve spatial skills.

12. Assessing young children's understanding of length measurement units

Yawei Yang*[1], Xiao Zhang[1], Kong Xiangzi Ouyang[2]
[1] Faculty of Education, The University of Hong [2] Department of Psychology, The University of Hong Kong)

Understanding measurement units lays the foundation for success in the STEM (Science, Technology, Engineering, and Mathematics) disciplines. However, young children's understanding of measurement units remains insufficiently understood, due mainly to a lack of appropriate assessment tools. The present research aims to develop and validate an assessment instrument of young children's understanding of length measurement units. In the pilot study, 88 children were assessed individually using a self-developed Pre-primary Understanding of Length Measurement Units Test (PULMUT). In the formal study, 245 children (age: M ± SD = 75.01 ± 5.86 months) were tested individually on their performance in length, area, and volume measurement and understanding of length measurement units. The results showed that a five-factor model that captured young children's concepts of partitioning, unit iteration, identical unit, accumulation of distance, and the relation between unit size and unit number fitted the data best. The PULMUT demonstrated good reliabilities, appropriate difficulty and discrimination, and satisfactory correlations with performance in length, area, and volume measurement. The results suggest that the PULMUT is a reliable and valid instrument that can be used to examine young children's understanding of length measurement units.

13. Assessing the association between math talk and math performance: A meta-analysis

Alex Silver[1], Daniela Alvarez-Vargas*[2], Drew Bailey[2], Melissa Libertus[1]
[1] University of Pittsburgh [2] University of California, Irvine

Differences in the home math environment have gained considerable attention as a potential source of variation in children's math performance, and recent research has suggested positive associations between the frequency of caregivers' math talk and children's math performance. However, to what extent associations reflect robust causal effects is difficult to test. In a pre-registered analytic approach (osf.io/q48jp), we are conducting a meta-analysis of the effects of parental math talk on children's math performance. Our initial search identified 22,621 potential articles. We have excluded 22,493 articles, identified 35 to include, and identified 21 to read fully to determine relevance for inclusion. Once inclusion is confirmed, a multi-level random effects meta-analysis will be employed. We will examine whether associations differ as a function of sample characteristics, observation context, observation length, type of math talk, math performance measure, and modelling approaches to math talk variable analysis. Specifically, we will test whether associations are larger when the content of the math talk overlaps with the skill being assessed, and whether they are robust to the inclusion of strong baseline covariates. We will provide a set of plausible statistical bounds of the influence of math talk on math performance, to inform power analyses and experimental work on the impact of parental math talk on math learning.

14. The effects of caregiver involvement on early childhood mathematica Achievement: A research synthesis

Mackenna Vander Tuin*
The University of Texas at Austin

Strong mathematics understanding sets individuals apart in the school system and the workforce. Data demonstrates how students have consistently underperformed in the area of mathematics. In the U.S., only 36% of fourth-grade students perform at or above mathematics proficiency standards (National Center for Education Statistics, 2022). There is a need to explore alternative teaching strategies to supplement school-based learning in mathematics. A possible solution is an exploration and utilization of the home math environment (HME) to improve early mathematics outcomes. Based on theory (Bronfenbrenner, 1974), home mathematics interactions with caregivers and children are positively associated with mathematics achievement (Daucourt et al., 2021). Past syntheses have analyzed correlational research and the importance of the home learning environment to student development of mathematics (Castro et al., 2015; Fan & Chen, 2001; Daucourt et al., 2021). With this synthesis, I examined the effects of caregiver interactions through interventions within the HME and the possible relationship with child mathematics achievement. I am in the process of my full-text screening and have identified seven articles to be included in the synthesis. Before the conference, I will finish my full-text screening, code and analyze the studies, and compile the results of my findings. With this poster, I will share the results of experimental studies in the HME and any effects or relationships associated with child mathematics achievement. Additionally, I will provide recommendations for caregivers that aim to enrich the HME and subsequently improve mathematics outcomes.

15. What counts as math? How adults view the importance of children's everyday activities

Megan Merrick*, Giulia Borriello, Emily Fyfe
Department of Psychological and Brain Sciences, Indiana University-Bloomington

Parents, teachers, and researchers are invested in improving children's performance on mathematics tasks. What qualifies as a mathematics task, especially in the home environment, is less clear (Hornburg et al., 2021). Our goal is to explore adults' conceptualization of mathematics knowledge and the everyday activities that can support it. University students (N=320, M age=19.38, 68% white, 51% STEM majors) generated a definition of mathematics and rated the importance of 12 everyday activities (e.g., playing board games, making music) for supporting children's mathematics, numeracy, patterning, and spatial skills. Adults' definitions of mathematics were largely equated with numeracy (e.g., 93% used terms like "the study of numbers."). The activity measuring ingredients had the highest rating for supporting both mathematics (M=4.44) and numeracy (M=4.45), and reading a book had one of the lowest ratings for supporting mathematics (M=2.55) and numeracy (M=2.88). Overall, the ratings for supporting mathematics and for supporting numeracy were positively correlated for each activity, rs=.28-.82, ps<.05. Adults rarely included patterning and spatial features in their definitions of mathematics (2.5% and 6.25%, respectively). The activities with the highest ratings for patterning (sorting objects, building blocks, completing puzzles) also had the highest ratings for spatial skills, and ratings for supporting patterning and for supporting spatial skills were positively correlated for each activity, rs=.32-.60, ps<.05. Adults think many everyday activities can support mathematics knowledge. They often equate mathematics tasks with tasks that focus on numbers, and appear to think of patterning and spatial tasks as a different category.

16. Do preschool children use spatial coding for serial order in working memory: a replication study

Tânia Ramos*, Carrie Georges, Christine Schiltz
University of Luxembourg

The ordinal position effect (OPE) refers to the tendency to categorize items from the beginning/end of a memorized sequence with left/right-sided responses, respectively. It is considered as evidence that serial order in WM relies on spatial coding mechanisms. The effect has been well replicated in adults, where it is shown to depend on reading direction. Conversely, so far, only one study (van Dijck, Abrahamse, & Fias, 2020) has assessed the OPE in preliterate children. They found that even though the effect was not significant at the group level, about one third of the children already associated serial order with space, yet with no uniform direction. In the present study, we aimed to replicate these findings in 156 preschool children (mean age: 6.4 years). No systematic spatial coding was observed at the group level. However, individual analysis showed a reliable OPE in 34% of the children. Among those, 58.5% coded from right-to-left while 41.5% were left-to-right mappers. Our findings are thus in line with the results of van Dijck et al. (2020) and support their conclusions that spatial coding of serial order in WM does not depend on the ability to read and write but is likely calibrated by it.

17. Symbolic ordering task performance with retrospective reports and its relation to arithmetic skills in children

Natalia Dubinkina*[1], Francesco Sella[2], Bert Reynvoet[1]
[1] Brain and Cognition, Faculty of Psychology and Educational Sciences, KU Leuven [2] Centre for Mathematical Cognition, Loughborough University

The relation between symbolic number ordering (i.e., is a triplet of digits in ordered or not?) and arithmetic fluency strengthens throughout development. In our study, we investigated whether the frequency and efficiency of different strategies used in asymbolic number ordering task related to arithmetic fluency in 6-7 and 10-11 years old children, and adults. In the retrospective version of the number ordering task, participants indicated the used strategy (i.e., memory retrieval, decomposition, arithmetic, other) after each trial (for the method, see Dubinkina et al, 2021). Surprisingly, younger children reported using memory retrieval more often than older children and adults, which may question the young children's insight on their own strategies. Nevertheless, in the young group, reaction times on memory retrieval trials were related arithmetic fluency, which was not the case for older children. These results highlight the complex relation between strategy use and arithmetic skills during the developmental shift from slow procedural operations to fluent retrieval of arithmetic facts.

18. Semantic priming across domains: from language to mathematics

Miguel Ayala-Cuesta*[1], Sofía Castro[2], Daniela Paolieri[1], Teresa Bajó[1], Pedro Macizo[1]
[1] Mind, Brain, and Behavior Research Center (CIMCYC), Department of Experimental Psychology, University of Granada [2] Jagiellonian University

The objective of this study is to investigate the possible existence of common semantic processing when people process linguistic (e.g., they read sentences) and numerical information (e.g., they solve arithmetic operations). For this purpose, we considered the semantic concepts of "increase" and "decrease". A new paradigm composed of blocks of two stages was designed. In the first stage, we used verbs containing the idea of increase ("to give", etc.), or decrease ("to remove", etc.). Participants read a sentence (e.g., "the boy was given the doll"), followed by two objects (e.g., doll, camera) and had to choose the object that matched the meaning of the sentence. In the second stage, the concepts of increase and decrease were implemented through addition and subtraction, respectively. Specifically, additions (e.g., 62 + 3) and subtractions (e.g., 33 – 6) appeared followed by two possible results, and participants selected the correct result for the operation. We expected to find a congruence effect: facilitation when participants solved additions preceded by "increase" sentences and subtractions that appeared before "decrease" sentences. The results revealed evidence for semantic priming. Additions were solved faster and more accurately when preceded by increase vs. decrease sentences, while the resolution of subtractions was better when preceded by decrease vs. increase sentences. The outcomes of this work, suggest the existence of shared semantic processes between language and mathematics.

19. Effects of differing degrees of direct parental support during arithmetic problem solving on children's performance

Analia Marzoratti[1], Gus Sjobeck[2], Steve Boker[1], Tanya Evans*[1]
[1] School of Education and Human Development, University of Virginia [2] University of Pittsburgh [3] Department of Psychology, University of Virginia

Caregivers' involvement in learning influences children's math outcomes, however its mechanisms and acute impacts on behavior or problem-solving approaches are not fully characterized.1,2 This study examines interactions between caregiver support-behaviors and children's performance during a 5-minute math-flashcard task. Videos of parent-child dyads were coded for number of flashcards answered, child strategy (automatic-retrieval or other), and parental support-behaviors (no-support, encouragement/prompting-support, or strategic-support). Motion energy analysis (MEA) of videos quantified dyad-member movement; movement synchrony was calculated via windowed cross correlation (WCC).3 Forward stepwise linear regressions revealed best-fitting models linking substantive factors.4No-support ($p<.001$, $R2= .529$) was positively associated with number of flashcards answered ($B=.727$, $p<.001$); strategic-support ($p=.034$, $R2=.198$) was negatively associated ($B=-.445$, $p=.034$). Encouragement/prompting-support ($p=.037$, $R2=.192$) was negatively associated with automatic-retrieval strategy. The best-fitting model explaining degree of parent support overall ($p<.001$, $R2= .818$), revealed negative associations with age ($B=-.497$, $p<.001$), female identity ($B=-.553$, $p=<.001$), and IQ ($B=-.709$, $p=<.001$), and positive associations with movement synchrony ($B=.424$, $p=.002$).Number of flashcards correctly completed was inversely related to the extent of parental support-behaviors, likely due to children needing more support being slower problem-solvers, or strategic-support being time-consuming. Older or higher-IQ children received lower support, backing the former explanation by suggesting that the extent of caregivers' intervention is tied to their perception of their child's skill-level.5 Support-degree was positively associated with movement synchrony, suggesting children may behaviorally accept support. Negative associations between encouragement/prompting-support and automatic-retrieval suggest that children using less-advanced strategies may evoke more parent-intervention, and/or need more strategic-support long-term to develop automaticity.

20. Examining the interplay between the cognitive and emotional elements of spatial processing.

Cynthia Fioriti*[1], Raeanne Martell[1], Richard Daker[1], Gerardo Ramirez[2], Erin Maloney[3], Adam Green[1], Ian Lyons[1]
[1] Georgetown University, Washington, DC [2] Ball State University, Muncie [3] University of Ottawa

Spatial ability is a stable predictor of engagement in STEM pursuits. Unfortunately, studies have found gender disparities in spatial processing, with men typically having lower spatial anxiety (SA) and higher Mental Rotation Task (MRT) performance than women. Mediation frameworks can be used to better understand the underlying mechanisms by which these variables may influence one another. One recent study found spatial anxiety mediates the relation between gender and MRT performance (%C = 11%). Here, we test the generalizability of this result across 5 datasets (Total N = 1,184; individual study Ns: 171-385). In addition, we test an alternative direction: that spatial ability explains gender differences in spatial anxiety. We then generate an average estimate of the mediation effect in each direction. In all 5 datasets, we found a significant mediation effect in both directions. In the Gender→SA→MRT direction, SA explained between 14% and 44% of the Gender→MRT relation with an average

mediation effect of 27%. In the Gender→MRT→SA direction, MRT explained between 11% and 56% of the Gender→SA relation with an average mediation effect of 29%. Together, these data support the notion that cognitive and affective gender differences in spatial processing are indeed deeply intertwined. However, somewhat contrary to prior claims in the literature, the direction of this relationship, or whether it is in fact bidirectional, remains unclear. Future longitudinal work may assist in determining this directionality, ultimately helping to narrow predictions for the relative efficacy of interventions targeting spatial anxiety or spatial ability.

21. Reliability and validity of commonly-used measures of attention in preschool children and their associations with preschool and kindergarten math ability

Anna H. Miller*[1], Vishakha Agrawal[1], Marcia A. Barnes[1], Greg Roberts[2]
[1] Special Education Department, Vanderbilt University [2] Meadows Center for the Prevention of Educational Risk, University of Texas at Austin

Attention is related to math in young children and predicts risk for co-occurring math and reading difficulties. Attention is measured using different tasks (flanker tasks, Continuous Performance Tests [CPTs], and teacher questionnaires [Child Behavior Questionnaire (CBQ)]). Limited information regarding reliability and validity of these measures, particularly for young children at high risk for math difficulties, exists. This study investigates reliability and construct validity of three attention measures in relation to math achievement in pre-k and kindergarten. 518 preschoolers from a math intervention study were included. We examine test-retest reliability of flanker, CPT, and CBQ measures and whether they are equally reliable across levels of math achievement. We conduct a confirmatory factor analysis (CFA) to examine constructs purported to underlie these measures (i.e., focused/sustained attention, controlled attention/inhibition), and test how well these measures predict mathematics performance in preschool and kindergarten. Preliminary findings show that measures of focused attention and inhibition on the flanker task are related to TEMA-3 scores at the end of pre-k. Similarly, focused attention and inhibitory control on the CBQ (but not hyperactivity) predicted the TEMA-3 at the end of pre-K. Predictors of kindergarten TEMA-3 scores were inhibition (flanker) and attention items from the CBQ. None of the CPT measures were related to math achievement at either time point. Additional analyses are being conducted including the CFA and examination of reliability across the range of math achievement. Findings connecting attention to mathematical cognition and measurement issues related to the early assessment of attention will be discussed.

22. Developmental associations of skills and self-concept of ability in reading and math across grades 1-9

Heidi Korpipää*[1], Asko Tolvanen[2], Kati Vasalampi[2], Jaana Viljaranta[3], Minna Torppa[4], Kaisa Aunola[2], Marja-Kristiina Lerkkanen[4], Anna-Maija Poikkeus[4]
[1] Department of Education, University of Jyväskylä [2] Department of Psychology, University of Jyväskylä [3] School of Educational Sciences and Psychology, Psychology, University of Eastern [4] Department of Teacher Education, University of Jyväskylä

Prior evidence has emphasized the contribution of domain-specific academic self-concept to skills development and in reading (Retelsdorf et al., 2014) and math (Arens et al., 2017) domains. The findings concerning the direction of effects between self-concept and skills in these domains have been, however, to some extent mixed at different phases of development. Moreover, the studies have been short follow-ups focusing on either primary or lower

secondary school years and mainly the traditional cross-lagged panel model (CLPM) has been used.This study investigated the developmental associations between skills and self-concept of ability in both reading and math (i.e., reading and arithmetic fluency) in a longitudinal sample of 2,518 students followed across grades 1-9. The aim was to investigate within-person changes in the direction of associations over different developmental phases by using the random intercept cross-lagged panel model (RI-CLPM). The results showed that in math, skills had an effect on self-concept of ability during early school years (1-4), and reciprocal effects were found from grade 6 onwards. In reading, only skills had an effect on self-concept of ability from grade 4 onward. The reinforcing developmental dynamic between skills and self-concept was found only for math during later grades. The role of self-concept of ability is more evident in math than in reading domain regarding fluency. As math self-concept plays a role in subsequent skill development later on, it would be crucial for students to have positive learning experiences and feedback that promote confident self-perceptions.

23. Gender differences in parents' beliefs and engagement in home mathematics activities

Suzanne Varnell*[1], Patrick Ehrman[1], Alexa Ellis[2], David Purpura[1]
[1] Department of Human Development and Family Science, Purdue University [2] Department of Human Development and Family Studies, University of Alabama

Early attitudes and gendered beliefs about mathematics can predict later achievement and academic choices in STEM (Gunderson et al., 2012; Master & Meltzoff, 2020). These attitudes are tied to parents' beliefs and interactions with their children surrounding mathematics (Simpkins et al., 2012). Given evidence that parents can hold gender stereotypes about mathematics (Tomasetto et al., 2011), we hypothesized that parents' beliefs about the importance of mathematics and appropriateness of mathematics activities would differ by the child's gender. Based on existing research that parents engage in more numeracy talk and spatial activities with boys than with girls (Chang et al., 2011; Pruden & Levine, 2017), we hypothesized that there would be gender differences in the frequency of mathematics activities engaged in at home. These hypotheses were tested through a series of 2 (child gender) x 6 (child age) between-subjects ANOVAs with parent beliefs, appropriateness ratings, and frequency of numeracy, spatial/geometry, patterning, and measurement activities as dependent variables. Results supported the hypothesized gender difference in the frequency of numeracy ($F(1,917) = 4.32$, $p = .038$) and measurement ($F(1,917) = 9.48$, $p = .002$) activities. Results did not support gender differences in parent beliefs, appropriateness ratings, or frequency of spatial/geometry and patterning activities. Exploratory t-tests showed that gender differences in the frequency of numeracy and measurement activities may begin around 5 to 6 years old. The results show the importance of examining early gender differences in subdomains of math and within the home mathematics environment.

24. The relationship between math performance and math anxiety: Insights from application of the quantile regression method to data from a large-scale international assessment

Chin-Yuan Chang, Wen-Chi Chiang*
Chung Cheng University

The effects of mathematics anxiety (MA), negative affects toward mathematics, on mathematics performance has been found in many studies testing students from different

societies. Recent investigations began to utilize data from large-scale international assessments and apply the quantile regression method. One such study analyzed the PISA 2012 database (established by OECD) and reported a trend of magnified/reduced impact of MA for high-/low-performance students from high schools. This trend warrants further inspection as it was based on averaging values of the MA estimate at every 10th level of mathematics performance across all participants (countries or economic bodies). Our study targeted on specific sub-groups from the same (PISA 2012) database, used quantile regression analyses to produce estimates of the impact of MA at every 10th level of mathematics performance, and compared them against the standard-regression estimate. The results revealed that: (a) For participants with substantial standard-regression estimate values (accounting for >20% performance variation), the trend was extremely weak – the quantile-regression estimates were mostly uniform across performance levels and did not differ from the standard-regression estimate – both as a group and individually; (b) for participants with low standard-regression estimate values (accounting for <5% performance variation), the trend emerged at the group level, but not consistently at the individual level. These findings suggest that quantile regression modeling may be more sensitive to variations in the math anxiety–math performance link than standard regression modeling, and indicate the importance of taking into account the heterogeneity of this link among different societies in the analyses.

25. Collaborating with educators to co-develop an early years mathematics and executive function intervention: Steps taken and lessons learnt.

Rosemary O'Connor*[1], Sylvia Gattas[1], Rebecca Merkley[2], Gaia Scerif[1]
[1] University of Oxford [2] Carleton University

Introduction: The benefit of educator-led interventions is their increased scalability and real-world validity. However, these interventions run the risk of failure due to a lack of compliance and buy-in from the professionals leading the intervention. To address this, it is important to include target users in the intervention design process to ensure that educator-directed programmes are easy to implement, appropriate for target staff and children and align with educator goals. Methods: The ONE programme is a preschool intervention that supports educators to challenge executive functions in the context of mathematics, through professional development sessions with educators and a set of activities to be played with children. The intervention was developed and trialled collaboratively with educators from nineteen early years settings across a four-stage iterative process, adapting materials based on feedback received from educators using via feedback posters, informal discussions, interviews and evaluation forms. Results: Although the intervention was generally received positively, several changes were made at each stage of the co-development process based on the suggestions of practitioners. Most changes were related to ensuring that activities were accessible for different child ability levels, non-repetitive, appealing for children, and clear for practitioners. Conclusion: Educators and researchers bring different priorities and expertise to the process of designing an intervention. When designing educational interventions, practical considerations of implementation should be a key consideration as well as theory. Future researchers should consider a co-development approach in order to create an intervention that is theory-driven, but also feasible and acceptable to its target audience.

26. Conceptual interference in mathematics: Associations with mathematical competencies and inhibition processes

Roland H. Grabner[1], Susanne Dögnitz[2], Thomas Krohn[2], Silvia Schöneburg-Lehnert[2], Michael Schneider[3], Stephan E. Vogel*[1]
[1] Institute of Psychology, University of Graz [2] Institute of Mathematics, University of Leipzig [3] Institute of Psychology, University of Trier

In science learning, there is increasing evidence that scientific concepts do not replace learners' naïve concepts but co-exist with them in memory. This has been demonstrated using speeded-reasoning tasks in which participants showed worse performance in evaluating science statements whose truth value differed between naïve and scientific concepts (incongruent) compared to those with same truth value (congruent). This conceptual interference effect (CIE) has been attributed to a cognitive conflict in incongruent statements whose solution requires the inhibition of the naïve concept. However, it is unclear whether this CIE can also be found in mathematics and whether its strength is related to adults' advanced mathematical competencies as well as inhibition. In two experiments with 62 and 80 adult students we administered a mathematical speeded-reasoning task with 200 statements related to different mathematical domains. In the experiments, we assessed participants' mathematical competencies using an advanced mathematics test and we employed different tasks to measure inhibition (Experiment 1: non-numerical inhibition test, Experiment 2: three numerical inhibition tests). Results of both experiments revealed a clear-cut CIE. In addition, the individual strength of the CIE was highly correlated with the participants' mathematical competencies but none of the inhibition scores showed a correlation with the CIE. These findings demonstrate that the CIE can also be found in mathematics and that more competent individuals are less affected by interfering naïve concepts. However, the lack of any relationship with inhibition test scores raises further questions on the nature of inhibition processes involved in overcoming naïve concepts in mathematics.

27. Learning opportunities for numerical skills in tabletop games identified from game and learning mechanics

Nicoletta Perini*[1], Tim Jay[1], Manuel Ninaus[2], Korbinian Moeller[1]
[1] Department of Mathematics Educations, Loughborough University [2] Institute of Psychology, University of Graz

Basic numerical skills acquired before entering school were repeatedly observed to be crucial for long-term mathematical learning. Therefore, it is very important to identify effective educational tools to facilitate their acquisition. Increasing evidence indicates that tabletop games may provide learning opportunities for basic numerical skills. However, it has not yet been specified what aspects of a specific game may create such opportunities for learning basic numerical skills. Therefore, we suggest to systematically evaluate game mechanics (e.g., rolling a die) and learning mechanics (e.g., analyse game features, for instance, identifying the colour of a card) of commercial games to identify and compare their potential for learning opportunities for basic numerical skills. Establishing an evaluation routine would help educators, researchers, and game designers to choose, research, or create games more likely to serve a specific educational purpose. Accordingly, building upon existing taxonomies of mostly digital games, we developed a taxonomy for evaluating tabletop games according to their game and learning mechanics and applied it to Ludo and Uno. The evaluation indicated that Ludo and Uno come with different game mechanics (i.e., dice rolling vs. card matching)

and learning mechanics (e.g., action/task - move a pawn vs. analyse). In turn, this suggested more opportunities for learning basic numerical skills in Ludo (e.g., for counting, conceptual subitizing, magnitude understanding) as compared to Uno (digit recognition primarily). This clearly indicates that an evaluation of game and learning mechanics of tabletop games is capable of identifying their learning opportunities for basic numerical skills.

28. A systematic review and meta-analysis of the relation between frequency of home mathematical activities and early mathematical achievement

Ella James-Brabham*[1], Emma Blakey[2], Claudia von Baston[2]
[1] Loughborough University [2] University of Sheffield

In recent years, there has been rapid growth in studies exploring the relation between the frequency of home mathematical activities (HMA) and mathematical achievement. However, the findings of these studies have been inconsistent, with some finding a positive relation, while others find no relation or a negative relation, making it difficult to draw conclusions about the importance of HMA in early mathematical achievement. We synthesised studies (k=73) reporting the relation between HMA and mathematical achievement in children aged seven years and under (n = 351) by conducting a pre-registered systematic multi-level meta-analysis. Potential moderators of this relation were explored. The meta-analysis found a small positive relation between HMA and achievement (r = .13). The results revealed that there was large variation in results both within- and between- studies. The relation was moderated by the type of mathematical achievement measure used. The relation was stronger when a composite mathematical measure or number knowledge measures were used in comparison to magnitude estimation measures. No other mathematical achievement measures moderated the relation, nor did study design, geographical location of data collection, or child age. The results demonstrate HMA relate to mathematical achievement, but that this relation is small. Based on this review, we propose three key areas moving forwards if we are to gain a better understanding of the role of the home mathematical environment in early mathematics: 1) constructing valid and reliable ways to measure it; 2) utilising randomised control trials to test causal relations; 3) recruiting socially diverse samples.

29. Domain-general and domain-specific factors explaining the multiplication skill

Jarno Rautiainen[1,2], Tuija Aro1, Mikko Aro[2], Asko Tolvanen[3], Tuire Koponen[2]
[1] Department of Psychology, University of Jyväskylä [2] Department of Education, University of Jyväskylä [3] Methodology Center for Human Sciences, University of Jyväskylä

Previous research proposes that early numerical skills form the foundation for the later mathematical achievement at school and that mathematical skills develop cumulatively. However, longitudinal studies examining the hierarchy of mathematical skills explicitly are scarce and taking the domain-general cognitive skills into account broadens the understanding of the factors behind the phenomenon. Skills such as verbal counting can predict the mathematical achievement from kindergarten to secondary education, and a prominent view is that also domain-general processes are crucial for mathematical development. Present study examines what the domain-specific and domain-general precursors of multiplication skill are and whether these factors have direct or indirect pathways through the addition skill, which has been taught earlier at school. The current study is a part of a longitudinal research project (n=207) comprising five assessments points of arithmetic, reading, cognitive skills and

motivational factors from 1st to 3rd grades. Present study extends the understanding of hierarchical development of arithmetic skills and its cognitive precursors by observing what cognitive and numerical skills at the beginning of the 2nd grade predict the 3rd grade multiplication skill and whether addition plays significant role. Path analysis revealed that number relations, counting skill, rapid automatized naming and processing speed predict the 3rd grade multiplication skill. Every pathway to multiplication skill was mediated by the addition skill. Number relations, counting skills, RAN and processing speed predicted both the addition and multiplication. The results emphasize the cumulative nature of arithmetic and the importance of prior skills on the development of the subsequent skills.

30. Strategic use of quantifiers in reporting statistics

Vinicius Macuch Silva*, Alexandra Lorson, Bodo Winter
University of Birmingham

People communicate quantities using a variety of different strategies, including quantifiers such as “some”, “every” and “none” (Moxey & Sanford, 1993). Little is known about how these expressions are used strategically when framing quantities as large or small. In two experiments, we gave participants 20 tables of school exam outcomes that they were asked to either frame as a strong or bad performance without blatantly lying. In Experiment 1, we asked 60 participants to fill sentences with two quantifiers and an adjective (i.e. “In this exam all/none/some/most of the students got all/none/some/most of the questions right/wrong”). Experiment 2 involved the same tables as stimuli, but participants (N = 30) provided open-ended text responses. Both experiments showed that people use informationally weaker quantifiers, such as “some” as opposed to “all,” when having to frame a good outcome as a poor performance or a bad outcome as a strong performance. These data suggest that people strategically exploit the vagueness of numerical communication when framing quantities.ReferencesMoxey, L. M., & Sanford, A. J. (1993). Communicating quantities: A psychological perspective. Lawrence Erlbaum Associates.

31. Perceptions of calculation mediate the relation between math anxiety and performance on SAT math problems

Alexander Avdellas*, Yixuan Zhao, Ian Lyons
Georgetown University

One of the proposed underlying cognitive mechanisms for the relationship between math anxiety and math performance is that anxiety taxes working memory load. The present study provides an additional explanation: math anxious individuals are more likely to perceive a problem as involving more calculation, and this perception can impact their performance. Few studies have investigated this relationship with perception of calculation. 205 Amazon MTurk participants (65F) completed a survey. Participants first completed a rating task where they rated how difficult and how much calculation they believe SAT math problems involve. Participants then solved the math problems and again rated how difficult and how much calculation they thought was involved. Overall, participants tended to overestimate the amount of calculation involved. LMAs adjusted their calculation ratings downward after completing a problem, whereas HMAs adjusted their post calculation ratings significantly less so. Furthermore, the extent to which HMAs failed to adjust their post-problem calculation ratings significantly mediated the relationship between math anxiety and SAT math performance (%C = 12.74). Math anxious individuals perceive the amount of calculation involved in a math

problem differently than low math anxious individuals (after controlling for initial perceptions of the problem). This difference in perception helps explain the relationship between math anxiety and math performance. Further investigating differences in calculation perceptions may provide additional insight to advancing math performance and education.

32. Associations of fraction number line estimation accuracy with gray matter volume: a voxel-based morphometry analysis

Silke Wortha*[1], Elise Klein[2], Korbinian Moeller[1], Manuel Ninaus[3]
[1] Centre for Mathematical Cognition, Loughborough University [2] LaPsyDE, CNRS, Université Paris Cité [3] Institute of Psychology, University of Graz

Accumulating behavioral evidence suggests that number line estimation (NLE) training can improve fraction magnitude processing[1]. Additionally, neurofunctional evidence indicates that this improved behavioral performance following NLE training is associated with stronger activation related to magnitude processing in the IPS[2]. On a neurostructural level, an association of grey matter volume in the IPS with mathematical achievement has been observed[3]. Therefore, we aim to evaluate whether better performance in numerical estimation (reflected by NLE accuracy) is structurally associated with gray matter volume in key areas for fraction magnitude processing like the IPS. We are performing a voxel-based morphometry analysis using the Computational Anatomy Toolbox on the structural magnetic resonance scans of 48 healthy adults (M=23.73 years, SD=3.65 years, female=32) from the study by Wortha et al.[2]. In particular, the accuracy of an NLE task with fractions is used for examining potential associations between performance and gray matter volume while controlling for age and sex. We expect to generalize previous findings on neuronal structures involved in whole-number magnitude estimation to the case of fraction magnitude. Analyses are ongoing and final results will be presented and discussed. This study will provide first evidence on the association of structural features and NLE accuracy for key brain areas involved in fraction magnitude processing.
[1] Hamdan, N. & Gunderson, E. A. Dev. Psychol. 53, 587 (2017).
[2] Wortha, S. M. et al. Trends Neurosci. Educ. 21, 100141 (2020).
[3] Price, G. R., Wilkey, E. D., Yeo, D. J. & Cutting, L. E. Neuroimage 124, 232–237 (2016).

33. Diversity in bilingual proficiency development for math and cognition among Latine dual language learners in the U.S.

Matthew Foster*[1], López Lisa[2], Karen Nylund-Gibson[3], Shaunacy Sutter[2], Dina Arch[3]
[1] Department of Child and Family Studies, University of South Florida [2] College of Education, University of South Florida [3] University of California, Santa Barbara

Introduction: Latine dual language learners (DLLs) enter school with substantial variability in their development; yet few studies have used direct measures of bilingual development in math and cognition. Method: Approximately 243 DLLs enrolled in Head Start at the study onset participated. Math and cognition were measured in English and Spanish using the WJIII/Bateria 3 at the end of preschool and beginning and end of kindergarten. Mixture models were used to examine the within group variability of participants' bilingual math and cognitive development.Results: The three-profile solution was the optimal solution, including Average Achievers, High Achievers, and Low Average Achievers. Participants' W scores indicated that all subgroups improved in math and cognition for English and Spanish. However, examination of participants' standard scores indicated that their improvements in Spanish did not keep up

with norm-referenced expectations–likely the result of English only classroom language practices in U.S. schools. As that may be, children's standard scores in English kept up with norm-referenced expectations. Finally, there was a rank ordering where children with the highest scores for cognition had the highest math scores, children with the lowest cognitive scores had the lowest math scores, etc. Conclusions: DLLs' English math achievement was commensurate with norm-referenced expectations, indicating that most DLLs finished Head Start ready for success in kindergarten and initial gaps in age-based achievement expectations were attenuated by the end of kindergarten. Additionally, the rank ordering of scores for math and cognition suggests that cognitive advantages confer benefits for math achievement, at least among DLLs.

34. Exploring the causal relation between spatial skills and math competence through a game-based spatial skills training: A randomized controlled trial. (P)

Terry Tin-Yau Wong*
Department of Psychology, University of Hong Kong

Spatial skills have been proposed to be closely linked to math competence, and recent studies have shown that spatial skills training is effective in terms of improving math competence (Hawes et al., 2022). Despite such positive findings, we have little knowledge about the specificity as well as the mechanisms underlying the causal link between spatial skills and math competence. The current intervention study aims to address these issues using a randomized controlled trial of spatial skills training. A sample of 450 third graders will be recruited, and they will be randomly assigned to receive one of the five series of training (four series of spatial skills training or a vocabulary training). The training will be conducted in a form of an educational app. They will be assessed on their spatial skills, reading and math achievement, potential mediators, as well as other potential mechanisms, before and after the intervention. The findings will inform us about whether different spatial skills training benefits math competence through the same mechanisms or contribute to math competence through different mechanisms.

35. Assessing the causal role of the home numeracy environment on children's mathematical skills. A pre-registered study of a familial intervention in preschool children. (P)

Cléa Girard*[1], Stien Callens[2], Angie De Lamper[2], Bert De Smedt[1]
[1] Parenting and Special Education Research Unit, Faculty of Psychology and Educational Sciences, KU Leuven, University of Leuven [2] Faculty of Psychology and Educational Sciences, KU Leuven, University of Leuven

The role of children's home numeracy experiences (HNE) in mathematical learning has been described through many studies. This research has two major limitations. First, there is considerable variation in the way HNE are analyzed, which makes it difficult to distinguish exploratory from confirmatory results. Second, most prior studies used correlational designs. This leads to question the causality of the relations identified between HNE and children's mathematical skills.To address these issues, we designed a pre-registered intervention study. We will target parental math activities (via a protocol of different types of activities) and their beliefs about mathematics (via short instruction videos. We plan to recruit 120 4-year-old children with one of their parents into 2 distinct groups: experimental condition (numeracy) and active control condition (literacy). Home learning environment and children's math

achievement will be assessed before and after the intervention period. Based on the previous literature, we made the following predictions. First, children's increase in math learning will be stronger for children in the experimental condition (vs. control). Second, HNE and parental beliefs will become more positive after the experimental intervention (vs control). Third, the effect of the intervention will be moderated by (a) parental implementation of the intervention and (b) the HNE characteristics at T1 (i.e., we expect a larger effect for children who were used to low level of home numeracy activities or/and whose parents had negative beliefs about math learning).

36. Ordinal and cardinal acquisition in children with Developmental Language Disorder. (P)

Heleen de Vries*, Caitlin Meyer, Judith Rispens, Alla Peeters-Podgaevskaja
University of Amsterdam

Language is often seen as an important prerequisite for the development of numerical knowledge (e.g., Carey, 2009). It is therefore no surprise that children with Developmental Language Disorder (DLD) frequently experience numeracy deficits, especially in verbal tasks such as counting, arithmetic and story problems (for an overview, see: Cross et al., 2019). To fully understand the nature of these difficulties, it is necessary to look at the early development of numerical concepts in children with DLD. More specifically, we are interested in whether difficulties with linguistic rules as seen in numeral derivation contribute to numeracy deficits in DLD. This poster presents preliminary results of a study examining the comprehension and production of ordinals and cardinals by Dutch-speaking kindergartners with DLD. The test battery consists of a Give Me and Tell Me task (e.g., Meyer, 2019), two counting tasks and a series of cognitive measures. The results will give us insight into numerical acquisition in children with DLD and its interaction with other cognitive skills (i.e., working memory). These insights will improve our understanding of numeracy problems associated with DLD, and thus contribute to the debate on the link between language and numerical development.
Carey, S. E. (2009). The origin of concepts. Oxford University Press, New York.Cross, A. M., Joanisse, M. F., & Archibald, L. M. (2019). Mathematical abilities in children with developmental language disorder. Language, Speech, and Hearing Services in Schools, 50(1), 150-163.Meyer, C. M. (2019). Rule and order: Acquiring ordinals in Dutch and English. Utrecht: LOT

37. Neurocognitive mechanisms of fraction processing in primary school children in South Africa.(P)

Kathleen Fonseca[1], Elizabeth Henning[1], Candida Barreto[1], Mojtaba Soltanlou[2]
[1] University of Johannesburg [2] University of Surrey

While middle school children's difficulty in developing a conceptual understanding of fractions has been widely documented (e.g., Spaull, et al., 2022), we do not know much about the neurocognitive mechanisms of fraction processing in primary school. This would be especially important in non-WEIRD countries where we have almost no neuroimaging data about mathematical thinking. While grades 4-6 are a critical period for fraction learning (National Council of Teachers of Mathematics, 2007), a vast majority of grade 5 South African students lack a conceptual understanding of fraction magnitude (Spaull et al., 2022). When students leave grade 6 with weak conceptual knowledge of fractions, they experience mathematical difficulties through middle and high school (Siegler & Pyke, 2013). Thus, this study aims to

investigate brain correlates of grade 5 students during fraction magnitude comparison using functional near-infrared spectroscopy (fNIRS). In a within-subject design, 40 students will be recruited. We hypothesize (1) frontoparietal activation in numerical comparison as compared to animal comparison (control condition) that is due to manipulation of numbers within the parietal regions and supportive executive functions in the frontal regions; (2) More accurate and rapid responses in comparing simple fractions (fractions with same denominators) than in comparing complex fractions (fractions with different denominators), together with higher frontal activation in latter than former condition. We will also do some behavioural measures including arithmetical fluency, reading, working memory, non-verbal IQ, and math anxiety. We will use contrast analysis for between-condition comparisons using Brain AnalyzIR and jamovi for fNIRS and behavioural data analysis respectively.

38. The role of working memory in the relation between spatial abilities and math performance. (P)

Chloe Oi Ying Leung*, Marian Hickendorff, Christine Espin, Dietsje Jolles
Education and Child Studies, Leiden University

There is an abundance of research showing a relation between spatial ability and mathematics. Yet, the underlying mechanisms contributing to this relationship are still not clear. One factor that might play a role is working memory. The current study aims at investigating the relationship between working memory, spatial ability, and math performance, taking into account the cognitive strategies used during tests of spatial ability. Data collection has just been completed and resulted in a sample of 282 fourth to sixth graders in the Netherlands. There were two data collection sessions during which participants completed a cognitive test battery, including tasks measuring visuospatial working memory, verbal working memory, spatial abilities, math performance, as well as other potential confounding factors such as verbal intelligence. Participants also answered questions about the cognitive strategies used in spatial tasks. Multiple linear regression analyses will be carried out to investigate the relation among working memory capacities, spatial abilities, cognitive strategies used in different spatial tasks and math performance, after controlling for verbal intelligence. In addition, whether visuospatial working memory serves as the underlying mechanism between spatial abilities and math performance will also be examined. Based on existing literature, it is expected that there are significant correlations between working memory capacities, cognitive strategies used during spatial tasks, and spatial abilities. Moreover, we hypothesize that visuospatial working memory and spatial ability significantly predict math performance.

Symposia 2.00 pm – 3.15 pm

Big ideas for little kids: Early conceptual foundations in mathematics

Chair: Alexandria A. Viegut
University of Delaware, United States

Young children bring a wide range of informal knowledge and skills to mathematics learning in school. Some of these abilities, like number sense, are well-known and often emphasized in early instruction. Others, however, are not, and may also serve as early foundations for mathematical development. Our symposium highlights the diversity and importance of these early knowledge and skills - many of which develop through everyday experiences without formal instruction. Critically, individual differences in these abilities are predictive of later and concurrent mathematics achievement. We will open by considering the breadth of students' informal mathematical knowledge by exploring the foundations of complex mathematical topics long before learning them in school. This includes children's informal knowledge of fractions (Viegut) and graphical representations of data (Ciccione). We will then close by investigating how spatial tools may support early mathematical knowledge, including children's gestures (Gibson) and spatial skills (Resnick). All four talks will consider methodological issues, like how to measure children's informal knowledge, as well as practical considerations, like how families or teachers can support these math-related skills. Presenting evidence from children in the United States, Australia, France, and Namibia, this set of talks considers challenges and opportunities in incorporating children's informal knowledge during schooling across a wide range of contexts. An outcome will be the consideration of how early mathematics instruction can more fully leverage the broad range of children's math-related informal skills to support formal mathematics achievement.

Presentation 1: Informal fraction knowledge in first grade supports later mathematics achievement

Alexandria A. Viegut*[1], Ilyse Resnick[2], Dana Miller-Cotto[3], Nora S. Newcombe[4], Nancy C. Jordan[1]
[1] University of Delaware [2] University of Canberra [3] Kent State University [4] Temple University

Long before learning about fractions in school, young children have informal knowledge about fractional quantity (e.g., Empson, 1999). For example, children use fractions in everyday experiences like folding a blanket in half or sharing a cookie. However, little is known about individual differences in early fraction knowledge and whether these differences matter for later mathematical understanding. To address this gap, we followed 103 children (M=6.69 years; 55% female, 45% male; 57% White, 7% Black, 18% Asian, 1% Hispanic, 7% multiple races, 10% unreported) from the fall to the spring of first grade. In one-on-one sessions in schools, we assessed multiple aspects of informal fraction knowledge, as well as theoretically-related mathematical and cognitive skills. Most children showed some early fraction knowledge at the beginning of first grade, especially with nonsymbolic fractions and halving in different contexts. This knowledge improved from fall (M=57.8%) to spring (M=67.2%) without explicit instruction (ES=.56). However, there were large individual differences in start-of-year early fraction knowledge, which explained significant variance in math achievement at

the end of first grade, even when controlling for whole number knowledge and other cognitive skills (ß = .19, $p < .05$). We will show how these data can inform activities to foster early fraction and integer knowledge in parallel to lay a strong foundation for later mathematics achievement. Empson, S. B. (1999). Equal sharing and shared meaning: The development of fraction concepts in a first-grade classroom. Cognition and Instruction, 17(3), 283-342.

Presentation 2: Detecting trends and patterns in graphs: A precursor of math and statistics understanding

Lorenzo Ciccione*, Stanislas Dehaene
Université Paris Saclay & Collège de France

Mathematics is a complex discipline, and the process of learning it relies on various cognitive foundations. Among these, the ability to intuitively grasp statistical regularities in graphs (e.g., trends and patterns) might be a crucial "building block" in the development of more complex knowledge in mathematics, such as calculus and functions. In a series of behavioral experiments, we investigated such intuitive abilities in both children and adults (Ciccione & Dehaene, 2021; Ciccione et al., 2022a). Our results indicate that precursors of "graphicacy" are present regardless of age, culture, and education level and correlate with measures of mathematical and statistical abilities. Specifically, we introduce a new test of graphicacy that assesses the ability to detect a trend in noisy scatterplots ("does this graph go up or down?"). In educated participants (N=3943), 6-year-old 1st graders (N=23), and unschooled participants living in remote Namibian villages (N=87), responses vary as a sigmoid function of the t-value that a statistician would compute to detect a significant trend in the graph. Our tool (Ciccione et al., 2022b) is publicly available online and might constitute one further (and easy) way to assess and investigate the non-numerical precursors of math achievements.
Ciccione & Dehaene (2021). Can humans perform mental regression on a graph? Accuracy and bias in the perception of scatterplots.
Ciccione, Sablé-Meyer & Dehaene (2022a). Analyzing the misperception of exponential growth in graphs.
Ciccione, Sablé-Meyer, Boissin, Josserand, Potier-Watkins, Caparos, & Dehaene, (2022b). Graphicacy across age, education, and culture: a new tool to assess intuitive graphics skills.

Presentation 3: Preschool children's nonverbal number knowledge: Number gestures and nonsymbolic quantities

Dominic J. Gibson*[1], Jacob Butts[2], Susan Goldin-Meadow[2], Susan C. Levine[2]
[1] foundry 10, United States [2] University of Chicago

To provide insight into how children transition from an intuitive sense of quantity to understanding the meanings of number symbols (e.g., "three"), we explored children's early understanding of number gestures (e.g., raising three fingers to convey "three"). Children accurately associate number gestures with corresponding quantities before they learn the meanings of number words (Gunderson et al., 2015) and how children gesture while speaking about numbers predicts subsequent learning from a number intervention (Gibson et al., 2018). However, it is not clear how number gestures may support children's number learning or why children's number gesture knowledge precedes their number word knowledge. We explored the possibility that children match number gestures to sets on the basis of their numerical equivalence (i.e., matching the number of fingers to objects in a set), the same way they match two sets of objects to one another. Contrary to this possibility, we found that children's ability

to match gestures to numerically equivalent sets of objects actually exceeded their ability to match two sets of objects, $t(111)=7.06$, $p<.001$, $d=0.67$. This suggests that children likely do not rely solely on the numerical equivalence between gestures and corresponding sets to make these mappings and also that number gestures could aid children's broader number learning by supporting their ability to match numerically equivalent sets of objects.
Gibson, D. J., et al. (2019). Number gestures predict learning of number words. Developmental science, 22(3), e12791.Gunderson, E. A., et al. (2015). Gesture as a window onto children's number knowledge. Cognition, 144, 14-28.

Presentation 4: Spatial reasoning skills and spatial tools support numeracy in the early years

Ilyse Resnick*, Tom Lowrie
University of Canberra

A recent meta-analysis (Hawes et al., 2021) found that improving spatial reasoning casually improves mathematics skills. Age moderates this effect, suggesting that young children may not be able to transfer spatial learning to mathematics contexts. However, there is strong theoretical evidence that spatial reasoning skills should support mathematics learning in preschool (Davis et al., 2015). It may be the case that young children require more scaffolding within embedded, authentic tasks. The present study examined if spatial learning grounded in early years pedagogical theory could help improve preschool numeracy performance. A large-scale, nationally representative sample of preschool children (n = 1,254) participated in one of three conditions: (1) a play-based spatial learning program, (2) the same spatial learning program that was scaffolded using spatial tools (e.g., gesture, sketching), or (3) a business-as-usual control. Compared to the control, engagement with the spatial program led to better overall spatial reasoning and transfer to numeracy. Engagement with the same spatial program using a "spatialized curriculum" had large additive effects. A moderation effect showed children with lower spatial reasoning made the largest gains in numeracy. Together, these findings highlight the importance of spatial learning in preschool mathematics, and the critical role of spatial tools and strong pedagogy. Davis, B., & the Spatial Reasoning Study Group. (2015). Spatial reasoning in the early years: Principles, assertions, and speculations. New York: Routledge.Hawes, Z. C. K., Gilligan-Lee, K. A., & Mix, K. S. (2022). Effects of spatial training on mathematics performance: A meta-analysis. Developmental Psychology, 58(1), 112-137.

Numerical and mathematical cognition among neurodivergent children

Chair: Arcan Altinar
School of Psychology, University of Surrey

Neurodiversity is defined as the heterogeneity of human minds and the countless variations of neurocognitive functioning (Walker, 2022). This diversity can make it difficult for a child to perform different kinds of cognitive processes that are usually needed for academic achievement, such as numerical and mathematical learning and development. For this symposium, we will be presenting research that investigated mathematical performance in two types of neurodivergent groups: children with autism spectrum disorder (ASD) (Jennifer Bullen and Sheeza Mahak) and children with reading difficulties/dyslexia (Anna Matejko and

Arcan Altinar).The first part of this symposium will focus on ASD, whereby, Jennifer Bullen will discuss their research on Number Line Estimation in autistic students, and other identified learning difficulties. This will be followed by Sheeza Mahak who will present their systematic review and meta-analysis which compares the mathematical performance of individuals with ASD to neurotypical individuals.The second part of this symposium will focus on research among children with reading difficulties/dyslexia. Anna Matejko will present their work on activation and connectivity during arithmetic problem solving and how this differs in children with mathematical difficulties compared to children who have combined math and reading difficulties. This will be followed by Arcan Altinar who will present results from a systematic review examining the numerical and mathematical differences among children with reading difficulties/dyslexia.Speakers will discuss the implications of their work, evaluate research practices, and highlight future directions of their research.

Presentation 1: Mathematical skills in children with dyslexia: A systematic review

Arcan Altinar*, Debbie Gooch, Mojtaba Soltanlou
School of Psychology, University of Surrey

Dyslexia is a learning difficulty hindering one's ability to read, spell and decode printed alphabetic symbols (American Psychiatric Association, 2013). This learning difficulty has a high prevalence of 7.1% among primary school children (Yang et al., 2022). While the primary deficit in individuals with dyslexia is reading difficulties, research has shown that difficulties across different mathematical knowledge and skills exist, including conceptual, procedural, and retrieval processes in dyslexia. For instance, children with dyslexia perform worse during a number fact retrieval task compared to typically developing children (Träff & Passolunghi, 2015). With this argument, it is debated whether this learning difficulty is comorbid with other developmental conditions, e.g., dyscalculia, as previous literature has highlighted comorbidities ranging from 11% to 56% (Moll et al., 2014). This raises the question as to whether mathematical weaknesses are a primary deficit or a secondary deficit along with reading difficulties. In this presentation, I will discuss our recent systematic review that compares the cognitive, behavioural and neuroscientific correlates of mathematical knowledge and skills among children with dyslexia/reading difficulties with typically developing children. First, I will describe the standardised procedure used, including eligibility criteria, blind literature screening, search strategy, data synthesis and management, and the research quality check. I will then report the behavioural, cognitive and neuroscientific findings of the eligible publications. Finally, I will discuss the limitations such as diagnostic criteria, sample sizes and power, lack of data from non-WEIRD (Western, Educated, Industrialised, Rich, Democratic) populations, and highlight the implications and future directions of this research.

Presentation 2: Mathematics ability in high-functioning autism: A systematic review and meta-analysis

Sheeza Mahak*, Kinga Morsanyi, Colin Foster, Waqas Bin Sarfraz
Department of Mathematics Education, Loughborough University

High-functioning autistic individuals are frequently perceived as mathematically gifted. However, the limited existing research on mathematical ability in autism is inconsistent (Bullen et al., 2020; Chiang & Lin, 2007). This meta-analysis investigates whether mathematics

performance in autistic individuals differs from in neurotypical individuals. We conducted a pre-registered meta-analysis measuring the mathematics performance of autistic and neurotypical individuals, following PRISMA guidelines. We searched electronic databases for studies published up to December 2022 and found 3306 records. After removing duplicates, 1372 records were screened for title/abstract, leaving 62 records for full-text review. Finally, 13 records met our inclusion criteria, where autistic (n=550) and neurotypical (n=578) participants were matched on chronological age and intelligence. A random-effects model with Hedges' g revealed that autistic individuals had a small, non-significant advantage over neurotypical individuals (g=0.12, p=.29, (95% PI (-0.92 to 0.68)). Although there was heterogeneity in effect sizes, our meta-regression analyses with the potential mediators of differences in effect sizes (age and type of IQ task) showed non-significant effects. Because several studies included effect sizes from multiple types of tasks, for further analysis, the mathematics outcome results were split into two categories: computation/arithmetic and problem solving. These analyses showed that, for problem solving only, the effect size for group differences was significant (g=0.25, p=.05, (95% PI (-0.99 to 0.50)), favouring autistic participants. Egger's regression test indicated no publication bias and the meta-regression models with moderating variables showed nonsignificant results. Overall, the findings suggest the importance of tasks for measuring mathematics outcome among autistic neurotypical individuals.

Presentation 3: Autistic children's performance on a number line estimation task and its impact on mathematical achievement

Jennifer Bullen*[1], Nicole Sparapani[1,2], Peter Mund[1,2]
[1] MIND Institute, University of California, Davis, Sacramento [2] School of Education, University of California, Davis

Estimates of dyscalculia in autism are unclear, however studies have reported that anywhere between 15-40% of their autistic samples have demonstrated difficulty with mathematics (Estes et al., 2011; Jones et al., 2009; Oswald et al., 2016). Despite this, few studies have investigated the role of numerical cognitive abilities in mathematics within autistic individuals. The Number Line Estimation (NLE) tasks has rarely been examined in autistic samples (Aagten-Murphy et al., 2015; Haas, 2010) despite its link to mathematics achievement in neurotypical (NT) children and adults (Schneider et al., 2018). Thus, this study will examine performance on an NLE task and mathematics achievement in autistic students between the ages of 5 and 8 years of age compared to their NT peers to assess if numerical cognitive abilities impact mathematics achievement differently in these children. Data analysis and collection for this study is ongoing until March 2023 (IES: R324A210288). The full sample is estimated to include 25 autistic students and 25 age- and cognitive ability-matched NT peers. Participants will complete 10 trials of a 1-20 NLE task and the Numeration and Applied Problem Solving subtests of the KeyMath-3 as measures of math achievement. Accuracy on the NLE will be assessed with the percentage of absolute error. Findings will be discussed in terms of their impact on our understanding of numerical cognition and mathematical achievement in autistic students.

Presentation 4: Does brain activity and connectivity during arithmetic differ in children with combined math and reading disability compared to children with math disability?

Anna Matejko*[1,2], Sikoya Ashbur[2,3], Melanie Lozano[2], Nicole Schlosberg[2], Guinevere Eden[2]
[1] Department of Psychology, Durham University [2] Center for the Study of Learning, Department of Pediatrics, Georgetown University, Washington DC [3] Department of Psychology and Neuroscience, University of North Carolina at Chapel Hill Guinevere Eden

Math disability (MD) and reading disability (RD) are characterized by weaknesses in arithmetic and reading, respectively. Despite different profiles, MD and RD frequently co-occur (MDRD). For children who have MDRD, little is known about whether their arithmetic processing is affected by attributes associated with their RD. For example, children with RD have poor retrieval-based arithmetic (e.g., addition), but intact procedural arithmetic (e.g., subtraction). This suggests brain activity and connectivity during retrieval-based arithmetic may differ between MDRD and MD, especially in left temporo-parietal regions known to be affected in children with RD.To test this hypothesis, we measured brain activity (using fMRI) during addition and subtraction in 24 MDRD (age=10.4) and 15 MD (age=10.7) children. A whole-brain ANOVA revealed a Group (MDRD, MD) by Operation (Addition, Subtraction) interaction in the right superior parietal lobule and precuneus. Post-hoc t-tests showed greater activation in MDRD compared to MD for addition, but no group differences for subtraction. These findings suggest that weaker retrieval in MDRD (due to their RD) leads these children to rely on procedural strategies supported by the superior parietal cortex. Next, we compared functional connectivity to characterize how differences in activity at the regional level fit with those at the network level. Analyses in 14 regions of the arithmetic network (bilateral hippocampi, superior parietal lobules, intraparietal sulci, angular, supramarginal, inferior and middle frontal gyri) revealed no group differences and will be revisited after including more participants. Together, this work provides a clearer understanding of the modulating role of RD in MDRD.

How much and where: Conceptualizing and measuring different types of children's mathematical language

Chair: Lauren Westerberg
Purdue University

Mathematical language encompasses children's comprehension and use of key terms and concepts used in mathematics and is considered one of the strongest predictors of mathematical development during preschool (Purpura & Logan, 2015). However, mathematical language has been measured differently across studies, including examining spatial language only (e.g., Bower et al., 2020; Casasola et al., 2020), quantitative language only (e.g., Barner et al., 2009), and grouping spatial and quantitative language together (e.g., Hornburg et al., 2018; Purpura et al., 2017). It is important to disentangle the specific types of mathematical language in order to better understand it as a construct and to improve measurement precision. The three studies in this symposium aim to provide a deeper understanding of what mathematical language is composed of and how it relates to children's mathematical skills during early childhood. The first study employs confirmatory factor analysis to examine and compare various theoretical models of mathematical language (e.g., spatial vs. quantitative) to identify the best overall

fitting structure. The second study modifies and expands an existing spatial language coding system (Cannon et al., 2007) to include quantitative language and compares children's spatial and quantitative language use during block play. Finally, the third study examines longitudinal relations of children's quantitative and spatial language with various mathematical skills. Examining the structure of mathematical language, how children use different types, and their relations to specific mathematics skills has implications for understanding how mathematical language can best be measured and how it may support learning in specific mathematical domains.

Presentation 1: Examining the factor structure of mathematical language

Lauren Westerberg*[1], Brianna Devlin[2], Erica Zippert[3], Alexa Ellis[4], Lindsey Bryant[5], Yemimah King[6], Elyssa Geer[2], Robert Duncan[1], Sara Schmitt[2], David Purpura[1]
[1] Purdue University [2] University of Oregon [3] University of Pittsburgh [4] University of Alabama [5] Mathematica [6] Spelman College

Mathematical language is suggested to include both quantitative (e.g., fewer, more) and spatial words (e.g., above, below; Hornburg et al., 2018; Purpura et al., 2019), as well as subcategories of these broader categories (e.g., spatial dimensions; Cannon et al., 2007). Despite that these categorizations have been used to guide the organization of mathematical language in previous work, the factor structure of mathematical language has not previously been evaluated. As such, the goal of this study was to determine the best fitting structure of mathematical language using confirmatory factor analysis. Data were drawn from the first timepoint of three intervention studies which yielded 605 children aged 3-to-5 years. Children were assessed on their mathematical language in the fall of their preschool year. First, a one-factor mathematical language model was compared to a two-factor quantitative and spatial mathematical language model. The two-factor quantitative and spatial mathematical language model demonstrated better fit (CFI = .95, TLI = .95, RMSEA = .024) than the one-factor mathematical language model ($\Delta\chi2(1) = 37.13$, $p < .001$). Findings provide support for the distinction between quantitative and spatial terms as opposed to treating mathematical language as a unidimensional construct. Further analyses will be conducted to examine alternative measurement models of mathematical language as well as the substructures of both the quantitative and spatial mathematical language factors. Examining different conceptualizations of mathematical language is a critical step for both measurement refinement and understanding the role of mathematical language in children's developing mathematical knowledge.

Presentation 2: Coding preschoolers' quantitative and spatial mathematical language-use during block play

Brianna Devlin*[1], Lindsey Bryant[2], Lauren Westerberg[3], Alexander White[4], Elyssa Geer[1], Tracy Zehner[1], Tanya Paes[3], Robert Duncan[3], David Purpura[3], Sara Schmitt[1]
[1] University of Oregon [2] Mathematica [3] Purdue University [4] Indiana University

Engaging preschoolers in semi-stuctured block play increases their early math knowledge (Schmitt et al., 2018), and a potential mechanism driving this outcome may be the use of mathematical language during play. However, past work on mathematical language-use during block play has focused on spatial language (e.g., "taller", "rotate"), and not considered quantitative language-use (e.g., "more", "equal"). Currently, there is no framework for systematically coding both quantitative and spatial language terms. The first goal of this work

was to modify and expand an existing spatial language coding system (Cannon et al., 2007) to include quantitative language, resulting in the Spatial and Quantitative Mathematical Language Coding System. We next explored compared preschoolers' use quantitative and spatial language terms during block play. Twenty-four preschoolers (Mage = 4 years, 9 months;) were assigned to a semi-structured block play intervention. Children participated in 14 small group play sessions. They were given a building prompt at the start of the session (e.g., "Today your job is to build a house together"), then were allowed to build freely. We coded children's mathematical language-use across block play sessions from video using the modified coding system. When frequency counts were weighted to account for the number of words in each category, children used spatial language terms (52.3% of all mathematical language terms) only slightly more than quantitative language terms (47.7% of all mathematical language terms) during block play. The modified coding system can be used to target support of the development of early mathematical language.

Presentation 3: Longitudinal associations between mathematical language and mathematical abilities in preschool

Eylül Turan*, Bert De Smedt
KU Leuven

Mathematical language is critical for mathematical abilities in early childhood (Turan & De Smedt, 2022). To date, no study has disentangled the roles of different types of mathematical language, namely quantitative (e.g., more) or spatial language (e.g., above). Further, existing studies assessed only children's numerical competencies, but did not consider broader domains of mathematics, such as measurement and geometry. We assessed 134 preschool children's (69 females) understanding of quantitative and spatial language. We investigated how both aspects of mathematical language relate to children's performance in different domains of mathematics (i.e., numerical competencies, measurement and geometry) using a longitudinal design. We additionally measured children's general language and spatial skill. Children were 4 years 8 months at the first testing point (T1) and 5 years 3 months at the second testing point (T2). Quantitative and spatial language correlated with all three mathematical abilities to a similar extent at both time points. Regression analyses indicated that T2 numerical competencies were predicted by children's general language and spatial language at T1. Children's geometry performance at T2 was predicted only by their T1 spatial skill. Finally, their measurement scores were predicted by their T1 general language, spatial language and spatial skill. Cross-lagged-panel analysis (CLPA) will be used to analyze the data further, and results from this analysis will be presented at the conference.

Discussant

Victoria Simms
Ulster University

Mathematical brain before school entry

Chair: Elizaveta Ivanova
University of Surrey

Before entering school, children begin to acquire symbolic numeracy, a skill that lays the foundation for mathematics learning and achievement throughout formal schooling (e.g., Duncan et al., 2007). Although major concurrent changes in the brain have been documented, the relationship between brain and cognitive development, particularly before and during initial number word acquisition, is not well understood yet. The current symposium gathers four different and exciting lines of research that probe the relationship between brain and cognitive development by using innovative methods that allow functional and structural brain measures of preschool children. First, Soltanlou will set the stage for the empirical work by presenting a comprehensive systematic review of neuroimaging studies of numerical and mathematical processing from birth to school to date. Next, Chen & Hyde will present work using event-related potentials (ERPs) to document the relationship interaction between domain-specific and domain general cognitive systems in the early acquisition of symbolic number concepts. Then, Vandecruys & De Smedt will present results from a longitudinal study using diffusion weighted imaging (DWI) to reveal whether the development of the white matter tracts is influenced by schooling, age-related maturation, or both. Finally, Ivanova & Soltanlou will present work using functional near-infrared spectroscopy (fNIRS) to investigate changes in frontoparietal activation and functional connectivity associated with the acquisition of the cardinality principle knowledge. Together this symposium will present a summary of some of the latest findings in the field regarding the neurodevelopment of numeracy in preschool children with a diversity of methods and theoretical perspectives.

Presentation 1: Mathematical brain from birth to school: A systematic review

Mojtaba Soltanlou*[1] , Vivek S. Patil[2], Daniel Ansari[2]
[1] University of Surrey [2] University of Western Ontario

The ability to process numerical information in adulthood can be traced back to the first years and even months of life. Understanding the neurocognitive mechanisms underlying these processes in early development would help to develop theories and provide evidence for brain-based diagnoses and interventions. We systematically reviewed the existing literature that investigated the neurocognitive mechanisms of numerical and mathematical processing from birth until school entry. The findings of 36 neuroimaging studies will be discussed. Pre-verbal infants can process nonsymbolic numbers such as changes in the number of visually or auditorily presented objects, or violation of mathematical expectation (e.g., 1+1=1). This ability leads to activation in the right intraparietal sulcus, the brain region that is involved in magnitude processing. Later, using their language skills, children start verbal counting, and gradually understand that each number in the count sequence refers to a specific set of items (e.g., 'two' means 'two things'). This ability is called the cardinality principle which is a milestone in cognitive development and is associated with the left intraparietal sulcus, the brain region that is involved in symbolic number processing. I will discuss developmental brain activation shifts from the right parietal region related to the processing of nonsymbolic numbers to the bilateral, mostly left parietal region related to the processing of symbolic numbers. I will

further discuss the limitations of those studies (e.g., power issues, lack of studies in toddlerhood, lack of longitudinal studies, lack of studies in non-WEIRD populations) and future perspectives in this field.

Presentation 2: Qualitative differences in neural signatures of number processing track conceptual change in preschool children

Chi-Chuan Chen*[1], Ilaria Berteletti[2], Daniel Hyde[1]
[1] University of Illinois at Urbana-Champaign [2] Gallaudet University

Numeracy first emerges as children learn the meanings of number words and how to use them to precisely count sets of objects. To better understand how children acquire these early symbolic number concepts and the nature of this developmental process, we measured event-related brain potentials in preschool-aged children (3-4 years, N=129) before and/or after demonstrating understanding of cardinality, an accepted benchmark of the conceptual development of numeracy. We observed that less conceptually advanced children showed stronger early posterior brain signatures (N1) indicative of attentional processing of visual arrays as individual objects, whereas more conceptually advanced children showed neural signatures indicative of attentional processing of multiple-object arrays as sets. Individual differences in this neural sensitivity to objects were negatively correlated with inhibitory control abilities, suggesting more conceptually advanced children may have been better able to inhibit focusing on individual objects and, instead re-focus on the cardinality of the set of objects. Second, only more conceptually advanced children showed later latency frontal (N2) sensitivity to the numerical-semantic distance between the number of visual items and a number word presented beforehand. There was some evidence that individual differences in this frontal sensitivity were related to language learning abilities. Together these results support the view of numerical development as qualitative conceptual change (e.g., Piaget, 1952; Carey, 2009) and implicate executive processing and language learning abilities in this change. Future work should investigate whether conceptual development can be promoted by encouraging set-based and relational modes of numerical thinking observed in more conceptually advanced children.

Presentation 3: Disentangling schooling and age effects on children's white matter networks of arithmetic and reading

Floor Vandecruys*, Maaike Vandermosten, Bert De Smedt
KU Leuven

One critical experience in early childhood is children's transition from preschool to primary school, where they learn to read and to calculate. To date, it remains unclear to which extent children's brain development in this age period is driven by maturational changes or by changes in the exposure to formal schooling. There are a small number of studies, albeit only in the field of reading and not in mathematics, that compared children before and after the start of formal schooling and observed changes in white matter tracts during the first years of reading instruction. Critically, these studies do not allow to isolate age-related maturational from schooling-related effects. To fill this gap, we use for the first time a longitudinal school cut-off design to experimentally disentangle the effects of maturation and schooling on children's white matter tracts supporting arithmetic and reading. To this end, we recruited 5-year-old children who underwent an MRI-scan and behavioral testing at two timepoints: in summer 2021 (n = 65), when all children attended play-oriented preschool and one year later, in summer

2022 (n = 58), when half of the children had experienced their first year of schooling whereas the others had remained in preschool. A full data-analysis plan is accepted for publication as registered report. All data is collected and is now analyzed along the preregistered plan. This study will reveal how an ecologically valid source of learning, going to school, influences children's white matter development, contributing to a major conundrum in developmental science.

Presentation 4: The origin of symbolic numerical knowledge in preschool children

Elizaveta Ivanova*, Mojtaba Soltanlou
University of Surrey

The cardinality principle is the ability to associate each number word in the count sequence to item sets (e.g., 'five' means 'five things'), and is the core of symbolic numerical knowledge (Wynn, 1990). Despite the abundance of behavioural studies of the cardinality principle, not much is known about brain changes chaperoning its acquisition. This understanding can further develop theories about the origin of symbolic knowledge in early development, which might help identify risk factors for later math-related difficulties early on. We hypothesised that children who know the cardinality principle will reveal higher left parietal activation related to the semantic processing of number words, higher bilateral parietal functional connectivity that links number words to their discrete quantity, and higher bilateral frontal activation related to supportive executive functions as compared to children who have not acquired cardinality principle yet (Hyde, 2021). To test our hypotheses, we conducted a study that measured bilateral frontoparietal activation and connectivity using functional near-infrared spectroscopy (fNIRS) during the auditory numerical adaptation task, in which a continuous stream of a number word 'six' was periodically interrupted by deviant number words and non-number words (Vogel et al., 2017). In total, 80 children (40 cardinality knowers and 40 subset knowers) between 3 and 4 years old participated in the study. Using the give-a-number task, children were allocated to one of the groups. We will present the results of between-group contrast analysis of the bilateral frontoparietal regions of interest and the functional connectivity between those regions.

Look what you made me do: Registered reports on early mathematics interventions

Chair: David Purpura
Purdue University

Registered Reports are an important mechanism for dissemination of high-quality research because they have rigorous external review prior to implementation and enable well-conducted null findings to be published in the literature minimizing publication bias. However, registered reports are relatively new for early mathematics interventions and few rigorous intervention studies have been published using these mechanisms. The three studies in this symposium are early mathematics intervention studies that have all been accepted as Stage 1 Registered Reports and nearing completion (all data have been collected and nearing submission of the Stage 2 Registered Report). The authors will present on the process of completing both the Stage 1 submissions, as well as the completed studies. Highlighted in the talks will be challenges and key considerations of planning, implementing, analyzing, and interpreting

registered report studies. These studies reveal that registered reports can be an important vehicle for the field, but also that further discussions on how to best implement such processes are needed.

Presentation 1: Mechanisms underlying transfer from domain-specific and domain-general cognitive training to children's math skills

Andrew Ribner*[1], Melissa Libertus [1,2]
[1] Learning Research and Development Center, University of Pittsburgh [2] Department of Psychology, University of Pittsburgh

Individual differences in the precision of non-symbolic representations of number and mapping between non-symbolic and symbolic number representations predict math achievement. Furthermore, prior investigations have suggested that honing these representations improves math skills. The goal of this registered report is to disentangle potential mechanisms of transfer. Approximately 324 children aged 4-6 years enrolled in one of about 20 classrooms across two years were assigned to one of three, 5-week computerized, teacher-facilitated training conditions for a total of 10 training sessions. Children were randomly assigned to a condition which targets their non-symbolic number processing, mapping between non-symbolic and symbolic number formats, or executive function. Participation is ongoing: As of the end of 2022, approximately 225 participants had completed the intervention with remaining implementation ongoing through the end of spring 2023. We intend to explore three primary mechanisms through which training-related improvements might operate: Improvement in non-symbolic number processing, in mapping between symbolic and non-symbolic number representations, or in attention to number. This investigation has in-principle acceptance and data collection will be complete by May 2023. At the time of presentation, descriptive characteristics for the entire sample and preliminary results of preregistered analyses will be discussed. In addition, we will discuss the lengthy process from proposal to intended completion of the registered report (Stage 1 first submitted October 2020; Stage 2 anticipated first submission summer 2023), data collection in the context of the COVID-19 pandemic, and challenges related to teacher-facilitated intervention.

Presentation 2: Assessing the impact of LEGO® construction training on spatial and mathematical skills

Emily Farran*[1,2], Emily McDougal[1], Priya Silverstein[1], Oscar Treleaven[1], Lewis Jerrom[1], Katie Gilligan-Lee[2,3], Camilla Gilmore[4]
[1] University of Surrey, Guildford [2] Centre for Educational Neuroscience, University of London [3] University College Dublin [4] Loughborough University

There is a known association between LEGO® construction ability, spatial thinking and mathematical abilities. The aim of this study is to determine whether this relationship is causal, by measuring the impact of Lego construction training on Lego construction ability and a range of spatial and mathematical abilities. On account of the digital revolution, we also compared the impact of physical vs. digital Lego training. Children aged 7 to 9 years (N= 195) took part in one of three training packages: physical Lego training; digital Lego training; and control training (craft activities). Each training package comprised twelve 30-minute sessions. Pre- and post-test tasks include: Lego construction ability, spatial skills (disembedding, visuo-spatial

working memory, spatial scaling, mental rotation, and a number line task) and mathematical abilities (geometry, arithmetic, and mathematical problem solving). Data collection completed in December 2022 and analysis will be complete by March 2023. We predict improvement in both spatial and mathematical skills for both Lego interventions, relative to the control condition. We will also discuss the pros (and cons) of conducting a registered report during a pandemic. This research will both contribute to the development of theories of mathematical cognition and identify the potential of Lego/block construction training to support mathematics learning.

Presentation 3: Unique and combined effects of quantitative language and numeracy instruction: Findings and reflections on a Registered Report

David Purpura*[1], Connor O'Rear[1], Alexa Ellis[2], Jessica Logan[3], Lauren Westerberg[1], Yemimah King[4], Mackenna Vander Tuin[5], Patrick Ehrman[1], Inga Nordgren[1], Kirsten Anderson[1], Jimena Cosso[6], Erica Zippert[7], Amy R. Napoli[8], Caroline Byrd Hornburg[9], Sara A. Schmitt[10], Jennifer Dobbs-Oates[1]
[1] Purdue University [2] University of Alabama [3] Vanderbilt University [4] Spelman College [5] University of Texas [6] Pennsylvania State University [7] University of Pittsburg [8] University of Nebraska [9] Virginia Tech [10] University of Oregon

Identifying ways to enhance mathematical instruction is crucial to understanding the ideal ways to promote academic success. Previous work has identified mathematical language (i.e., words/concepts such as more, same, or fewest) as a key mechanism that can be targeted to improve children's development of early numeracy skills (e.g., counting, cardinality, and addition). Current recommendations suggest a combination of numeracy instruction and quantitative mathematical language instruction to promote numeracy skills. However, there is limited direct support of this recommendation. The goal of this study was to compare the unique and combined effects of each type of instruction on children's numeracy skills. We randomly assigned 234 children (ages 3 to 5) to one of four conditions where they worked with trained project staff who read picture books targeting: (1) Quantitative Mathematical Language Only (e.g., more or less), (2) Numeracy Only (e.g., cardinality, addition), (3) a Combined combination of [Quantitative Language+Numeracy], or (4) a non-numerical condition (Active Control) picture books. Results revealed no significant effects of the Quantitative Language Only or Numeracy Only conditions, and promising effects of the Combined condition. These findings indicate that combining quantitative language and numeracy instruction may be the most effective method for enhancing young children's mathematical learning, but more work is needed on how quantitative language and numeracy instruction should best be delivered (e.g., integrated, sequential) to preschool children to maximizing learning opportunities.

Discussant

Sara Hart
Florida State University

Poster session 2 (3.45 pm – 4.45 pm)

1. COVID-19 infection and children's mathematics learning

Annie Yixun Li, Catherine Capio, Derwin K.C. Chan, Sum Kwing Cheung*
Department of Early Childhood Education, The Education University of Hong Kong

Clear evidence suggests that children ended the school year during the pandemic with lower mathematics achievement than a typical year (e.g., declines in 9 to 11 percentile points; Lewis & Kuhfeld, 2022). However, little empirical work has directly examined the impact of COVID-19 on mathematics achievement. Even less attention has been paid to the potential learning needs of children with a history of COVID-19 infection. In this ongoing longitudinal study, we asked if COVID-19 infection and Long COVID symptoms link to children's mathematics achievement over three years. This paper reports the data collected in the first year. Participants are 90 children (Mage = 9;1, SDage = 2;8, 45 girls) in Hong Kong either: (1) with a history of COVID-19 infection and reporting Long COVID symptoms (N = 24), (2) with a history of COVID-19 infection but without reporting Long COVID symptoms (N = 31), or (3) without a history of COVID-19 infection (N = 35). Four subsets of the Wechsler Individual Achievement Test - Third Edition (Wechsler, 2009) were used as age-appropriate. The internal reliabilities were high: Math Problem Solving (α = .95), Addition Fluency (α = .97), Subtraction Fluency (α = .97), and Multiplication Fluency (α = .98). Upon assumption check, a one-way ANCOVA was run to test group differences in mathematics achievements, while controlling for children's age and grade. No significant differences were observed across groups. This study provides direct empirical evidence for clarifying the effects of COVID-19 on mathematics achievements and paves the way for further investigations.

2. "In math class, I am confident in solving word problems": Creating a strengths-based mathematics survey

Gillian Grose*[1], Martin Buschkuehl[2], Yi Feng [3], Susanne M. Jaeggi[3], Mary DePascale[4], Geetha Ramani[1]
[1] University of Maryland, College Park [2] MIND Research Institute [3] University of California, Irvine [4] Boston College

Children's beliefs about their math competence and interests are related to their later mathematical achievement (Susperreguy et al., 2018). Prior measures of math competence often focus on math learning and skills more generally (e.g., Simpkins et al., 2006). However, the strengths children believe they bring to a math classroom could vary across numerous dimensions beyond just math skills. Understanding children's beliefs about the various strengths they bring to a mathematical classroom could provide insight into how teachers and researchers can build on these strengths to promote better mathematical achievement (Kobett & Karp, 2020). We have developed a strengths-based mathematics questionnaire to understand fourth and fifth-grade children's beliefs about their strengths in the math classroom. This survey was created with input from focus groups with teachers. We piloted a 21-item questionnaire that asked children about how confident they are in various aspects of math class (e.g., "asking my classmates for help," "showing my work," "explaining how I solved a problem"). Children indicate the extent to which each phrase describes them on a 5-point scale. Fourth and fifth graders (N=107) completed the strengths-based survey. Scale reliability was good (alpha= .88). An exploratory principal component analysis with Promax rotation indicated two underlying components, which can be summarized as "problem-solving skills"

(alpha=.87) and "peer-help-seeking skills" (alpha= .73). Administration of a modified survey is planned for this spring with a new sample to explore how this measure relates to other areas of children's beliefs and math ability following a math intervention.

3. Does executive function moderate and/or mediate the spatial-math link?

Elyssa A. Geer*[1], Brianna L. Devlin1, Irem Korucu[2], Lindsey Bryant[3], David Purpura[4], Robert Duncan[4], Sara A. Schmitt[5]
[1] Prevention Science Institute, University of Oregon [2] Yale School of Medicine [3] Mathematica [4] Purdue University [5] College of Education, University of Oregon

Executive functions (EF) and spatial skills uniquely predict math skills in young children (e.g., Atit et al., 2021). Less work, however, has sought to examine the role that EF may play in the link between spatial and math skills (Hawes et al., 2019). Importantly, there may be overlap in the skills underlying EF and spatial cognition such that the more general EF skills may underlie the spatial-math link. The present work expands on our previous work, by examining if EF moderates and/or mediates the spatial math link across two waves of data. Data for this study come from a sample of approximately 243 preschoolers from the Midwest United States. Math skills were measured using the PENS-B (Purpura & Logan, 2015) which assesses children's early numeracy skills. Spatial skills were assessed using the Test of Spatial Assembly (Verdine et al., 2017). EF were measured using the Head-Toes-Knees-Shoulders (McClelland & Cameron, 2011), Card Sorting Task (Zelazo, 2006), Day-Night Stroop (Gerstadt et al., 1994) and the Tower of Hanoi (Carlson et al., 2004). Data for wave two is currently being entered and cleaned, thus we can only discuss proposed analyses and expected results. We will conduct regression analyses to examine predictors of math. Specifically, moderation and mediation analyses will be conducted to identify the role of EF in the spatial-math link. Preliminary results within wave one suggest we may find that only Tower of Hanoi (complex planning skills) will moderate the link between spatial and math skills ($p < .001$).

4. Children's gender stereotypes about the relative roles of effort and talent in math achievement

Jillian Lauer*
University of Cambridge

Both parents and teachers endorse gender stereotypes about the causal roles of effort and talent in children's math performance (e.g., Frome & Eccles, 1998; Robinson-Cimpian et al., 2014). Whereas adults tend to attribute girls' math successes to high levels of effort, they tend to attribute boys' math achievements to high levels of talent. This research examined whether children endorse similar stereotypes about math during elementary school, a critical time for the development of math interests and gender differences therein. In Study 1, 144 elementary-school children were presented with novel characters that varied in levels of mathematical talent (high, low) and effort devoted to math classes (high, low). Participants then indicated how well they believed each character would perform in math. Children expected talented male characters to perform well in math classes regardless of the character's effort level, yet expected talented female characters to succeed only when they displayed high levels of effort. Study 2 (N=145) utilized an alternative paradigm to replicate and extend these findings. Children reported that effort was significantly more important to girls' math achievements relative to boys', whereas talent was equally important to girls' and boys' math successes. Moreover, girls who rated effort (but not talent) as more important to math achievement

reported greater math anxiety and reduced math interest relative to their peers. These results demonstrate that children possess attributional gender stereotypes about the causal roles of effort and talent in math achievement and suggest that these early emerging stereotypes may limit girls' mathematical development.

5. Frequency and adaptivity of children's subtraction by addition use: The role of conceptual knowledge

Stijn Van Der Auwera[1]*, Joke Torbeyns[1], Bert De Smedt[2], Lieven Verschaffel[1]
[1] Center for Instructional Psychology and Technology, KU Leuven [2] Parenting and Special Education Research Unit, KU Leuven

We examined the frequency and adaptivity of children's subtraction by addition strategy use (SBA; e.g., 712–346=?; 346+54=400, 400+300=700, 700+12=712 and 54+300+12=366) when doing mental multi-digit subtractions, and, more particularly, whether these two strategy parameters are associated with (1) their understanding of the addition/subtraction complement principle (i.e., if A+B=C, then C–B=A and C–A=B), and (2) their knowledge of different conceptual models of subtraction (i.e., understanding that subtraction can be conceived not only as "taking away", but also as "determining the difference").SBA frequency and strategy adaptivity were examined with a task in which children could freely choose between SBA and direct subtraction (e.g., 712–346=?; 712-300=412, 412-40=372, 372-6=366) to solve 15 subtractions. To measure children's understanding of the complement principle, we used a looking-back task, in which the answer to a problem (e.g., 91–43=?) could be derived by looking back at the previous item (e.g., 43+48=91), and a letter task, in which the digits of related problems were substituted by letters (e.g., if 'H–C=F' is given, is 'C+F=H' correct?). To examine whether children understood subtraction also as "determining the difference", we used a word problem task, in which they had to judge whether word problems that were formed according to the determining-the-difference-model, were correct translations of given numerical subtractions (e.g., 71–37=?).No associations were found between SBA frequency and the conceptual knowledge tasks, but strategy adaptivity was related to the looking-back and letter task. Conclusions will be presented at MCLS 2023.

6. Family support professionals as models of early mathematical dialogue: More questions than answers?

Sarah Pan*[1], Alisha Wackerle-Hollman [2], Michele Mazzocco[1]
[1] Institute of Child Development, University of Minnesota, Minneapolis [2] Department of Educational Psychology University of Minnesota, Minneapolis

Research into mathematical dialogues between caregivers and young children suggest that when caregivers initiate "math talk" during everyday scenarios (e.g., play), children's and adults' math utterances are predominately declarative statements (e.g., "there are four cups") rather than questions (>91%; Chan et al., 2020). These findings lead researchers to speculate that encouraging caregivers to pose more questions may support deeper conversations around mathematical thinking. But the types of questions posed may also matter: Open-ended questions (e.g., "I wonder if we have enough cups for everyone?") may prompt children to explore abstract ideas, unlike closed-ended questions that elicit a specific response (e.g., "How many cups are there?"). Since caregivers may seek guidance from professionals they encounter who are knowledgeable about child development (e.g., librarians, parent educators, home visitors), in this study we explored how these family support professionals (FSPs) envision

math conversations with children. We asked FSPs to generate examples of intentional math-focused utterances suitable for everyday caregiver-child scenarios, and coded each response as an open- or closed-ended statement or question. We also identified math topic(s) implicated by each response. Our preliminary findings reveal that, in contrast to observational studies of caregiver-child dyads, FSPs generated more questions than declarative statements. However, their questions were predominantly close-ended. Additionally, among the math topics embedded in FSPs' responses, numbers and counting were overrepresented relative to six other math topics coded. Our ongoing qualitative analyses may also reveal themes that describe what FSPs perceive as meaningful math dialogue with young children.

7. Impact of manipulatives on 3rd-grade students' performance in math tasks: The case of money as a manipulative material in math education

Styliani Politi*, Christine Schiltz
University of Luxembourg

It is widely assumed that using real-world objects could facilitate performance in math. At the same time, even though the use of manipulative materials in education is encouraged, perceptually rich objects have been shown to harm students' performance (e.g., McNeil et al., 2009). The present study, using a within- and between-groups design, explores the effects of real money, in the form of banknotes and euro coins, as a manipulative material in education, specifically, on the math performance of 3rd-grade students (n=63, 38 girls). First, students were introduced to money as manipulative material in a teaching session of 45' in classrooms and practiced using money while solving math tasks. One week later, an assessment of math tasks with and without manipulatives took place. Demographic data were collected from parents' questionnaires. The effect of the manipulative material was explored together with possible interactions with students' general math and language fluency, and socioeconomic status (SES) using data from a standardized math assessment based on national curriculum. Overall, money did not affect students' performance. Boys outperformed girls in our assessment, but not in the standardized national math test. Furthermore, there was a significant interaction between students' pre-established language skills and the use of money, as money seems to harm the performance of students with high pre-established language skills. These findings are discussed as a result of a trade-off that the use of manipulative materials entails in math education.

8. A person-centered analysis of the relations between motivation, math achievement, and STEM career interests among Black high school students

Rebecca Adler*[1], Bethany Rittle-Johnson[1], Marian Hickendorff[2], Kelley Durkin[1]
[1] Vanderbilt University [2] Leiden University

The current study explored individual and gendered differences in Black students' motivation for learning mathematics using three key Situated Expectancy-Value Theory (SEVT) constructs (expectancies of success, interest, and utility value). It also evaluated whether math motivational profiles predicted later math achievement and STEM career interest among Black secondary-school students. Black students (n = 410, 55% female) attending schools in a metropolitan area of Tennessee, USA and mostly from families surviving economic marginalization completed surveys and math achievement assessments across middle and high school. Latent Profile Analysis identified three profiles of math motivation: a profile comprised of high levels of math motivation on all three constructs (30% of students); a profile comprised

of medium-high levels of math motivation (50% of students); and a divergent profile comprised of low levels of math expectancies of success and interest, relative to math utility value (29% of students). Black girls were less likely to be in the high motivational profile than Black boys, and more likely to be in the divergent profile. Students in the high math motivational profile in 6th grade had higher math test scores in 10th grade. In contrast, math motivation profiles did not relate to STEM career interest in 10th grade. Overall, findings suggest that SEVT is useful for understanding motivation and academic performance among Black students when a person-centered analytic approach is used, but more work is needed to expand the theory to understand the development of Black students' STEM career interests.

9. Schema instruction for word-problem solving in the early grades: A research synthesis

Alison Hardy*
The University of Texas at Austin

Word problems are difficult for many students, and students with mathematics difficulty (MD) often have limited strategies for solving them (Powell et al., 2020). Although much of the existing research on word-problem solving focuses on students in Grades 3-12, word problems are prominent in mathematics curricula and assessments beginning as early as kindergarten. Schema instruction, a word-problem solving method in which students learn to identify the underlying structure of various word-problem types, has been identified as an evidence-based practice for students with and without MD (Peltier & Vannest, 2017). Evidence suggests that schema instruction has a larger effect size for elementary students than for secondary students (Lein et al., 2020). However, no previous synthesis has been conducted that isolates the effect of schema instruction on students in the earliest grades. With this synthesis, I analyzed the implementation and effects of schema instruction for word-problem solving in kindergarten, first grade, and second grade. After reviewing 704 studies, I identified 12 studies for inclusion. For this poster presentation, I will share the efficacy of the studies, the schemas included in the studies, and how students learned about the schemas. I will emphasize the importance of word-problem instruction even in the early grades, particularly for students with MD.

10. The prediction of mathematical creativity scores: Mathematical abilities, personality and creative self-beliefs

Michaela Meier*, Stephan Vogel, Roland Grabner
Educational Neuroscience, University of Graz

Creativity has become more and more important in mathematics. Despite this, it is still rather unclear which variables can predict mathematical creativity, especially compared to what we know about predictors of domain-general creativity. In domain-general creativity, not only cognitive variables (e.g., intelligence) but also personality traits and creative self-beliefs can explain variance. In mathematics, there is evidence that mathematical achievement is positively related to creativity [1] but we know almost nothing about the influence of personality traits and creative self-beliefs. Thus, the main aim of this study is to investigate the relationship between mathematical creativity and mathematical abilities, personality traits, and creative self-beliefs. To this end, mathematical creativity is assessed in at least 160 college students. Data collection is currently ongoing but will finish in April 2023. Mathematical abilities include measures of higher mathematical knowledge, arithmetic abilities, and basic numerical abilities, personality traits include the Big Five, the Dark Triad, need for cognition, and

curiosity, and creative self-beliefs include creative self-efficacy, creative personal identity, self-rated creativity, and creative mindset. First results suggest that mathematical knowledge and arithmetic abilities are more powerful in explaining individual differences in mathematical creativity than basic numerical abilities, and that the influence of personality traits seems to be less important for mathematical creativity compared to domain-general creativity. Overall, this study will help to understand the complex field of mathematical creativity. [1] Bicer, A., Chamberlin, S., & Perihan, C. (2021). A Meta-Analysis of the Relationship between Mathematics Achievement and Creativity. The Journal of Creative Behavior, 55(3), 569-590.

11. A mathematics-writing synthesis: Kindergarten through 12th grade mathematics-writing efficacy and instructional methods

Tessa Arsenault*
The University of Texas at Austin

The inclusion of mathematics writing in the classroom targets the development and assessment of student understanding of mathematical concepts (Powell et al., 2021). Yet, little consensus exists on how to effectively support mathematics writing (Powell et al., 2017). In this synthesis, I examined studies focused on mathematics writing to determine the overall efficacy of mathematics-writing instruction, the methods used within mathematics-writing instruction, and the methods used within mathematics-writing instruction for students with mathematics difficulty (MD). To answer these research questions, I conducted a systematic review of peer-reviewed studies, conducted since 2000, focused on instruction in mathematics writing conducted in Kindergarten through Grade 12. I included 37 studies with both a full range of students and students with MD. Results demonstrated positive student outcomes on mathematics and mathematics-writing measures. A total of 66% of author teams reported positive effects on mathematics measures and 75% of author teams reported positive effects on mathematics-writing measures. Across all studies, the four most used mathematics-writing instructional methods included discussion, modeling, journal writing, and explaining problem solving with informative writing. Of these studies, 10 included only students with MD in their treatment groups. These studies most frequently included discussion, attack strategy, graphic organizers, argumentative writing, and note taking. These instructional methods frequently aligned with practices used for mathematics instruction and writing instruction. In this synthesis I identified positive outcomes related to mathematics-writing instruction, but additional high-quality research is needed to determine which of the commonly used methods produce the strongest effects for supporting mathematics writing.

12. Development of Maths Whartels intervention programme using play as part of a neuropsychological approach to improve maths achievement in different cultural contexts of United Kingdom and South Africa

Wandile Tsabedze*, Petro Erasmus
Community Psychosocial Research (COMPRES), School of Psychosocial Health, Faculty of Health Sciences, North-West University

Poor achievement in maths is a global challenge and a priority for most governments, as mathematics is a requirement for entry into any career in medicine, science, and engineering. This study aims to explore how using the Maths Whartels method in different cultural contexts can contribute to improving maths achievement of pre-primary and primary school learners. Our overall goal is to develop an intervention strategy and screener for children in the early

developmental phases as well as an intervention programme. This study has been provisionally and ethically approved (Nr. NWU-00057-22-S1) by the North-West University, in the Health Sciences Research Committee. We got permission to conduct the study from the Department of Education in three focus provinces (North-West, Western Cape and Gauteng). In the empirical study we will use a sequential explanatory mixed methods research design to obtain an in-depth understanding of an individual's experiences which underlie and drive their perceptions and behaviour. A social constructivist and pragmatist approach to the research is adopted to understand how the child creates meaning while engaging with the Maths Whartels apparatus. The study has phases, namely, Phase 1: Systematic literature review, Phase 2: Empirical Step 1: Quantitative phase and Step 2: Qualitative phase, Phase 3: Development phase, and Phase 4: Validation phase. Learners from between the age of 6-12 from English-medium primary schools will be sampled. The study will assist in developing effective educational intervention programme (Maths Whartels programme) for pre-primary and primary school learners.

13. Children's use of the inversion principle in arithmetic problems

Celine Poletti*[1], Sylvain Braconnier[2], Catherine Thevenot[1]
[1] University of Lausanne [2] Ministere de l'Education Nationale France

During their development, children must learn the procedures required to solve arithmetic operations and must also master the concepts and principles underlying these operations. Among them, the inverse relation between operations is particularly important. It is classically tested using problems on the form: "a + b - b" or "d × e ÷ e". If children's give the answers a or d without performing calculations, it is concluded that they master the principle. However, we argue that such problems are not fully adequate to test the inversion principle because they can easily be solved via negation and identity principles (b - b = 0 and a + 0 = a for additive problems and e ÷ e = 1 and d × 1 = d for multiplicative problems). This is the reason why we compared the strategies used by children aged between 11 and 15 years when presented with classical inversion problems and modified versions on the form: a + b - a and d × e ÷ d. We reasoned that if classical problems really test the inversion principle, this principle should be also applied in modified problems. Our results showed that it was not the case because children more often used shortcut strategies for classical than modified problems. We conclude that the age at which children master the inversion principle has been anticipated in previous literature and that methodological precautions have to be taken if convincing evidence for its understanding are derived from the use of classical problems.

14. Measuring spatial biases in the context of symbolic arithmetic processing via an SSVEP paradigm

Maria Glaser[1], Talia Retter[2], Carrie Georges[2], Nicolas Masson[3], Mila Marinova[2], Aliette Lochy[2], Christine Schiltz[2], André Knops*[4]
[1] Department of Psychology, Humboldt-Universität zu Berlin, Berlin, Germany [2] Institute of Cognitive Science and Assessment, Department of Behavioral and Cognitive Sciences, Université du Luxembourg [3] Psychological Sciences Research Institute, Université Catholique de Louvain [4] Laboratoire de Psychologie du Développement et de l'Éducation de l'Enfant, Université Paris Cité, CNRS

In the recent years, several studies have demonstrated spatial biases in the context of mental arithmetic. Yet, the active responding in the adopted behavioural paradigms (e.g. target detection or temporal order judgment tasks) bears the risk of inducing spatial biases.

Furthermore, behavioural paradigms lack the temporal precision in measuring attentional biases. To alleviate the problems, the present study exploits the measurement of attentional deflections via steady-state visually evoked potentials (SSVEP). We presented a symbolic arithmetic task (2d ± 1d), while two squares were flickering at the left and right side of the screen at 10 and 12 Hz, respectively. Within each operation, we compared frequency-coded SSVEP amplitudes that were elicited by the left and right, i.e. either operationally cued or uncued flicker frequencies. This allowed identifying potential shifts of spatial attention towards one side during the mental arithmetic in the absence of active responses. Task engagement was established via catch trials that required a response but were not analysed. Data is currently under analysis but preliminary results demonstrate attentional deflections towards the left for subtraction and towards the right for addition – in line with the idea that spatial attention contributes to displacements on a spatially oriented mental number representation during mental arithmetic.

15. The impact of number length and numerical value on multi-digit number processing

Nadav Neumann*, Michal Pinhas
Department of Psychology, Ariel University

The decimal structure associates length with value so that the longer the number is, the larger its value. Past research revealed that perceived numerical value is influenced by both number length and digit values. Building on that, the present study examined the effect of incremental increases in number length on multi-digit number processing. We hypothesized that when comparing numbers varying in length, both the digits' values and number length would be processed, resulting in a Stroop-like congruity effect, with number length serving as the more salient factor. To test this, we presented participants with pairs of numbers which differed in their left-most digit and length (i.e., differences of 1/2/3 digits' in length; e.g., 300 vs. 70). We manipulated the task instructions between three groups of participants so that the first group chose the number with the largest left-most digit, while ignoring the numbers' lengths, the second group chose the longest number, while ignoring the left-most digits' values, and the third group chose the largest multi-digit number. We found a larger congruity effect in the group that chose the number with the largest left-most digit comparted to the other two groups. Moreover, in the later groups, the congruity effect was larger under number length differences of 1, compared to 2 and 3 digits. These findings reveal that comparative decisions regarding numbers that differ in length mainly rely on these length differences, and that the values of the left-most digits are processed only when the difference in length is rather small.

16. A Novel task for measuring spontaneous focus on numerals among adults: A psychometric investigation

Shachar Hochman*[1], Mattan S. Ben-Shachar[2], Avishai Henik[2]
[1] School of Psychology, University of Surrey [2] Department of Psychology and School of Brain Sciences and Cognition, Ben-Gurion University of the Negev, Beer Sheva

The tendency to attend to numerical information without any guidance has been found to predict various mathematical skills, but this has mainly been examined among children. Here, we present a novel computerized task to assess spontaneous focus on numeral values among adults. The stimuli used for this task were taken from the numerical-Stroop task (Henik and Tzelgov, 1982) in which numerical values and physical sizes could be either congruent, or incongruent, when the physical size and the numerical value did not correspond. In our task,

each block was composed of a sequence of congruent stimuli and the participants learned whether the smaller or the larger stimuli rewarded success in the block. After the learning trials, an incongruent trial of the same stimuli was presented. We measured whether the participants spontaneously responded according to the numerical value or to the physical size of the incongruent trial. The task was analyzed using a hierarchical Bayesian drift-diffusion model with the drift rate toward either the numerical value or physical size as the central measure. Results showed that focus on numeral values is impacted by the saliency of the physical and numerical dimensions, and that participants tend to make numerical-based decisions. Importantly, the task has high potential for individual differences research with high internal consistency, and construct and predictive validity when correlated with external tasks. Reference:Henik, A., & Tzelgov, J. (1982). Is three greater than five: The relation between physical and semantic size in comparison tasks. Memory & cognition, 10(4), 389-395.

17. Two processes across two domains: Shared global-holistic and componential-analytical mechanisms in language and numerical cognition

Filip Andras*, Pedro Macizo
Department of Experimental Psychology, University of Granada & Mind, Brain and Behavior Research Center (CIMCYC), Granada

In the present study, we propose two shared mechanisms in language and numerical cognition: global-holistic processes (related to the lexical-semantic route in language and global processing in mathematics) and componential-analytical processes (related to the sublexical route in language and local processing in mathematics). To this end, 54 participants completed two linguistic tasks (i.e., lexical decision task and a verification task of semantic categories and features), mathematical task (i.e., number comparison task; Nuerk et al., 2021), and a classical Navon task of global-local perception. We predicted that the individual differences in the global-preference index from the Navon task, would be positively related to global indexes from language and numerical cognition (i.e., word frequency effect, the difference in verification of semantic categories vs. features, overall distance effect) and negatively related to indexes of local processing (i.e., syllable-frequency effect, unit-decade compatibility effect). Linear regression analysis confirmed that the individual differences in the global-preference index from the Navon task were positively related to global indexes in language (word-frequency effect) and mathematics (overall distance effect). On the other hand, the global-preference index was not related to local indexes from either domain. We discuss these findings that shed new light on the common processes underlying language processing and numerical cognition and show how both domains relate to each other in a previously unexplored way. References Nuerk, H.-C., Weger, U., & Willmes, K. (2001). Decade breaks in the mental number line? Putting the tens and units back in different bins. Cognition, 82(1), B25–B33. https://doi.org/10.1016/S0010-0277(01)00142-1

18. Do children show spatial asymmetrical choice in an ordinal-spatial task with a landmark? A pilot study

Annamaria Porru*[1], Emma Visibelli[1], Daniela Lucangeli[1], Silvia Benavides-Varela[1], Rosa Rugani[2]
[1] Department of Developmental Psychology and Socialization, University of Padova [2] Department of General Psychology, University of Padova

Humans and animals organize and represent numerical information according to a specific left-to-right spatial orientation (Dehaene, et.al,1993). Various studies indicate that permanent cultural artifacts progressively modulate this association (Shaki et al.,2009). Recent studies show that also temporary cues (such as the location of the experimenter) might influence participants' original searching strategy in a spatial-ordinal task (Rugani et al.,2022). We extend the previous work by assessing preschoolers with an adapted age-appropriate version task. Children were asked to find a target item hidden under the second of six cups aligned in a sagittal arrangement in front of them. Successively, the experimenter covered and rotated the arrangement by 90° and asked the participant to find the target. To investigate spatial lateralization, the spontaneous searching strategy was recorded (left-or-right-lateralized). Crucially, the position of the experimenter was manipulated to assess the influence the child's choice. In the first experiment -MiddleCondition(MC)- 22 children were tested (Mage=44.09 ±3.93months), and only one experimenter was located in the center. In the second experiment -LateralCondition(LC)- 22 children (Mage=64.72 ±10.32months) were tested and a second experimenter was seated on the right side.A one-way ANOVA test comparing the children's lateralization of the searching strategy in MC vs LC, showed a significant difference between the two groups ($F(1,42) = 8.09$, $p = .007$). Children in the LC confirmed a higher tendency to search the target in the left compared to children in the MC. These preliminary results confirmed that children's choices may be influenced by the position of the experimenter.

19. Parent spatial talk complexity during spatial play is associated with toddlers' spatial relation comprehension

Danielle Fox*, Heather Bachman, Elizabeth Votruba-Drzal, Melissa Libertus
University of Pittsburgh

Increased exposure to spatial language is positively correlated with children's spatial language comprehension and performance on mental rotation tasks (Casasola et al., 2020; Kisa et al., 2019). We recently showed that the complexity of parent spatial language, not the number of spatial utterances that parents used within a spatial play context was predictive of 4-year-old children's spatial ability one year later (Fox et al., under review). The present study extends the previous work to investigate how frequency and complexity of parents' spatial language during spatial play relate to toddlers' spatial language comprehension at age 2. Two-year-old children (N=132) and their parents participated in a study investigating associations between the home learning environment and children's math skills, including a measure of children's comprehension of spatial language to describe spatial relations (e.g., "between", "on top of"). Additionally, dyads engaged in three semi-structured play activities with a puzzle, a wordless picture book, and grocery toys which were recorded, transcribed, and coded for parental spatial language input. Parents who used more complex spatial language (i.e., longer spatial utterances) during the puzzle task, on average, had children with more advanced spatial relation comprehension at age two, controlling for average non-spatial utterance length, and child age ($B=.22$, $p<.05$). No significant association between the frequency of parents' spatial language

use and children's skills were found. These findings suggest that the complexity of parents' spatial language within a spatial play context is important for toddlers' spatial relation comprehension.

20. Investigating affective mimicry in math anxious individuals

Rachel Pizzie[1], Christina Kim*[1], Rachel Sortino[1], Rachel Inghram[1], Taylor Delorme[1], Thalia Guettler[1], Bridget Lam[1], David Kraemer[2]
[1] Department of Educational Neuroscience, Gallaudet University, Washington, DC [2] Department of Psychological and Brain Sciences, Dartmouth College, Hanover, NH

Math anxiety (MA) is characterized by negative thoughts and feelings associated with math computations and is negatively associated with math performance. MA also seems to be "contagious." For example, more math anxious parents tend to have more math anxious children, and more math anxious teachers tend to have more math anxious students. In stressful or ambiguous situations, individuals may use reactions or behavior of others to guide their own behavior. For example, if you observe someone nervously fidgeting, you are more likely to mimic and internalize this negative behavior. Past research has connected this social referencing behavior to increased amygdala activity and increased negative perceptions. Math anxious individuals are potentially more susceptible to "catching" negativity from others about math. In this study, we examined how varying emotional cues from others might influence math performance, exploring how MA may exaggerate this reactivity to negative cues. Undergraduate students (N = 55) observed a negative, neutral, or non-social cue, and completed subsequent math problems or analogies. We will use behavioral and psychophysiological data to investigate if mimicry of negative expressions is associated with poorer performance on math problems. We expect that individuals with higher MA will show exaggerated mimicry of negative expressions, which will be associated with decreased math performance. These results will explore possible mechanisms by which nonverbal cues may exacerbate the negative effects of MA.

21. Exploring the development of children's ordinality knowledge

Jake Kaufman, Bethany Rittle-Johnson*
Vanderbilt University

Children's understanding of the ordered numeral sequence, known as numeral ordinality knowledge, has been associated with their mathematical achievement (Gilmore & Batchelor, 2021; Lyons et al., 2014). However, less is known about how children's ordinality knowledge develops. The current project aimed to further our understanding into the learning trajectory of children's number word and numeral ordinality knowledge. Ninety-four five- to eight-year-olds (M = 6.89, SD = 0.95) met individually with an experimenter over Zoom. Participants completed tasks judging whether a sequence of three number words or numerals were in order from smallest to biggest, and producing the order of three out of order numerals (e.g., 3-4-2). Sequences either matched the count list (i.e., adjacent; e.g., 2-3-4), or did not directly match the count list (i.e., non-adjacent with equal (2-4-6) or unequal (2-5-7) intervals). Judging if a sequence was in order was more challenging than producing the order of a sequence. Furthermore, judging the order of non-adjacent sequences was more difficult than adjacent sequences, but the distance between numbers in non-adjacent sequences did not impact difficulty. Additionally, children's number word ordinality knowledge was a unique predictor of their numeral ordinality knowledge, $\beta = .43$, $p < .001$; however, there was no significant

difference in children's number word and numeral order judgment performance, t = -0.60 (70), p = .27. Results suggest that producing an in-order sequence is easier than recognizing one, recognizing non-adjacent sequences as in-order is reflective of deeper ordinality knowledge, and number word and numeral ordinality knowledge are related.

22. Association Between Relational Reasoning and Mathematical Achievement: Mediating Roles of Arithmetic Principle Understanding and Word Problem Representation

Eason Sai-Kit Yip*, Terry Tin-Yau Wong
Department of Psychology, The University of Hong Kong

The association between relational reasoning (RR) and mathematical achievement has been revealed in recent research. In particular, the contribution of RR in different representations has gained preliminary empirical support (Yip & Wong, 2022). However, the directionality of the RR-math relation and its underlying mechanism remain unexplored. The current study therefore aims to advance the literature with a longitudinal design and examine the potential mediating role of domain-specific cognitive abilities. 190 seventh graders in Hong Kong were assessed on their RR (nonverbal and verbal) and mathematical achievement (computational skills and mathematical problem solving) for two times in an interval of one year. Their domain-specific skills (arithmetic principle understanding and word problem representation) were also examined at the later time point. Results showed that adjusting for the effect of control variables and autoregressors, computational skills were significantly predicted by nonverbal RR only. For mathematical problem solving, while nonverbal RR had unique contribution, verbal RR's contribution was also marginally significant. A subsequent structural equation model revealed that the contribution of nonverbal RR to computational skills was fully mediated by arithmetic principle understanding. Meanwhile, the ability to represent word problems completely mediated the prediction from RR in both representations to mathematical problem solving. These findings provided another empirical evidence of RR-math relation. The current study further unfolded the directionality and mechanisms between the two constructs. Implications and future directions will be discussed.

23. Word problems, item difficulty and low performers

Pernille Bødtker Sunde*[1,2], Mette Bjerre[1], Peter Sunde[3], Pernille Pind[4]
[1] VIA University College [2] KU Leuven [3] Aarhus University [4] Forlaget Pind og Bjerre

Word problems are amongst the most difficult problems students encounter (1). We investigated students' ability to recognize the symbolic problem matching the arithmetic situation of the word problem and whether this was influenced by item difficulty in semantic structure (easy vs. difficult) and students' mathematics achievement level (teacher ratings: 1-5). A total of 1081 3rd to 6th grade students (86 classes, 31 schools) answered a paper-and-pencil test including 64 multiple-choice items (single-digit and multi-digit numbers: 14 addition, 13 division, 14 multiplication and 23 subtraction) with four answer options (one correct). Example: "Paul eats 6 carrots. Noah eats 2 less than Paul. How many carrots does Noah eat?" Options: 2+6; 2-6; 6-2; 4-2. We modelled the four operations separately with item as observation unit, correct answer (1/0) as a binary response variable and student-ID as random effect. Fixed effects were grade, mathematics achievement (high achievers [HAs] vs. low achievers [LAs], item difficulty and their interaction. For addition problems LAs performed worse on 'difficult' items compared to HAs, suggesting that difference in ability

between LA and HA to choose correct symbolic problem partly relates to the difficulty of the problem. In other arithmetic operations it relates to the operation itself. Thus, teaching word problems should not only focus on solving the problem but also the understanding that multiple types of situations can be expressed by the same symbolic problem.
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24. Need for better standardization of ANS acuity and 'mathematical ability' measures

Marco Carlo Ziegler*, Carolin Marx
Department of Psychological Assessment, Justus Liebig University Giessen

The approximate number system (ANS) is assumed to be a cognitive system that allows humans to perceive numbers (> 4) in an imprecise manner. Some studies found that the ability to correctly discriminate approximate quantities (ANS acuity) is related to formal mathematical ability (Schneider et al., 2017). However, this link has sparked various controversy. We think that some controversies are partly due to a lack of methodological standardization in predictors and criteria. ANS acuity is usually measured by a dot comparison task (DCT), which often suffers from low reliability. In addition, there are different operationalizations of what 'mathematical ability' is and how it is measured. In this work, we want to test whether the association between the two constructs can be demonstrated with reasonable standardized measures. We use a well-standardized paired DCT, a reasonable-defined measure of "arithmetic fluency" (which is often used as a criterion for mathematical ability), and a standardized intelligence scale (GkKT, 2017) to investigate the relationship between ANS acuity and mathematical ability. We conducted an online experiment with 132 undergraduates (age, M(SD) = 23.22(4.48) years) that completed a 480-trial DCT, a test for arithmetic fluency, and a standardized intelligence test. We demonstrate that both ANS acuity (w) and arithmetic fluency are significant predictors for numerical intelligence. Furthermore, we show that our standardized arithmetic fluency is substantially correlated with numerical intelligence, r(129) =.72, p = <.001. We argue that better standardized measures can clarify the nature of the link between ANS acuity and mathematical ability.

25. Novel symbol learning and transfer to mental arithmetic problem-solving: a pilot study

Jacob Paul*
School of Psychological Sciences, University of Melbourne

Learning to associate symbols with numerical quantities is integral for understanding many mathematical concepts and operations. If learning signifies a greater differentiation between the relational structure of symbols, this should be evident in behavioural responses and neural activity patterns. Thirty-one adults were trained to associate a set of unfamiliar symbols with specific numerical quantities by completing symbol-to-position and position-to-symbol number line tasks with feedback. Sensitivity to feedback was assessed by asking participants to rank-order these newly learned symbols, and learning was assessed via single-digit addition/subtraction problems using these symbols. Mental arithmetic accuracy after training (Mean = 0.68, SD = 0.17) was significantly greater than chance, $t(30) = 6.11$, $p < 0.001$, suggesting successful transfer of new symbol-number associations after very little training (144 trials). Next steps include recruitment of individuals with maths learning difficulties

(dyscalculia) and mapping changes in neural representational similarity following learning using ultra-high-resolution neuroimaging (7 Tesla fMRI).

26. Potential factors determining the small number bias in random number generation

Mauro Murgia*[1], Serena Mingolo[1], Alberto Mariconda[1], Tiziano Agostini[1], Sors Fabrizio[1], Valter Prpic[2]
[1] Department of Life Sciences, University of Trieste [2] Department of Philosophy and Communication Studies, University of Bologna

Research has shown that people generate more small numbers than large numbers during random number generation ("Small number bias", SNB; Loetscher & Brugger, 2007). This preference has been attributed to a spatial bias called "pseudoneglect", which leads people to preferentially allocate attention to the left side of the mental number line when processing numbers (Loetscher & Brugger, 2009). However, SNB could also be explained by the fact that small numbers are used more frequently than large numbers (Dehaene & Mehler 1992). Here we pit these two accounts against each other, in an attempt to clarify which of the two best explains SNB. Participants performed random number generation, retrieving numbers from 1 to 12 while looking at a picture of a regular or inverted clockface display. In the regular clockface, small numbers are presented on the right while, in the inverted clockface, they appear on the left. In the inverted clockface both accounts would predict SNB. Differently, in the regular clockface, they would predict opposite outcomes. Indeed, pseudoneglect would determine a "large number bias", while the frequency of use would still determine SNB. In the inverted clockface condition participants' performance showed a trend towards the SNB, while in the regular clockface condition no bias emerged. The SNB seems to emerge only when both pseudoneglect and frequency induce a consistent outcome, but it would be disrupted when they elicit opposite effects. Taken together, the results suggest that both pseudoneglect and frequency play a role in SNB.

27. Mathematics and emotions in young in 3-6 year-old children, what's the link?

Laura Alaria*[1], Carol Berger[1], Edouard Gentaz[2], Anne Lafay[1]
[1] Laboratoire de Psychologie et NeuroCognition, Department of Psychology, University Savoie Mont Blanc [2] Department of Psychology and Education, Swiss Center for Affective Sciences, University of Geneva

Research shows that emotion skills contributes significantly to children's academic success, including mathematics (Cavadini et al., 2021; MacCann et al., 2020). If the emotional component is certainly involved in mathematics skills, the nature of the links remains to be clarified. This study aimed to assess the extent to which kindergarteners' (ages 3 to 6) emotion skills are related to academic performance in mathematics tasks. A group of 585 3-6-year-old French pupils were recruited. Contrary to a control group, an experimental group was trained by their teachers in emotion skills. Before and after the intervention, children were administered tests on emotion skills and mathematics skills. Results first showed that emotion score and mathematics score in the pretest were significantly, positively, and moderately correlated (Pearson's $r = .64$, $p < .01$). However, although children in the experimental group (especially the youngest children) well improved their emotion skills more than the control group, they did not improve their mathematics skills. These results indicate that young children's mathematics skills are related to their emotion skills. Our results, however, did not provide evidence of a causal relation.

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28. Professional architects reveal a smaller distance effect than controls in the angle magnitude classification task, but none of them display an association between angle magnitude and response side

Mateusz Hohol*[1], Piotr Szymanek[1,2], Bartosz Baran[1], Krzysztof Cipora[3]
[1] Mathematical Cognition and Learning Lab, Copernicus Center for Interdisciplinary Studies, Jagiellonian University in Krakow [2] Doctoral School in the Social Sciences, Jagiellonian University in Krakow [3] Centre for Mathematical Cognition, Loughborough University

Phenomena analogous to the distance effect (it is easier to compare numbers that are further apart) and the SNARC (faster left/right sided responses to resp. small/large magnitude numbers) have also been found beyond numerical processing. We investigated them in the domain of angle processing. Firstly, we aimed to revisit Fumarola et al.'s (2016) finding that persons highly familiar with angles reveal right-to-left spatial-angle association (SANARC). To this end, we compared the performance of two groups: professional architects and controls (total n = 62) in two behavioral tasks: the direct angle magnitude classification task (participants have to assess whether the angle magnitude is greater/less than 90 degrees) and indirect task (they have to decide whether the angle is dashed/continuous). We did not find evidence for the SANARC effect in any group in any task. Since architects extensively work with angles, a more pronounced SANARC effect would be expected than in civil engineering students originally investigated by Fumarola et al. Secondly, we calculated the distance effect using the data from the direct task. While this effect is known to be present in angle processing, none of the previous studies focused on its relationship with geometric expertise. We found a distance effect at the whole sample level and in each group separately. Interestingly, architects responded more slowly but with greater accuracy than controls and revealed a smaller distance effect for accuracy. Based on these results, we conclude that architects have a more precise/refined, however nonspatial, representation of angle magnitude than controls.

29. Effect of gender on math anxiety: Insights from the frAMAS study

Laurie Geers*, Mauro Pesenti, Michael Andres
Numerical Cognition Lab, Psychological Sciences Research Institute, UCLouvain

Math anxiety refers to negative emotional responses to math and math-related situations with important short-term and long-term consequences (e.g. math avoidance and career path foreclosures). We took the opportunity of a validation study (N = 1000) of a French version of the Abbreviated Math Anxiety Scale (frAMAS) to look at the influence of gender and other personal variables on math anxiety experienced by adults aged from 18 to 87 years. The questionnaire was administered online, one item after the other, with optimized visual display. The results confirmed the two-factorial structure (related to learning vs. being tested), strong internal consistency (alpha = .89), and good convergent/divergent validity (r = .45) with a measure of general anxiety (STAI-Trait). A regression analysis confirmed the previously reported effect of gender on math anxiety, with women being more anxious than men.

Interestingly, this difference was more pronounced for testing than learning situations. The professional sector had an effect beyond gender, with individuals from the Sciences & Technologies sector being less anxious than individuals from other sectors. Other factors influenced the responses beyond gender and sector. In particular, perceiving the attitude of math teachers as negative was associated with a higher level of anxiety, especially in women. Overall, the results show that gender is an important but not unique predictor of math anxiety scores and open up interesting perspectives to minimize anxiety levels through classroom accommodations.

30. Can individualized math instruction improve the social participation of students with special educational needs?

Michael Grosche[1], Miriam Balt*[1], Janine Schledjewski[1], Katrin Böhme[2], Monja Schmitt[3], Amelie Labsch[3], Cornelia Gresch[4]
[1] University of Wuppertal [2] University of Potsdam [3] Leibniz Institute for Educational Trajectories, Bamberg [4] Humboldt-Universität zu Berlin

In inclusive schools, students with special educational needs report that they are less socially included than their peers. Differentiation and individualized instruction, however, have the potential to influence such exclusions. This article therefore examines the question of how individualized math instruction affects participation of students with special educational needs. Data from a student survey (N= 4.654) was used. Social participation was assessed using a subscale from the 'Perceptions of Inclusion' (Venetz, Zurbriggen, Eckhart, Schwab & Hessels, 2015) questionnaire supplemented by questions on other dimensions of social participation. The extent of individualization in the classroom was surveyed. Performance in mathematics was measured. Preliminary regression analyses show protective effects of individualization that are indeed particularly effective for students with special educational needs. Venetz, M., Zurbriggen, C. L. A., Eckhart, M., Schwab, S., & Hessels, M. G. P. (2015). The Perceptions of Inclusion Questionnaire (PIQ). German Version. https://piqinfo.ch/wp-content/uploads/2019/08/piq-deutsch.pdf

31. Crossmodal recognition of layout geometry in house cricket Acheta domesticus

Bartosz Baran*[1], Jacek Francikowski[1], Mateusz Hohol[2]
[1] Faculty of Natural Sciences, Institute of Biology, Biotechnology and Environmental Protection, University of Silesia in Katowice [2] Mathematical Cognition and Learning Lab, Copernicus Center for Interdisciplinary Studies, Jagiellonian University in Kraków

Insects have been known to be capable of processing geometric properties such as the symmetry of small-scale objects, i.e. flowers. Additionally, there are few studies concerning the capacity of insects to navigate spatial layouts using geometric properties. Albeit, most of the aforementioned studies focused on visual modality. However, it has recently been demonstrated that insects could recognize the shapes of small-scale objects [1] and spatial layouts [2], utilizing tactile modality in the absence of other cues. Moreover, Solvi et al. proved that thusly acquired knowledge of small-scale objects could be transferred between modalities. These results suggest a more integrative, multimodal understanding of insects' object recognition. The presented research aimed to test whether this effect applies to spatial layouts. To this end, we employed a modification of the task used in the previous study [2] - searching for the centre in the equivalent of the Morris water maze. The experiment consisted of 7 training

trials performed either under red (invisible to crickets) or white illumination, followed by a test trial performed under converse conditions.

32. Should self-efficacy align with one's actual math skills? The case of low performing children

Pilvi Peura*, Tuire Koponen, Tuija Aro, Mikko Aro
University of Jyväskylä

High beliefs in one's capabilities in math (i.e., high self-efficacy) are proposed to contribute to higher math achievement by promoting effort and persistence for learning. Still, whereas some children lack confidence in their capabilities, some may be overly confident of their capabilities, but we know less whether low performing children are prone to be under- or over-efficacious of their capabilities. Moreover, less is known how the alignment of efficacy beliefs with actual math performance relates to children's math skill development. In this study, we examine low math performing primary school children's (N =256) level of math self-efficacy and math skill development over a year. Low achieving children's math self-efficacy was found to vary from complete confidence to complete lack of confidence. The achievement gap in math widened between the children with low self-efficacy compared to groups with positive or highly confident self-efficacy over one year. Moreover, efficacy beliefs seem to have somewhat different role in math skill development depending on whether self-efficacy considers current capability to do math tasks or the ability to learn math. Those children who were completely sure of their capabilities to learn math seem to develop more in their math skills compared to those with positive or low self-efficacy. Considering children's beliefs of their current abilities, children with high and positive self-efficacy seem to develop more than children with low self-efficacy beliefs. The results feed into the discussion whether self-efficacy should align with one's actual skills and what is the optimal level of self-efficacy.

33. Calibration effect on estimation in 7-year-old children and adults

Fanny Gimbert*[1], Edouard Gentaz[2], Karine Mazens[3]
[1] LaRAC, University Grenoble Alpes [2] SensoriMotor, Affective and Social Development Laboratory, Faculty of Psychology and Educational Sciences, University of Geneva [3] LPNC, CNRS, University Grenoble Alpes

Mapping process between symbolic numbers and numerical magnitude they represent is a fundamental ability for mathematics achievement. It can be evaluated in two different directions using estimation tasks. In perception task, participants have to estimate the magnitude of a collection with a symbolic number whereas in production task, participants have to approximately produce the numerosity of a symbolic numerical input. In children and adults, underestimation is observed for perception and overestimation for production (Crollen et al., 2011; Ebersbach et al., 2014; Odic et al., 2015). Calibration has been used to improve performance in perception tasks (Izard et al., 2008; Sullivan et al., 2013, 2014). Current research examined if using calibration is efficient to improve children's estimation performance in production and perception tasks as it has been shown in adults in perception task. The participants were 54 2nd graders and 46 adults. They were submitted to one of four conditions: perception, perception with calibration, production, production with calibration. In

each condition, 12 target magnitudes, from 13 to 90, were presented twice, in two different blocks, either in Arabic numeral or in set of dots. Participants gave their estimate by turning a potentiometer on a response box. In the calibration conditions, two inducer trials (30 and 70 in set of dots and Arabic numeral) were presented before each block. Results showed, in perception tasks, that performance was better with calibration in children and adults. In production tasks, calibration changed estimates only in adults, and does not make them more accurate.

34. Does the number of opportunities to learn mathematical language differ based on the representation of the quantity (e.g., symbolic vs non-symbolic)?

Rene Grimes*
Tennessee Tech University

Mathematical language is a critical skill across domains of mathematics (e.g., Hornburg et al., 2018). In this exploratory learning analytics study, I employed linear mixed effects models to analyze the log-file data from a previous randomized control trial (Grimes et al., 2021) and from a data set of over 2000 children. Data were from a numeracy intelligent tutoring system (ITS). ITS, build a student model providing individualized pathways to mastery. I sought to examine how individuals varied in the number of responses required to reach mastery for (a) labeling quantities 1 through 9, and (b) selecting the correct responses requiring understanding relational language (e.g., more, smaller), based on the representation of the quantities (e.g., Arabic digits, tally marks, number rods, and sets). Results indicated both intra- and inter-individual differences and implications include the necessity of providing multiple opportunities to learn mathematical language as well as the need for randomized variables within the intelligent tutoring systems rather than at the group level. Grimes, K. R., Park, S., McClelland, A., Park, J., Lee, Y. R., Nozari, M., ... & Bryant, D. (2021). Effectiveness of a numeracy intelligent tutoring system in kindergarten: A conceptual replication. Journal of Numerical Cognition, 7(3), 388-410.Hornburg, C. B., Schmitt, S. A., & Purpura, D. J. (2018). Relations between preschoolers' mathematical language understanding and specific numeracy skills. Journal of experimental child psychology, 176, 84-100.

35. Game elements increase perceived self-efficacy in children with dyscalculia

Manuel Ninaus[1], Verena Dresen[2], Isabella Kreilinger[3], Antero Lindstedt[4], Kristian Kiili[4], Korbinian Moeller*[5]
[1] University of Graz [2] University of Innsbruck [3] Private University for Health Sciences and Health Technology, Hall in Tirol [4] Tampere University [5] Loughborough University

Children with dyscalculia usually perceive less self-efficacy and more math anxiety when solving mathematical tasks. Beyond general deficits in basic numerical skills, such non-cognitive factors can negatively impact their mathematics achievement. Game-based learning has been shown to increase performance, motivation, and emotional engagement. The current study, therefore, investigated whether the use of game elements may support children with dyscalculia, when solving mathematical tasks. For this purpose, 60 children (35 boys, 25 girls) with learning disorders (dyscalculia group: N = 22 dyscalculic children + 13 children with dyscalculia and dyslexia; dyslexic group: N = 25 dyslexic children) aged 7,1 to 14,7 years (M=124.33 months, SD=20.49) participated. All children completed three different versions of a number line estimation task [i) digital with game elements, ii) digital without game elements, and iii) paper-pencil]. As expected, trait math anxiety was significantly higher in the dyscalculic group. Overall, children with dyscalculia had significantly higher estimation errors

as compared to children with dyslexia. However, performance did not differ significantly across task versions. Moreover, independent of participant group, children significantly preferred the task version with game elements over the other two versions. Furthermore, children perceived themselves to perform best in the task version with game elements present compared to the other two versions even though none provided feedback. These results suggest that using game elements in math tasks may support children with learning disorders on a non-cognitive level by increasing their expectations to perform well and their enjoyment of the task.

36. Characterizing how the brain encodes symbolic and nonsymbolic numerical quantities; an fmri study. (P)

Nidhi Shah*
Western University

From ants, birds and elephants to young infants, a significant body of research demonstrated that we share an approximate number system (ANS) that allows us to estimate non-symbolic quantities in our environment. This ANS is characterized by an analog representation of numerical quantity in which adjacent numbers (e.g., 2 and 3) share overlapping representations to a greater degree than numbers that are far apart (e.g., 4 vs 8). Along with the ability to process non-symbolic quantities, humans also learn to represent numerical quantities using abstract symbols (e.g., Arabic numerals, number words). This raises several questions regarding how these symbols are acquired and represented in the brain. The dominant view assumes that through learning and development, symbolic numbers are mapped onto their corresponding non-symbolic numerical quantity. Recent neuroimaging studies have revealed qualitative differences in the patterns of brain activity associated with symbolic and non-symbolic number processing. These findings suggest that although numerical quantities are processed in similar brain regions, the brain codes for these number formats differently. According to the discrete semantic system (DSS) proposed by Krajcsi et al. (2016), symbolic numbers function as discrete categories and they are represented in the brain as a network of nodes interconnected based on their semantic similarities and frequency. Using a multivoxel pattern analysis (MVPA) approach, we will examine the pattern of neural responses across voxels within each ROI and compare these distributions against the predictions of the ANS and DSS to better understand how the brain represents numbers.

37. Parent-based maths apps in the home learning environment: A randomised control trial. (P)

Laura A. Outhwaite*[1], Jo Van Herwegen[2]
[1] Centre for Education Policy and Equalising Opportunities, University College London, IOE's Faculty of Education and Society [2] Psychology and Human Development, University College London, IOE's Faculty of Education and Society

Informal learning experiences in the early years are vital for children's maths development (Skwarchuk et al., 2014). But parents only engage in maths activities at home once a week, compared to every day for reading (OECD, 2020). High quality interventions are therefore needed to support parental engagement with early maths at home (Cahoon et al., 2022). The prevalence and accessibility of mobile technologies make parent-based applications (apps) a potential innovative solution, but one that is under researched (Outhwaite et al., 2022). In response, we have co-designed with parents a new parent-based maths app, 'Maths@Home'. The app includes age-appropriate maths games that are designed to encourage off-screen

engagement between parent(s) and their child, using resources easily accessible in the home. This pre-registered poster will present a pilot randomised control trial (RCT) designed to establish proof-of-concept of the impact of the 'Maths@Home' app. 60 parents of children aged 3-4 years in the UK will be randomly allocated to either: 1) use the app for 8 weeks (30 families) or 2) be in a waiting list control group (30 families). It is hypothesised that the 'Maths@Home' app will have significant benefits on 1) parents' self-efficacy and motivation to support maths in the home environment and 2) children's emergent maths skills (Early Numeracy Test), compared to controls. Change over time on these two outcome variables will be compared across groups using Analyses of Covariance (ANCOVA) with respective pre-test scores and children's cognitive functioning (Raven's Coloured Progressive Matrices) as co-variates.

38. The association between gray matter volume and mathematical performance in 5-year-old children. (P)

Davina Van den Broek*, Floor Vandecruys, Bert De Smedt
Parenting and Special Education Research Unit, Faculty of Psychology and Educational Sciences, KU Leuven

Before the start of formal mathematics education, children develop some early mathematical skills such as knowledge about numerical magnitudes, number symbols and number order. These skills are not only important predictors for later mathematical achievement but also for skills in other academic domains. Despite the importance of these early skills, little is known about their neural basis. Most brain imaging studies have focused on the functional basis of mathematical cognition, while research on its structural basis is limited. This is especially the case in children who did not start formal schooling yet. Therefore, this preregistered study investigates the structural neural correlates of mathematical skills in 5-year-old children by using voxel-based morphometry. We aim to verify which gray matter regions, that have been correlated with mathematical cognition, are associated with individual differences in mathematical performance in 5-year-old children. We collected structural brain imaging data and measures of children's early mathematical skills in a sample of 62 5-year-olds. None of these children received formal education yet. These data will be used to perform a correlational analysis between the early mathematical skills and the gray matter volume. In the preregistration we propose a set of 11 regions of interest (ROI's) that will be used in the correlational analysis. These ROI's are selected a priori based on the network of regions that previous structural and functional brain imaging research found that were related to mathematical skills (Peters & De Smedt, 2018). More details about the analytic plan are presented in the preregistration.

39. Effects of multisensory input on numerical representations of diverse-SES preschoolers. (P)

Kerry Jordan*
Department of Psychology, Utah State University

INTRODUCTION Mathematical competence is critical for success in today's society. Children's early ability to recognize symbols and read numerals (e.g., Geary & vanMarle, 2016; Neumann, et al., 2013), count and understand cardinality (e.g., Jordan et al., 2007; Pinto et al., 2016), and enumerate sets/discriminate nonsymbolic quantities predict later mathematics achievement (e.g., Clarke et al., 2008; Libertus et al., 2020). Considering these predictive

qualities of early math achievement, it is crucial to identify ways to impact early math achievement. It is also important to determine whether certain populations are most receptive to any such early learning influences identified. PLANNED METHODS AND ANALYSES The work planned here and funded by the National Science Foundation will ask whether multisensory numerical input enhances nonsymbolic and symbolic numeracy in preschoolers of diverse socioeconomic status (SES) through the following aims: 1) To determine whether multisensory information about number differentially impacts preschool performance on a nonsymbolic numerical matching task, by SES. 2) To determine whether multisensory information about number improves preschool performance on a symbolic numerical matching task. Data analysis will reveal whether performance on multisensory symbolic and nonsymbolic numerical matching tasks are correlated, and whether multisensory information about number differentially benefits numerical performance of preschoolers by SES. 3) To determine whether performance of preschool children on addition and subtraction tasks improves when children are provided with multisensory vs. unisensory information about number. Analyses will reveal whether any such effects are mediated by SES, and whether they are correlated with performance on nonsymbolic and symbolic matching.

Symposia 4.45 pm – 6.00 pm

Exploring the underlying mechanisms of number processing and math cognition

Chair: Xueying Ren
Department of Psychology, University of Pittsburgh

Processing numbers and solving math problems are critical cognitive abilities that are essential for daily life. However, number processing and math problem-solving do not occur in a vacuum and intersect with other cognitive abilities. In this symposium, we will present four studies that examine links between math cognition and cognitive skills that have so far received limited attention in their associations with math, namely quantifier language, frequency distributions of symbolic number use in natural language and numerical stimuli within tasks, and error detection. The first study explores whether the approximate number system (ANS) is influenced by manipulating quantifiers before making approximate number judgements. Findings demonstrate that quantifier language affects the ANS. The second presentation used a vector semantic model to show that language estimates obtained from number word frequencies in everyday language significantly predict participants' performance in non-symbolic and symbolic number comparisons. The third study investigates if the size effect of a number comparison task can be determined by the frequency of stimuli. Results indicate that stimulus frequency shapes the size effect, and a psychophysics-based representation is not necessary to explain the phenomena. Finally, the last study examines how proficient children are at identifying mistakes in math and how it relates to their math knowledge. Results indicate that children are excellent at detecting mistakes and the ability to catch mistakes is associated with their math abilities. Overall, these studies provide important insights into the links between numerical and mathematical cognition and other, lesser-known cognitive abilities.

Presentation 1: Language and the Approximate Number System

Harmen Gudde[1], Kenny Coventry*[2]
[1] Utrecht University [2] University of East Anglia

The approximate number system (ANS) underlies our rapid and intuitive sense for quantities (Feigenson et al., 2004). The ANS, tapped into when performing rapid number judgement (DeWind et al., 2015), is affected by the properties of visual stimuli (e.g., object density and grouping). In these studies, we test whether the ANS is also affected by semantic information, an effect previously found in the processing of other types of spatial information (e.g., language presented at encoding affects spatial memory, see Gudde et al., 2016; Loewenstein & Gentner, 2005). We present the results of a series of experiments manipulating vague quantifiers (few, several, many, lots, 'no quantifier') prior to flashing a visual scene containing a number of objects. If higher-level cognition can penetrate the ANS, we expected that quantifiers presented at encoding would bias approximate number judgments towards the previously presented quantifier. Such results would provide compelling evidence that expectation mediates low-level visual processes.

Presentation 2: (Dis)Similarities Between Non-symbolic and Symbolic Number Representations: Insights from Vector Space Models

Xueying Ren*, Melissa Libertus
Department of Psychology, University of Pittsburgh

Competing theories have emerged about the relation between non-symbolic and symbolic number representations. For instance, previous studies have suggested that both non-symbolic and symbolic number representations can be traced back to a preverbal system commonly referred to as the approximate number system (ANS). Another theory has suggested the similarities between non-symbolic and symbolic number processing can be explained by the principle of efficient coding, which suggests that perception should be optimized when the stimuli occur more frequently in natural environment. In line with this, language learning and use are also contextual and probabilistic, which could follow the same efficient coding principle. In this study, we used a vector semantic model to quantify word distributions in natural language environment and investigate the (dis)similarities underlying non-symbolic and symbolic number representations. Specifically, we aimed to investigate whether participants' task performance can be best explained by the numerical ratio between numbers or by efficient coding principles. Importantly, we tested whether these results differ by number format. To this end, we tested 73 adult participants on a number comparison task with both non-symbolic (dots arrays) and symbolic numbers (English words and Arabic numbers). We found that numerical ratios significantly predict participants' performances in number comparison tasks either with symbolic (i.e., numbers and words) and non-symbolic (i.e., arrays of dots) numbers. More importantly, language estimates derived from number word frequencies in everyday language predict participants' performances in the non-symbolic task and symbolic task with number words, which suggests underlying similarities between symbolic and non-symbolic number representations.

Presentation 3: Stimulus Frequency Alone Can Account for the Size Effect in Number Comparison

Attila Krajcsi[1], Petia Kojouharova*[2]
[1] Cognitive Psychology Department, Institute of Psychology, ELTE Eötvös Loránd University, Budapest [2] Research Centre for Natural Sciences, Institute of Cognitive Neuroscience and Psychology, Budapest

In a number comparison task, the size effect (i.e, smaller values are easier to compare than larger values) is usually attributed to a psychophysics-based representation. However, alternative models assume that the size effect is a frequency effect: smaller numbers are easier to process because they are observed more frequently. Previous studies have demonstrated that the frequency of the digits fundamentally influences the comparison size effect: In new number symbols, the frequency entirely determines the size effect. In contrast, in Arabic notation, the size effect aggregates the frequency in the actual session and the previous regular size effect. Here, we investigate whether the previously acquired regular size effect can depend on the frequency of the stimuli as well or on a psychophysics-based representation that is not yet active in new symbols. Participants in the study compared numbers that were denoted with new symbols, with the frequency of the symbols being changed throughout the session. We found that the frequency of the stimuli in both halves of the session was aggregated in the size effect. In addition, no psychophysics-based size effect was found throughout the session. These results confirm that the size effect can be created and shaped purely by the frequency of the symbols,

while a psychophysics-based representation is not necessary to account for these size effect-related phenomena.

Presentation 4: The Role of Catching Mistakes in the Development of Early Mathematics

Maria Brandao*, Darko Odic
Department of Psychology, University of British Columbia

Making mistakes is fundamental for learning, but to learn we need to notice and correct these mistakes. Deciding if we answered correctly or not is tremendously challenging since there are often an infinite number of answers and few cues to help identify mistakes. In two experiments, we test how well children can detect mistakes in math, and how this relates to their knowledge of mathematics. In Experiment 1, 5 to 9 years-old children (N = 42; Mage = 7.17; SD = 1.03) watched as a puppet solved 22 age-appropriate math problems while getting only half of the answers correctly, and decided whether the puppet's answers were right or wrong. Children also solved the same problems at a later phase. We found that even our youngest children could reliably catch mistakes that the puppet made. Furthermore, children's ability to catch mistakes was correlated with – but not perfectly predicted by – their own math abilities, with children being able to detect mistakes made by others even when they reliably made them themselves on similar questions. In Experiment 2, we find that individual differences in error detection predict children's formal math scores, even when controlling for their basic number sense via the PANAMATH task and spatial working memory via a Corsi Block task (N = 63; Mage = 6.75; SD =1.09). Our results suggest that children are excellent at catching mistakes made by others in early mathematics. We discuss the possibility of using prediction-based learning as a strategy for early math education.

Dyscalculia – early detection and prevention of neuromyths

Chair: Karin Kucian
Center for MR-Research, University Children's Hospital Zurich

Developmental dyscalculia (DD) is a learning disorder that hinders children and adults in perceiving and processing numerical information accurately and affects personal as well as professional fulfilment. Awareness and knowledge about DD is necessary to enable early identification and support in order to prohibit negative development. The present symposium provides insights into early detection and assessment of DD, educators' knowledge about DD, neuronal correlates of DD and related neuromyths.

Presentation 1: Dyscalculia: Areas of math difficulties and educators' knowledge

Alison Roulstone*[1], Kinga Morsanyi[1], Lê Thị Mai Liên[2], Carlo Tomasetto[3], Julia Bahnmueller[1]
[1] Centre for Mathematical Cognition, Loughborough University [2] Faculty of Psychology, Vietnam National University [3] Faculty of Psychology, University of Bologna

This talk presents two studies related to the identification of dyscalculia in school-age children and educators' knowledge about dyscalculia. Dyscalculia (specific learning disorder in

mathematics) is characterised by severe impairments in acquiring mathematical skills, which becomes apparent in the early years of schooling. Nevertheless, there is limited research on whether different content domains within the mathematics curriculum are equally affected. In our first study, we compared the performance of dyscalculic children (n = 20) aged 8 to 11 and a carefully matched group of neurotypical children (n = 20) on a curriculum-based math assessment. The results showed that dyscalculic children were equally impaired in all content domains (including arithmetic, shapes, measurement, etc.). Moreover, question format (i.e., multiple-choice vs. open-ended) did not moderate the magnitude of group differences. These results suggest that dyscalculia is more than just an arithmetic difficulty. Furthermore, different question formats can be equally appropriate for screening purposes. In our second study, we report on educators' awareness of DD in the UK, Italy, and Vietnam (n > 1,300). Educators were administered a 24-item questionnaire, which measured their level of agreement with some basic information relating to dyscalculia (e.g., main symptoms, prevalence, co-morbidities, etc.) Educators also answered some questions relating to the availability of relevant training, screeners and intervention materials. Although educators had some basic understanding of dyscalculia, the results also revealed some significant knowledge gaps, which were only partially overlapping across countries. Educators also generally reported low availability of screeners and a limited knowledge of efficient intervention approaches.

Presentation 2: Addressing teachers' knowledge about dyscalculia and common neuromyths: Co-creation of a new toolkit ADD UP

Jo Van Herwegen*[1], Elisabeth Herbert[1], Unta Taiwo[1], Laura Outhwaite[2]
[1] Psychology and Human Development, University College London, IOE's Faculty of Education and Society [2] Centre for Education Policy and Equalising Opportunities, University College London, IOE's Faculty of Education and Society

Despite dyscalculia being a common neurodevelopmental disorder, affecting approximately 1 in 5 children in a classroom (Morsanyi et al., 2018), our previous research shows that teachers often find it difficult to identify these children or know how to support these children (Costa et al., 2021). However, it is not quite clear what kind of continued professional development (CPD) programmes would work best to increase teaching staff's knowledge to identify and support pupils with mathematical learning difficulties or what their real CPD needs are. Recent research has also suggested that co-produced or participatory workshops might lead to more embedded practice and wider impact. In this study, we report for on the results of our survey with 229 teachers in the UK and assessed what common neuromyths they endorsed related to dyscalculia and how these relate to other learning difficulties. These findings showed that 42.4% of practitioners reported no or slight familiarity with dyscalculia, compared to only 15.7% for dyslexia. However, teaching practitioners held more neuromyths about dyslexia, compared to dyscalculia, suggesting that despite increased awareness of literacy-based difficulties, there is still the need to ensure information campaigns are accurate and do not exacerbate neuromyths. In addition, we will discuss how we co-created the ADD UP toolkit with teachers to address these neuromyths and raise further awareness about dyscalculia amongst teachers and the general public.

Presentation 3: Structural surface differences in brains of children with developmental dyscalculia

Ursina McCaskey*, Patricia Meier, Ruth O'Gorman Tuura, Karin Kucian
Center for MR-Research, University Children's Hospital Zurich

Structural differences in the brain have been reported in several studies in children with developmental dyscalculia. Most results report decreased grey and white matter volume in different regions of the fronto-parietal numerical network. The goal of the present study is to investigate not only volume but also surface characteristics of brains of children with developmental dyscalculia. In the present study, we collected neuropsychological measures and structural images of 52 children with and without dyscalculia between 8 and 16 years. Voxel and surface based morphometry analyses were conducted by means of the computational anatomy toolbox. The results are in line with earlier studies, showing that children with developmental dyscalculia have smaller volumes in different regions of the fronto-parietal numerical network. Furthermore, affected children show fewer deep sulci and a less pronounced surface complexity compared to typically developing peers. No differences were found in cortical thickness between the two groups. In conclusion, our results confirm earlier findings showing decreased grey matter volume in dyscalculic children. Moreover, children with dyscalculia show differences in surface characteristics. This knowledge might add to the understanding of the development of dyscalculia.

Presentation 4: Screener to assess numerical skills in kindergarten

Noemi Gloor[1], Elisabeth Moser Opitz[1], Hedwig Gasteiger[2], Julia Bruns[3], Karin Kucian*[4]
[1] Institute of Education, University of Zurich [2] Institute of Mathematics, Osnabrück University [3] Institute of Mathematics, Paderborn University [4] Centre for MR-Research, University Children's Hospital Zurich

Research showed that numerical skills in kindergarten predict the mathematical development. Therefore, it is important to assess the numerical skills already in kindergarten. Individual testing is time consuming, and tests which can be carried out in small groups with young children are lacking. In addition, the prognostic validity is seldom examined in existing tests. The aim of the study is to develop a screener to identify children at risk for mathematical learning disabilities in kindergarten in a group setting, and to assess the prognostic validity. Participants were 472 kindergarten children from Switzerland and Germany (nCH = 335; nDE = 137; Mage = 5.59, SD = 0.45). Numerical skills were tested twice, one year before school entry (screener with a group setting and an individual setting, 32 items, Cronbach's alpha .91) and one year later (researcher developed group test, 31 items, Cronbach's alpha .92). Regression Analyses revealed that the results of the screener predicted the learning gains one year later ($\beta = .76$, $p < .001$).

Mathematical explanations

Chair: Matthew Inglis
Loughborough University

Explanations are central to education. To a large degree, teaching consists of offering instructional explanations (e.g., Leinhardt, 2001), and learner-generated self-explanations can develop learners' understanding (e.g., Hodds et al., 2014). However, both instructional explanations and self-explanations vary in quality, and sometimes have negative effects (e.g., Rittle-Johnson et al., 2017). Furthermore, student-generated explanations can be used in educational assessment, particularly when one wishes to focus on the depth of students' conceptual understanding (e.g., Bisson et al., 2016). It is therefore important to understand what makes a high-quality explanation. This is a particularly live issue in the context of learning mathematics, where educators value mathematical arguments that explain over those that merely demonstrate. But what constitutes a high-quality mathematical explanation and how do teachers and students judge this? Perhaps strangely, given the centrality of explanations to mathematical learning, these questions have not been widely studied by mathematical cognition or mathematics education researchers. This symposium addresses mathematical explanations from a variety of perspectives. We pay particular attention to how teachers and students assess explanation quality. Flores-Medrano and Xolocotzin explore the factors that teachers use to assess the quality of textbook explanations in differential calculus contexts. Inglis, Evans and Mejia-Ramos ask whether teachers and students agree with each other about the quality of mathematical explanations. Woollacott and Alcock explore how the spatial layout of textbook explanations influence their perceived quality. Finally, Ingram investigates how mathematical explanations arise in genuine classroom discourse and explores how teachers assess these naturally occurring explanations.

Presentation 1: How is the derivative explained in textbooks? The view of teachers

Karina Flores-Medrano, Ulises Xolocotzin*
Cinvestav

Mathematics textbooks are essential learning resources in various contexts. However, textbook research focuses on classroom activity. Therefore, it remains to be seen whether the explanations of concepts and procedures presented in textbooks are adequate for learning activities outside the classroom, such as individualized study. We addressed this issue from the perspective of teachers. We conducted semi-structured interviews with 10 differential calculus teachers, who shared their views on whether the textbooks they use offer adequate explanations about the derivative concept. Through a thematic analysis, we found that, for teachers, adequate explanations integrate multiple representations, e.g., symbolic expressions, graphs, tables, and text, which supports the ability to transit between representational formats and promotes a deeper conceptual comprehension of the derivative. Teachers said that textbooks should have graphic elements to support the interpretation of symbols and graphs, e.g., displaying textual explanations in frames; or presenting functions and secant lines in sequential graphs. Complementarily, teachers said that students require skills to understand the explanations of a book. For example, students need to make inferences and be aware of their understanding of an explanation. They also need procedural and conceptual knowledge to interpret symbolic expressions and the ability to visualize change when reading graphs. The desired characteristics

of books mentioned by teachers might inform the design of written material, such as books, with explanations that can adequately support students in understanding the derivative concept during individual study.

Presentation 2: Do mathematicians and undergraduates agree about explanation quality?

Matthew Inglis*[1], Tanya Evans[2], Juan Pablo Mejia-Ramos[3]
[1] Loughborough University [2] University of Auckland [3] Rutgers University

Offering explanations is a central part of teaching mathematics, and understanding those explanations is a vital activity for learners. Given this, it is natural to ask what makes a good mathematical explanation. This question has received surprisingly little attention in the mathematics education literature, perhaps because the field has no agreed method by which explanation quality can be reliably assessed. In this presentation, we report on the study that explored this issue by asking whether mathematicians and undergraduates agree with each other about explanation quality. A corpus of 10 explanations produced by 10 mathematicians was used. Using a comparative judgement method, we analysed 320 paired comparisons from 16 mathematicians and 320 from 32 undergraduate students. We found that both mathematicians and undergraduates were able to reliably assess the quality of a set of mathematical explanations. Furthermore, the assessments were largely consistent across the two groups. We conclude by arguing that comparative judgement is a promising technique for exploring explanation quality and discussing the implications for theories of mathematical explanation.
Evans, T., Mejía-Ramos, J. P., & Inglis, M. (2022). Do mathematicians and undergraduates agree about explanation quality? Educational Studies in Mathematics, 111(3), 445-467. https://doi.org/10.1007/s10649-022-10164-2

Presentation 3: The Spatial Contiguity Principle in Mathematics Explanations

Beth Woollacott*, Lara Alcock
Loughborough University

Textbooks are typically the largest source of mathematical text in the classroom. But research suggests that students rarely read them and when they do, they do not read proficiently. We therefore ask, how can mathematical textbooks be improved to encourage more proficient reading? We approached this by investigating what makes a good mathematical explanation, using explanations from textbooks written for 16-18 year-olds. We used comparative judgement to ascertain perceptions of explanation quality, then used eye-tracking technology to relate this to reading behaviour. We first asked three groups to judge explanation quality: 17-18 year-old mathematics students, teachers of this group and undergraduate mathematicians. Our application of comparative judgement not only indicated that it was an appropriate tool to investigate explanation quality but suggested that perceptions of quality were similar across groups. Furthermore, we found that diagram placement influenced perceptions: explanations with diagrams placed in the main text were perceived as higher quality than those with diagrams in the margins. This supports the spatial contiguity principle, a robust effect from multimedia learning which states that corresponding text and pictures should be placed as close together as possible. We found further evidence of the spatial contiguity principle in the eye-tracking study: we asked 17-18 year-olds to read the same explanations, finding that students spent longer looking at diagrams in the main text compared

to those in the margins. Our research is the first to suggest that this principle extends to mathematical explanations and, furthermore, highlights a straightforward approach to improving mathematics textbook explanations.

Presentation 4: Mathematical explanations within classroom interactions: what are they?

Jenni Ingram*
University of Oxford

Mathematicians and mathematics education researchers often have strong views and definitions about what counts as a mathematical explanation. Mathematics teachers also often have working definitions primarily drawn upon in assessments about what makes a good mathematical explanation (or not). However, children's learning of what counts as a mathematical explanation can be strongly influenced by how their explanations are treated during classroom interactions and discussions and the norms around these that are developed over time. Using a discursive approach, 42 mathematics lessons from 17 teachers teaching mathematics in 8 different secondary schools were analysed focusing on where these teachers asked for explanations and where students gave explanations. Results show that the majority of student explanations focus on describing or reporting procedures or the steps they took rather than explaining these steps or explaining the meaning behind the processes, ideas or concepts involved. However, when students offered explanations that contradicted a previous students' explanation, there was often more of an explanation focused on meanings, processes and ideas. Importantly, teachers predominantly accepted all of these explanations as (mathematical) explanations in similar ways, without making distinctions between the different types of explanation both explicitly and implicitly. Fundamentally these findings suggest that in practice mathematical explanations in secondary classrooms include both explanations of how and explanations of why but what makes an explanation more or less mathematical, or what makes one explanation better than another is not part of the norms of mathematics classrooms.

Measurement and impact of parent-child interactions for mathematical learning in the home environment

Chair: Colette Duncan
Ulster University

The overarching aim of this symposium is to prompt a discussion on methods of coding used to measure the impact of parent-child interactions in the home environment and its relationship with mathematic learning. This is prompted by previous highlighting difficulties in the validity of self-report, consistency of measurement, and coding subtle behaviours. Duncan will discuss the measurement of parent support and child responsiveness between very pre-term pre-schoolers (3-4 years) and their parents compared to full-term pre-schoolers and their parents. Susperreguy will speak about exploring parental aspirations, experiences, and attitudes that are not captured by other commonly used methods. Retanal will present a study that used multi-method approach to garner a deeper understanding of the quality of math homework-helping interactions between parents and their children. Finally, Weiers will discuss results of a systematic review on methods used to code mathematics and number talk and the relation with

mathematics achievement in children (8 years or younger). Also included in this talk is a meta-analysis for a subset of studies (n=26) that also reported children's mathematics skills. The symposium will provide a forum to discuss synergies of learning across these four insightful studies.

Presentation 1: Mathematics in Pre-Term Pre-schoolers (MIPP)

Colette Duncan*, Victoria Simms
Ulster University

A risk factor for poor mathematical attainment is being born very preterm (VP, <32 weeks' gestation; Simms et al., 2015; Wocadlo & Rieger, 2007), and research has identified cognitive reasons which may account for this low attainment (Guarani et al., 2014). However, time spent learning in the home environment before entering school is a critical period for typically born children (Fox et al., 2010), and currently there is a lack of research focusing on the social mechanisms that may account for the difficulties that VP children experience in mathematics (Landry et al., 2003; Treyvaud et al., 2016). The aim of the current study was to observe parental support and child responsiveness between very pre-term pre-schoolers (3-4 years) and their parents and compare these to full-term pre-schoolers and their parents in the home environment whilst playing mathematical games. Participants were full-term pre-schoolers and their parents (N=44) and VP pre-schoolers and their parents (N=26 and still recruiting). Parents and their children played games in their home, and this was observed via Zoom. All children also completed some general cognitive tasks and mathematic skills games. This talk will focus on group level differences in parent-child interactions that may contribute to differential learning outcomes in VP children.

Presentation 2: Home Mathematics Beliefs and Experiences of Chilean Families of Preschoolers: A Qualitative Study

María Susperreguy*[1,2], Valentina Aguilera, Camila Barahona
[1] Pontificia Universidad Católica de Chile [2] Millennium Nucleus for the Study of the Development of Early Math Skills (MEMAT)

Research on children's math experiences at home highlights the associations between parental math beliefs, math practices at home, and early mathematical skills (Daucourt et al., 2021). However, there is a need for a deeper understanding of these beliefs and parental practices at home, especially in groups that are underrepresented in research. Building on the work by Cahoon and colleagues (2017, 2022), this study reports qualitative research findings with Chilean primary caregivers of preschool children. The main goal was to explore the parental visions, experiences, and attitudes about the home mathematical environment that are not captured by other commonly used methods (e.g., surveys). We conducted 20 semi-structured online interviews with parents of 3- to 4-year-old children attending public low-SES preschools in the Metropolitan area of Santiago, Chile. In line with prior work with Latin American children (Cahoon et al., 2022), we explored parent perception of children's interests in mathematics, parental attitudes towards mathematics, parent math interactions with their children at home, children's use of technology, and the mathematical expectations of parents for their children. We used a thematic analysis to identify the main themes and codes of the interviews (Braun & Clarke, 2006). Preliminary findings highlight themes identified in prior research (e.g., parent-child interactions) and provide insight into unique themes (e.g., beliefs

about mathematics). We will discuss how these findings are related to the available research with Latin American parents from other sources of data collection and the future directions of this line of research in diverse contexts.

Presentation 3: Relations Between Math Achievement, Math Anxiety, and the Quality of Parent-Child Interactions While Solving Math Problems

Michela DiStefano[1], Fraulein Retanal*[1], Jean-François Bureau[1], Heather Douglas[2], Thomas Hunt[3], Anne Lafay[4], Jo-Anne LeFevre[2], Helena Osana[5], Victoria Simms[6], Sheri-Lynn Skwarchuk[7]
[1] University of Ottawa [2] Carleton University [3] University of Derby [4] Université Savoie Mont Blanc [5] Concordia University [6] Ulster University [7] University of Winnipeg

Previous research has shown that math homework-help from higher-math-anxious parents leads to poorer math achievement and higher math anxiety in their children, and further research suggests that this may be due to the homework-helping interaction being altogether more negative. In the current study, we used a multi-method approach to garner a deeper understanding of the quality of math homework-helping interactions between parents and their children, and how parents' and children's own math achievement and math anxiety relate to the quality of the interaction. Specifically, 40 parents and their children (grades 5 to 7) completed a self-reported measure to assess their levels of math and general anxiety. Further, standardized assessments of parents' and children's math achievement were obtained. Parents and children were then recorded engaging in a simulated math homework interaction, which was coded by trained coders who assessed the quality of the interaction. Using a correlational design, we demonstrated that, although parent-child dyads generally performed well on the simulated math homework task, task performance varied in relation to the quality of the interaction with higher quality interactions being associated with better higher accuracy on the math task. Further, the variability in the quality of the interaction was associated, at least in part, with parents' and children's math achievement and children's, but not parents', math anxiety. Identifying the elements that may alter the way in which parent-child dyads approach a math-related situation is essential to developing effective interventions to scaffold children's math learning and attitudes.

Presentation 4: How do researchers code parents' mathematics talk and what is the relation with children's mathematical skills? A systematic review and meta-analysis

Hanna Weiers*[1], Felicity Slocombe[2], Ella James-Brabham[1], Camilla Gilmore[1]
[1] Centre for Early Mathematics Learning, Loughborough University [2] School of Social Sciences and Humanities, Communication and Media, Loughborough University

Individual differences in mathematics achievement emerge before children start formal schooling, and these predict later achievement. Variations in the Home Math Environment (HME) may contribute to these individual differences. Indeed, a recent meta-analysis (Daucort et al., 2021) found a small significant effect of HME on mathematical skills that was moderated by different aspects of the HME. In particular, there was uncertainty around the relation between parent-child mathematics talk and children's mathematics skills. Given the wide variation of methods used, we conducted a systematic review of the methods used to code mathematics and number talk and the relation with mathematics achievement in children aged 8 years or younger. We identified 107 studies which coded mathematics talk. Based on similarities across studies in coding methods, we identified nine coding categories into which

studies could be categorised. These ranged from simple coding of the frequency of number words used to more complex coding schemes that considered different types of number domains, or the different types of utterances used by parents. We also conducted a meta-analysis for a subset of studies (n=26) that also reported children's mathematics skills. The correlation between parent mathematics talk and children's mathematics skills was 0.08. The type of coding category was not a significant moderator of the size of this effect. We will discuss the methodology and theoretical implication of this.

Equity-focused programs to measure and promote math learning and executive functioning

Chair: Geetha Ramani
University of Maryland, College Park

Disparities found in children's mathematical achievement are often due to unequal access to opportunities and resources. Therefore, providing rich, challenging, and evidence-based approaches for all students is critical for reducing differences in math outcomes. Targeting foundational underlying skills, such as executive functioning (EF), also could assist in reducing these inequalities found in math performance. This symposium includes four projects that are a part of the EF+Math Program, which supports multidisciplinary teams to develop methods and tools to measure and promote math learning by strengthening EF skills. The program centers students in grades 3-8, with a particular focus on Black and Latine students experiencing poverty in the United States. The symposium will present innovative methods and tools designed with a focus on diversity, equity, and inclusion to test and promote math learning and executive functioning. In the first presentation, Guo will discuss an active and playful learning approach to promote children's rational number learning and emotions. In the second presentation, Pahor will present a novel set of tools to measure and visualize math and EF skills using mobile app technology. In the third presentation, Buschkuehl will present findings from a novel web-based program to promote math fact fluency and EF skills simultaneously. Finally, Meyers will discuss a curriculum overlay for 3rd-5th grade students to improve EF skills, math identity, and math outcomes for Black and Latine students. Together, the symposium will present innovative approaches that could be used as resources and opportunities to enhance students' math outcomes.

Presentation 1: Impact of Fraction Ball Activities on Students' Mathematics Emotions

Siling Guo*, Lourdes Acevedo-Farag, Jesse Giovanni Sanchez, Daniela Alvarez-Vargas, LuEttaMae Lawrence, Andres Bustamante, Kreshnik Begolli, Katherine Rhodes, Lindsey Richland, Drew Bailey
University of California, Irvine, School of Education

Rational number learning is challenging for elementary students and may cause frustration and anxiety about mathematics. Fraction Ball allows students to actively learn fractions through embodied and playful activities that integrate teacher knowledge and the science of learning. The intervention consisted of six outdoor basketball games and six classroom lessons co-

designed with teachers. In a cluster randomized trial with 16 teachers and 360 students in fourth and fifth grade, we found the intervention improved students' overall rational number learning (Authors, 2023). We will present the impact of our intervention on students' self-reported emotions (e.g., happiness, boredom, and nervousness) toward math tests. The study was pre-registered at https://osf.io/kjqmz. Preliminary analyses suggest positive impacts ranging from .20 SD to .31 SD on positive emotions and negative impacts ranging from -.02 SD to -.33 SD on negative emotions. The estimates were robust to the mixed models with random intercepts by teacher and the model using Full Information Maximum Likelihood for missing data. In addition, students with higher negative emotions at pre-test demonstrated greater reductions in their levels of negative emotion after the Fraction Ball activities. Subsequent analyses will also examine whether classrooms showing larger effects on fraction learning also showed larger effects on emotional outcomes. These findings suggest that Fraction Ball represents an effective way to positively impact students' rational number learning and emotions related to mathematics. Implications for future interventions aiming to improve both learning and feelings connected to mathematics will be discussed.

Presentation 2: Developing a Low-Cost Mobile App to Reveal Excellence in EFs and Math Learning

Anja Pahor*[1], Susanne Jaeggi[2], Aaron Seitz[3], Geetha Ramani[4], Imani Goffney[4], Jacob Gardner[5], Dennis Barbour[6]
[1] University of Maribor, Department of Psychology [2] University of California, Irvine, School of Education [3] University of California, Riverside [4] University of Maryland, College Park [5] University of Pennsylvania [6] Washington University of St. Louis

Executive functions support math learning; however, executive functions also fluctuate daily and students are rarely given the opportunity to understand how this affects their learning processes. We developed a set of equitable tools to assess and visualize math skills, underlying executive functions abilities, and fluctuations in those abilities using mobile app technology (iOS and Android). In parallel, we are implementing machine learning algorithms to constrain a very short battery of tests that can be administered on a daily basis. It is hypothesized that an enhanced understanding of children's EF states will help educators to better determine individual students' strengths and needs, and to facilitate the use of this information to guide personalized instruction. A validation study involving 280 students in grades 4 and 5 is currently underway, along with a pilot multiple-session study to examine variability in executive function over time. I will present the results of these studies and discuss how using the shortened battery could be administered during lessons to guide instruction.

Presentation 3: ST Math Fluency+: The Impact of Combined Math Fact Fluency and Executive Function Training

Martin Buschkuehl*[1], Yi Feng[2], Geetha Ramani[3], Gillian Grose[3], Susanne Jaeggi[2]
[1] Mind Research Institute [2] University of California, Irvine, School of Education [3] University of Maryland, College Park

Math fact fluency describes the skill to solve relatively simple math problems accurately and quickly. Being proficient in math facts has many benefits, for example, early proficiency with math facts predicts subsequent math achievement. Executive functions (EFs) are cognitive processes that allow to control, supervise, or regulate thinking and behavior for goal achievement. There is a bidirectional relationship between EFs and math. On one hand, EFs

provide the mental workspace to acquire and perform math operations. On the other hand, procedural requirements such as keeping track of partial results during mental math provide opportunities to train EF skills. There is accumulating evidence that training EFs in a curricular context is beneficial. ST Math Fluency+ is a novel web-based program that strategically aims to train both, math fluency facts and EFs at the same time to specifically support math-related EFs. Preliminary intervention data indicated beneficial effects of Fluency+ on untrained measures of EF and math fact fluency, demonstrating the program's promise. Here, we will report the data of an ongoing curricular trial involving 12 different classrooms with more than 270 students from a diverse background to further establish the program's efficacy.

Presentation 4: Our Mathematical World

Amanda Mayes*[1], Caroline Byrd Hornburg[2], Tamika L. McElveen1, Sara A. Schmitt[3], Ma Bernadette Andres-Salgarino[4], Sarah R. Powell[5], David Purpura[1]
[1] Purdue University [2] Virginia Tech [3] University of Oregon [4] Santa Clara County Office of Education [5] University of Texas at Austin

Our Mathematical World (OMW) aims to improve executive function skills, math identity, and math outcomes for Black and Latine students and students experiencing poverty through a curriculum overlay that includes a sequential set of activities designed to center 3rd-5th grade students as strong math problem solvers who use appropriate EF skills to guide their process. The focus of the OMW team has been the co-ideation, construction, implementation, and refinement of a curriculum overlay that incorporates three strands: Math Stories, Executive Function, and Problem Solving. In response to limited teacher time during the pandemic, the OMW team implemented ways for educators to participate as time allowed, including the use of asynchronous feedback logs, independent readings, and online document editing. Asynchronous teacher recommendations were presented to the team for further ideation. Reflecting the cyclical nature of inclusive R&D, lessons were revised, piloted, and another round of feedback was sought. This process has resulted in a series of lessons and books that reflect district partner students' interests and identities and alignment with math curriculum and learning goals. The full 9-week curriculum overlay pilot study was conducted in Spring 2022 with 8 teachers and 119 students from two school districts. Teachers from both districts came together monthly with core members of the R&D team to discuss comments from their implementation logs and suggestions for revisions. Overall, the current, revised lessons being piloted in the 2022-23 academic year, are a result of the co-ideation and co-revision built from centering student and educator voices.

WEDNESDAY 7 JUNE

Symposia 9.00 am – 10.15 am

How is numerical syntax complex, and why is it hard?

Chair: Michal Pinhas
Department of Psychology, Ariel University

Processing multi-digit numbers is a nontrivial cognitive skill and a major predictor of math abilities. It involves not only numerical but also linguistic mechanisms that handle the numerical symbols (digits and number words) as well the relations among these symbols, namely the number syntax. Research in the recent years has increasingly pointed at numerical syntax as the crux of the human ability to perceive and manipulate symbolic numbers. The present symposium will explore several novel aspects of this numerical syntax. We will discuss syntactic processing in children and in adults, the characteristics of number syntax, and its relation with the syntax of sentences in natural language. We will examine the different origins of syntactic and non-syntactic errors when reading and writing numbers – in children as well as in adults with impaired number reading/writing (dysnumeria). We will show how children learn different syntactic systems that vary in their degree of complexity and familiarity. Finally, we will present the processing of symbolic and syntactic information in an irregular end-situation that transcends the standard decimal system syntactic rules – the case of infinity. Overall, the symposium will shed new light on several specific syntactic mechanisms, and will propose several directions for the yet-unanswered question – why is so hard to process the syntax of numbers?

Presentation1: I've got nine-ten-nine problems, but number transparency ain't one: The Influence of number word transparency on multi-digit number-matching in children

Katie Smith*, Iro Xenidou-Dervou, Julia Bahnmueller
Centre for Mathematical Cognition, Loughborough University

English-speaking children often struggle when they begin to name and use two-digit Arabic numbers due to non-transparent English number words (e.g., thirteen instead of one-ten-three or one-ty-three; thirty-two instead of three-tens-two or three-ty-two). To overcome these difficulties, dual counting has been suggested to support children's early multi-digit number learning. With this method, practitioners teach children multi-digit number names using traditional and transparent number word formats (e.g., one-ten-three or one-ty-three). However, empirical evidence supporting this approach is so far lacking. To address this research gap, the present study used an audio-visual matching paradigm to investigate whether English-speaking children of different age groups can process transparent number words and how number word form influences performance. In the study, children were asked to indicate whether a spoken number word matched a visual Arabic two-digit number. The number range covered both teens and numbers above 20. Furthermore, the study manipulated the structure of number words as either: (i) traditional (thirteen), (ii) transparent 1 (one-ten-three), and (iii) transparent 2 (one-ty-three). Overall, children could match number words to Arabic digits across conditions. However, there were unique performance patterns between children of

different ages and number ranges. These findings suggest that children's pre-existing multi-digit number word knowledge impacted their performance and flexibility to process and profit from number words with a transparent number word structure.

Presentation 2: Writing 1-to-3 digit numerals to dictation in Spanish: predictors and error analysis

Javier García-Orza*, Ismael Gutiérrez-Cordero, Cristina Gutiérrez-Fernández, Juan A. Álvarez-Montesinos, Marina Cuadra
Laboratorio de Cognición Numérica, Universidad de Málaga

Mastering number transcoding demands from children the acquisition of the complexities of the Arabic place-value system and the specific rules of multi-digit numbers of their language. The present research explores the writing to dictation of 1-to-3-digit numerals in an initial sample of Spanish 1st (N = 208) and 2nd grade school children (N = 96). Language rules for multidigit numbers in Spanish are similar to those in other languages (e.g., Italian) with some variations: there are irregularities (e.g., inversion) between 11-15, but a regular pattern after this that involve both multiplicative and additive rules (432: cuatrocientos treinta y dos, literally: fourhundreds thirty and two"). Results indicated that 2nd grade children made anecdotical errors (< 2%), showing mostly digit substitution (lexical) errors (e.g., 167 instead of 567). First graders showed a more diverse pattern of errors (19%) with digit substitutions, syntactic errors and mixed errors. Qualitative analysis showed similar error rates for irregular and regular multidigits suggesting a non-syntactical treatment of these numbers. Within syntactic errors, we claim that transposition (107 instead of 170) and structural errors (10070 instead of 170) have different sources and involve different compensation mechanisms. Finally, in a subset of the data we also explored the role of non-symbolic comparison, number to mental line position and completion of numerical sequences in predicting number writing. Whereas completing Arabic numerical sequences arose as significant predictor, no role for variables related to the analogical representation of numbers was found. This seems to support asemantic models of transcoding.

Presentation 3: Core Number Syntax and Its Dissociation from Language Syntax

Noa Handelsman*, Dror Dotan
Mathematical Thinking Lab, School of Education and School of Neuroscience, Tel Aviv University

Number-reading skills are a central part of elementary school math curriculum and a major predictor of mathematical proficiency. Number reading is also quite hard: we present data from 120 literate adults who read aloud multi-digit numbers, and show that ~8% had dysnumeria, a learning disorder that disrupts number reading. Importantly, the main reason for their difficulty was processing the syntactic structure of the number, while processing the identity of each digit or number word, and their relative order, was easier.Previous studies showed several visual and verbal processes that handle various low-level aspects of numerical syntax. Here we report, for the first time, evidence for the existence of a core syntactic representation of numbers, which is separate from the syntax of language. We examined two participants with developmental disorders. RD had a selective deficit in the core syntax of numbers: she performed poorly in tasks that required creating this core syntactic representation, e.g., transcoding or merging single digits into multi-digit verbal numbers; and she performed well in tasks that tapped low-level syntactic processing of numbers, and in linguistic tasks of sentence processing. SV had a selective deficit in language syntax: she performed well in all

numerical tasks, but had syntactic difficulty in tasks such as sentence reading, elicitation and repetition. These double dissociations between the core and low-level syntactic processing of numbers, and between the core syntax of numbers and language syntax, demonstrate the existence of a core numerical syntax, which is not driven by the syntactic mechanisms of language.

Early algebraic thinking

Chair: Ulises Xolocotzin
Cinvestav

The teaching of algebra usually begins in secondary school. However, it is well established amongst mathematics education researchers that students can learn the foundations of algebraic thinking during elementary school. Numerous studies suggest that children can develop skills for noticing and expressing generalization with diverse symbolic and non-symbolic representations. Moreover, children can develop algebraic ways of thinking about ideas first encountered in the context of arithmetic, such as numerical operations and equivalence (Kieran, 2022). However, the cognitive processes associated with the early development of algebraic concepts and skills still need to be explained. This symposium presents diverse ways a cognitive perspective can produce insights into the early acquisition of algebraic ideas and skills. We focus on cognitive challenges in the transit from arithmetic to algebraic thinking in the elementary grades. Simsek, Xenidou-Dervou, Hunter and Jones present a cross-cultural study that explores individual and classroom-level factors that influence students' understanding of mathematical equivalence. Jones and Simsek explain why elementary students can consider the equals sign as a symbol meaning one side can be substituted for the other side. Sherwood, Jones and Xenidou-Dervou propose a cross-cultural comparison of how learning materials present inequality signs. Finally, Medrano-Moya, Xolocotzin and Flores report an analysis of the non-symbolic representations produced by elementary students while solving early algebra problems.

Kieran, C. The multi-dimensionality of early algebraic thinking: background, overarching dimensions, and new directions. *ZDM Mathematics Education 54*, 1131–1150 (2022). https://doi.org/10.1007/s11858-022-01435-6

Presentation 1: A Cross-Cultural Investigation of Factors Related to Understanding of Mathematical Equivalence

Emine Simsek*[1], Iro Xenidou-Dervou[1], Jodie Hunter[2], Ian Jones[1]
[1] Loughborough University [2] Massey University

Students' understanding of mathematical equivalence have significant and long-lasting effects on arithmetic and algebra achievement. Most primary school students have difficulty understanding mathematical equivalence, and the literature has shown that the situation is worse in some countries than others. Based on theories suggested previously, e.g. the change-resistance account arguing that excessive experience with traditional arithmetic (equations with no operations on the right side, e.g., ???? + ???? = ????) reinforces the development of a

primitive, operational understanding of the equals sign (McNeil & Alibali, 2005), the goal of this cross-cultural study is to explore the individual and classroom-level factors that influence students' understanding of mathematical equivalence. The participants were 2760 primary school students and their teachers (N = 108) across six countries (China, England, New Zealand, South Korea, Turkey, and US). We also analysed the arithmetic practice presented in the textbooks. Using multilevel structural equation modelling, we found that (i) students' knowledge of definitions of the equals sign, and (ii) teachers' knowledge of students' relational strategies related to students' understanding of equivalence, but (iii) teachers' knowledge of students' operational strategies and (iv) textbooks did not. The findings showed that these relationships were similar across the participating countries. This is a novel finding, which challenges previous results and has implications for practice, research, and policy.

McNeil, N. M., & Alibali, M. W. (2005). Why won't you change your mind? Knowledge of operational patterns hinders learning and performance on equations. *Child Development, 76*(4), 883–899. https://doi.org/10.1111/j.1467-8624.2005.00884.x

Presentation 2: When 77 = 11 + 33: The case for a substitutive view of the equals sign

Ian Jones*, Emine Simsek
Loughborough University

We present the case that the equals sign can be considered as a symbol meaning one side can be substituted for the other side. Crucially, we will focus on evidence demonstrating that this substitutive view is distinct from viewing the equals sign as meaning both sides have the same value. Our motivation arises from renewed interest in the substitutive view of the equals sign, and recent assertions that the sameness and substitutive views are not distinct, and that the latter is a consequence of the former (e.g., Kieran, 2022). We support our case with three forms of evidence. First, Jones and Pratt (2012) showed that secondary students focussed on substitution but not sameness when presented with arithmetic equations (e.g., 30 + 1 = 31, 77 = 11 + 33) in the context of solving specially designed puzzles. Second, Jones et al. (2012) found that primary students' ratings of operational, sameness and substitutive definitions of the equals sign loaded cleanly onto three factors. Third, Şimşek et al. (2019) found that secondary students who endorsed a substitutive definition of the equals sign outperformed those who did not on conceptual algebra items. We conclude that differences of opinion about whether the sameness and substitutive views are distinct or indistinct are due to differences in how substitutive views of the equals sign are defined.

Presentation 3: How inequality symbols are presented in learning materials: a cross-cultural comparison

Jemma Sherwood*, Ian Jones, Iro Xenidou-Dervou
Loughborough University

Inequalities are an important mathematical concept and yet have received very little attention from researchers. The idea of comparison of magnitude is first taught in the early years of education and, over time, children learn to solve algebraic inequalities of increasing complexity until the concept reaches applications in fields such as linear programming, optimisation, economics, statistics and mechanics. The mathematical concept of inequality is closely linked to that of equality and mathematical procedures such as solving equations have relatives in solving inequalities. Such procedures are not identical but share the use of arithmetic processes and their associated axioms. It is known that students' errors in solving inequalities seem to

come from conflating them with equations but to what extent conceptions of the inequality signs are influenced by conceptions of the equals sign is not known. This paper will compare the presentation of inequality signs in commonly-used learning materials from England and Singapore, considering the conceptions of the signs promoted by the materials in order to inform future research about conceptions of the inequality signs.

Presentation 4: Analysing the pre-symbolic representation produced by elementary students solving early algebra problems

Ana María Medrano-Moya[*1,] Ulises Xolocotzin[1], Rosa del Carmen Flores-Macías[2]
[1] Cinvestav [2] UNAM

Expressing algebraic structures with symbolic notation is a central learning objective in early algebra instruction. However, before producing symbolic representations, elementary students often represent algebraic situations with non-symbolic representations, which role in the development of algebraic thinking remains unclear. In this presentation, we report a study involving third-grade elementary students (n=27) that participated in an early algebra intervention. We analysed how spontaneously produced representations, such as drawings, diagrams, and idiosyncratic symbols, related to students' problem-solving in early algebra domains, such as generalised arithmetic and functional thinking. Our coding scheme ranked the sophistication of students' representations according to the closeness to symbolic expressions. The sophistication of the representations did not vary during the intervention. Those students who used more sophisticated representations also solved more functional problems correctly. However, the representations' sophistication did not correlate with performance on generalised arithmetic problems. We discuss how the production of external representations supported the acquisition of algebraic ideas such as generalisation and variables. To conclude, producing non-symbolic external representations can help students develop insights for solving early algebra problems.

Risk assessment for mathematics difficulties and disabilities

Chair: Patrick Ehrman
Purdue University

Developing and testing strategies for identifying children at risk for mathematics difficulties and disabilities is a critical venture in the effort to support the success of all students in school. The three studies in this symposium detail different approaches to identifying risk for mathematics. The first examines a broad range of early cognitive and academic factors as predictors of proficiency ratings on 3rd and 4th-grade state tests in the United States. The second study reports the psychometric properties of an additive word-problem screener to identify children experiencing difficulty with word problems. The third study utilizes latent profile analysis to take a person-centered approach to identify children in Belgium with characteristics of low performance and related the four generated profiles to 1st and 3rd-grade assessments. The three studies presented in this symposium cover both broad and specific difficulties that children experience in mathematics, target children from preschool through elementary school and contain populations from different socioeconomic, racial, ethnic, and geographic backgrounds.

Presentation 1: Efficiently Predicting 3rd and 4th Grade Mathematics Proficiency Using Preschool Assessments

Patrick Ehrman*[1], Robert Duncan[1], Sara Schmitt[2], David Purpura[1]
[1] Purdue University [2] University of Oregon

State mathematics tests are a benchmark many children in the United States fail to meet (NAEP, 2022), yet are highly predictive of future success. Early identification strategies are needed to identify and support children at risk for failing to reach proficiency in mathematics. However, mathematics does not develop in a silo, with other academic (i.e., vocabulary) and cognitive skills (i.e., executive function) being highly related to mathematics development (Schmitt et al., 2021). Therefore, the current study predicted proficiency status on 3rd and 4th-grade mathematics tests with 430 low-income preschoolers' scores on early mathematics, math language, vocabulary, executive functioning, and school readiness assessments using preregistered analyses. Three separate multilevel ordinal logistic regression models were run. Each model initially included all predictors and controlled for grade of state testing. Backward stepwise selection was used to remove predictors not significant at a p-value of .1 or lower. Model 1 included predictors from the fall or preschool, with four assessments significantly predicting proficiency status: a school readiness measure, two executive function measures, and a math measure. Model 2 included predictors from the spring of preschool and was the most efficient model, with three assessments significantly predicting proficiency status: an executive function measure and two early mathematics measures. Model 3 included the average and change scores from the fall to spring of preschool. Six predictors significantly predicted proficiency status: four average scores and two change scores.

Presentation 2: Identification of Word-Problem Difficulty: Measuring the Psychometric Properties of an Additive Word-Problem Screener

Tessa Arsenault*, Sarah Powell
University of Texas

To provide effective instruction to students experiencing difficulty with word problems, educators must first accurately identify which students have trouble solving word problems. This can be accomplished by administering an efficient word-problem screener. Although several word-problem measures exist, few can be administered to a whole class in a short amount of time with a specific word-problem type focus (Brown et al., 2013). Therefore, our team created the Additive Word-Problem Screener to support educators, frequently in Grades 2, 3, and 4, to identify which students may benefit from word-problem supports (Powell et al., 2015). We examined the psychometric properties of the Additive Word-Problem Screener by collecting data across three school years (2015-2018) from 2,841 third-grade students (Powell et al., 2021). The screener, administered to whole classes by trained researchers, included 8 additive word problems including total, difference, and change schema problem types. Next, we used classical test theory (CTT) and item response theory (IRT) to explore reliability and correlation between items. For reliability, Cronbach's alpha was .80 (95% CI: .79, .81) and omega was .81 (95% CI: .80 to .82). Bivariate correlations between all item scores ranged between .21 to .54. The results indicated three main conclusions. First, the IRT results indicated the screener measured a single latent trait of word-problem ability. Second, the

screener captured the word-problem ability distribution being modeled. Third, based on the differential item functioning test, students with word-problem difficulty needed greater word-problem ability to answer the items correctly compared to their typically achieving students.

Presentation 3: Longitudinal Pathways of Numerical Abilities in Preschool: Cognitive and Environmental Correlates and Relation to Primary School Mathematics Achievement

Bert De Smedt*[1], Merel Bakker[1], Joke Torbeyns[2], Lieven Verschaffel[2]
[1] University of Leuven [2] KU Leuven

Children start preschool with large individual differences in their early numerical abilities. Little is known about the importance of heterogeneous patterns that exist within these individual differences. A person-centered analytic approach might be helpful to unravel these patterns and the cognitive and environmental factors that are associated with them. We applied a person-centered approach to a 5-year longitudinal study (N = 410, 213 boys) from preschool to grade 3. Preschoolers (Mage = 58.14 months) were selected to represent the full range of socioeconomic backgrounds. We examined via Latent Profile Analysis the heterogeneous patterns that exist in preschoolers' early numerical development using measures of counting, numeral identification, comparison, ordering, and arithmetic abilities. We investigated the association between the derived numerical ability pathways, general cognitive factors (working memory, language, spatial ability) and the home math environment. We also evaluated the relation of these early numerical ability pathways to later mathematics achievement in grade 1 and 3. Four longitudinal pathways emerged: a low (15%), below-average (28%), above-average (44%), and a high numerical ability pathway (13%). Differences between the four pathways were mostly quantitative. Most of the general cognitive factors contributed to pathway membership, whereas the home math environment and socioeconomic status (SES) did not. The pathways differed in mathematics achievement in grade 1 and 3, and most of these differences remained when the covariates were considered. The results highlight the heterogeneity that is already present in preschoolers' numerical abilities and their predictive value for subsequent mathematics achievement.

Discussant

Lynn Fuchs
Vanderbilt University

Children's strategies in arithmetic

Chair: Catherine Thevenot[1] & Jérôme Prado[2]
[1] Université de Lausanne [2] Université de Lyon

Despite decades of research on this topic, there is still much to discover concerning the strategies that children use to solve arithmetic problems. In this symposium, we will see that EEG and fMRI technics can help us to make progress in understanding how children process and represent arithmetic problems. We will also see that the way children represent the problems on their fingers might have a long-lasting influence on the way problems are solved.

Finally, we will see that the way the problems are processed does not depend exclusively on cognitive factors and that emotions can also play a role.

Presentation 1: The silent production task: A novel task to study mental arithmetic

Jérôme Prado[*1], Andrea Díaz-Barriga Yáñez[1], Céline Poletti[2] , Catherine Thevenot[2]
[1] Centre de Recherche en Neurosciences de Lyon (CRNL), INSERM U1028 - CNRS UMR5292, Université de Lyon [2] Institut de Psychologie, Université de Lausanne

Cognitive arithmetic has mainly been studied using two types of experimental paradigms, one involving the vocal production of a response (3+2=?) and the other involving the verification of a response using response keys (3+2=6, True or False?). Production tasks are the most ecological because they mimic the situation mental arithmetic is most often used in the classroom and everyday life. However, these tasks come with a number of disadvantages, including the need to systematically record and analyze a vocal response that can be noisy as well as the unavoidable head movements associated with such a vocal response. This latter drawback explains why most neuroimaging studies (for which head movement needs to be minimized) have employed verification tasks. Yet, verification tasks are difficult to interpret because performance can be based on familiarity with the whole equation. Here we propose a novel type of task, the silent production task, in which participants produce the correct answer of a problem in their head and press on a single response key as soon as that answer was produced. In this talk, we will show that a version of this silent production task involving addition problems is associated with patterns of RTs that are largely similar to those observed in a vocal production task, with problem size effects that are comparable across adults and children between tasks. Thus, the silent production task is a valid paradigm to study mental arithmetic, which may be particularly useful in a neuroimaging context.

Presentation 2: Non-Cognitive Determiners of strategic behaviors in children's arithmetic: The case of emotions.

Patrick Lemaire*
Aix-Marseille Université & CNRS, Marseille

A strategy approach of arithmetic development proved to be useful to understand how changes occur during childhood. This is because it documents age-related changes in the mechanisms via which children accomplish a task under different conditions and at different points during development/ learning. In this talk, I will illustrate how a strategy perspective provides important insight into the role of emotions on elementary-school children's arithmetic performance. In a series of experiments, 8- to 15-year-old children accomplish arithmetic problem-solving tasks under neutral, positive, and negative emotions. I tested arithmetic problem-verification tasks (e.g., 8+4=12. True? False?), computational estimation answer selection tasks (e.g., which of the following is the closest estimate of 23+48, 60 or 80?), and computational estimation production tasks (e.g., find the closest estimate of 23+48). Above and beyond effects of emotions on children's performance, and age-related differences therein, the data shed important light on the loci of these emotional effects. In particular, emotions influence strategy variability, strategy selection, and strategy execution in all age groups. Also, the extent to which strategy dimensions are influenced by emotions changes during the course

of development, with some dimensions more influenced by emotions than others in younger children, and the reverse in older children. All in all, the data illustrate the usefulness of a strategy perspective to further our understanding of age-related changes in effects of non-cognitive factors (including emotions) on children's arithmetic performance.

Presentation 3: Oscillatory EEG Patterns of Arithmetic Problem Solving in Children

Stephan E. Vogel*[1], Clemens Brunner[1], Nikaulos Koren[1], Judith Scheucher[1], Jochen A Mosbacher[1], Roland H. Grabner[1], Bert De Smedt[2]
[1] Educational Neuroscience, Institute of Psychology, University of Graz [2] Parenting and Special Education Research Unit, KU Leuven

Various studies have identified oscillatory electroencephalography (EEG) patterns associated with arithmetic problem-solving strategies in adults (De Smedt et al., 2009). Whereas fact retrieval (i.e., recalling the answer) has been linked to enhanced left-hemispheric theta event-related synchronization (ERS), procedural strategies (i.e., calculating the answer) have been associated with increased bilateral alpha event-related desynchronization (ERD). Despite these findings, it is currently not known whether these EEG patterns also generalize to children. We collected 32-channel EEG data from 31 children in fourth grade (between nine and ten years) who were asked to solve single and multi-digit multiplication and subtraction problems. Based on problem size (i.e., longer reaction time and lower accuracies when solving problems with larger operands compared to smaller operands) and verbal strategy reports, we categorized arithmetic problems into calculations that were solved via fact retrieval or procedural strategies. Results revealed similar signal patterns to those reported in adults. While retrieved items showed a left-hemispheric theta ERS on frontal and parietal electrodes, procedures showed larger lower-alpha and upper-alpha ERD on bilateral electrodes. Interestingly, we also observed a significant difference between retrieved multiplications and retrieved subtractions: multiplications showed a larger theta ERS than subtraction problems. Because we did not observe reaction time differences, the latter finding could be indicative for distinctive neurocognitive processes when children retrieve the answer to multiplications or subtractions.

Presentation 4: Adaptive use of finger counting strategies to solve addition

Catherine Thevenot*, Celine Poletti
Institut de Psychologie, Université de Lausanne

In this presentation, I will show that tie (e.g., 3 + 3) and non-tie addition problems (e.g., 3 + 4) are not represented and solved similarly by children because of their specificity when represented on fingers. Whereas tie problems are mostly represented by first graders with one operand on one hand and one operand on the other, giving rise to a symmetrical pattern, non-tie problems are more often represented in a continuous process. For example, 3 + 2 will lead to 5 fingers raised on one hand. In the case of tie problems, the resulting finger pattern would allow children to quickly memorize the combinations between operands and results, whereas for non-tie problems, only the response to the problem will be readily available and the entire fact could not be straightforwardly encoded.

Beyond the surface: Which features of instructional materials help or hinder mathematical learning

Chair: Megan Foulkes[1] & Suzanne Splinter[2]
[1] Loughborough University [2] KU Leuven

Instructional materials are important for representing and teaching mathematical ideas, and therefore play a key role in the provision of high-quality mathematics education. The varying features of different instructional materials (e.g., the colour and shape of representations, the text related to the to-be-counted set, the number of representations used) can influence their potential to help or hinder learning and performance when individuals are completing different mathematical activities. This symposium will consist of four presentations, considering the learning opportunities provided by different features of various instructional materials. Specifically, the presentations will discuss (1) how the textual features of a picture book impact its effectiveness for supporting children's numeracy learning, (2) which features of a picture book influence the complexity of numerical questions asked by parents when interacting with children, (3) how different features associated with manipulatives (e.g., colour, shape, number of representations used) impact young children's behaviours and performance on different mathematical tasks, (4) how the features of visual representations (i.e., perceptual salience) influence university students' base-ten unit coordination. Together we will highlight the importance of considering the features of instructional materials, and provide important implications for future research and practice.

Presentation 1: The contribution of the picture books' text to its effectiveness for supporting cardinality principle knowledge

Suzanne Splinter*, Lieven Verschaffel, Fien Depaepe, Joke Torbeyns
KU Leuven

Picture books were recently shown to be effective instructional materials for stimulating preschoolers' mathematical development, and especially their cardinality principle (CP) knowledge. However, the textual features of the picture book contribute to its effectiveness (e.g., Mix et al., 2012). Previous studies on the contribution of these picture book features to the effectiveness of this instructional material had mixed findings and various methodological shortcomings. This study aimed to analyze which text in a picture book is most effective for supporting 3-4-year-old's CP knowledge of numerosities 1-10. The study consisted of a pretest-intervention-posttest-retention test design. During the intervention, children were read four picture books with numerosities 1-10 that varied in the textual input that was offered during the reading in four conditions: (1) counting only (1, 2, 3 lambs), (2) labeling only (3 lambs), (3) first counting and next labeling (1, 2, 3, thus 3 lambs), or (4) first labeling and next counting (3 lambs, 1, 2, 3). The results showed that the third condition was most effective for supporting children's CP understanding as measured by the Give-N task. The third and fourth conditions were most effective for supporting children's CP understanding as measured by the Puppet-miscounting task. The effects did not remain at the retention test. Preschoolers' subitizing scores, language scores, and age predicted their growth on the CP tasks from pretest to posttest and retention test. The results highlight the importance of taking picture book features and children's characteristics into account when considering the potential of this instructional material.

Presentation 2: The Association Between Book Features and Parent Questions During Number Book Reading

Elizabeth Clark*, Connor O'Rear, Sophie Donegan, Suzanne Varnell, Cayla Woten, Alexa Ellis, Sarah Eason, David Purpura
Purdue University

Recent survey work has suggested that for preschool aged children, both parent (parent rating of child skills) and child factors (gender) are related to the complexity of questions parents ask during number book reading (Uscianowski et al., 2020). In the current study, we sought to test for a replication of these findings. Parents (108 male; 85 female) of three-to-five-year-old children (Mag=4.30, SDage=.87; 104 boys, 89 girls; 147 white, 18 biracial, 11 Hispanic or Latino, 10 African American, 7 Asian) were asked to come up with questions they would ask their child for six different example pages for number books. We did not replicate the original findings, instead finding non-significant relations between child gender and the measures of question complexity as well as non-significant relations between parents' perceptions of their child's number skills and the measures of question complexity. In exploratory analyses, we investigated whether recent work identifying book features as important to overall number talk (O'Rear et al., 2023) were also related to the questions parents asked. We found that books with higher word counts and those that included more numerical representations were associated with parents asking less-complex questions. Comparing to previous work (O'Rear et al., 2023), this suggests books with a higher word count and more numerical representations may shift readers focus onto counting and cardinality, but limit readers' tendency to ask more complex number-related questions. These findings can help inform our understanding of how the best design for number books may shift across different points in development.

Presentation 3: Do different manipulative features influence 4-5-year-old children's performance, behaviours and strategies when completing mathematical tasks? An observational video study.

Megan Foulkes*, Francesco Sella, Camilla Gilmore
Loughborough University

Manipulatives, such as toy animals and counters, are common in early years settings and play an essential role in representing mathematical concepts to children. However, there is conflicting evidence regarding the features associated with different types of manipulatives and whether they help or hinder learning. Researchers often suggest that practitioners should minimise the use of manipulatives with more extraneous features (e.g., bright colours, interesting textures/shapes), such as toy animals, as they can distract children from the mathematical concept being taught. However, different combinations of extraneous features may have different influences on learning outcomes, with factors such as levels of prior knowledge and the number of representations used found to impact performance (Bennett et al., 2019; Petersen & McNeil, 2013).This study adopts a between subjects design to explore the performance, strategies and task relevant and irrelevant behaviours of 4-5 year old children when using manipulatives with different features to complete mathematical tasks (N = 128, pre-registered sample size https://osf.io/gq4pr, 80 currently recruited). The main manipulation in this study is whether manipulatives are high or low in extraneous details (i.e., toy animals

and fruit versus blocks and counters), and whether children are using an identical or dissimilar set. The analysis of video recordings will further reveal how the different features associated with these instructional materials may help or hinder learning outcomes and opportunities for children.

Presentation 4: Base-Ten Unit Coordination: Can Perceptual Salience in Visual Representations Help?

Mélanie Barilaro*[1], Helena Osana[1], Anne Lafay[2]
[1] Concordia University [2] Université Savoie Mont-Blanc

Understanding the base-ten numeration system relies on "unit coordination," which involves flexible regrouping processes in two directions: composing higher-level units from lower-level ones (e.g., creating one unit of 100 from 10 units of 10) and decomposing, which requires regrouping in the opposite direction. The present research focuses on the features of instructional materials that have the potential to support the learning of base-ten unit coordination. We hypothesized that the perceptual salience (i.e., visibility) of units in visual representations would differentially impact performance on composing and decomposing tasks. Undergraduate and graduate students (N = 58) were randomly assigned to two visual conditions (tens-visible, n = 18; tens-not-visible, n = 20) and one symbolic condition (n = 20). In the visual conditions, participants were shown images of three-digit quantities where the denominations (ones, tens, and hundreds) were represented with squares and rectangles. In the symbolic condition, they were presented only with a numeral (e.g., "324"). Performance on composing items was higher than decomposing regardless of condition, but as predicted, the main effect of direction was moderated by condition. Decomposing target units in a numeral (How many tens in 324?) was relatively more difficult than composing (How many hundreds in 324?) than in the two visual conditions, between which there was no effect of perceptual salience. The results likely reflect the participants' previous educational experience, where only superficial instruction on numeration concepts is provided. We speculate that the visual representations, regardless of the degree of perceptual salience, supported the participants' decomposing processes.

Open Submission Talks 10.45 am – 12.00 pm

Math attitude/anxiety & gender

Presentation 1: Math-attitudes intervention programs for school-age students: A meta-analysis and overview of the literature

Enrica Donolato*[1], Alice Masi[2], Sara Caviola[2,3], Monica Melby-Lervag[4], Arne Lervag[1]
[1] Department of Education, University of Oslo [2] Department of Developmental and Social Psychology [3] School of Psychology, University of Leeds [4] Department of Special Needs Education, University of Oslo

Math attitudes or beliefs towards math, such as math-anxiety, math self-concept and motivation, contribute to math achievement and career choices (Levine & Pantoja, 2021). Recent interventions for children and adolescents aim to target negative math attitudes and improve math skills through diverse programs. This meta-analysis, designed in line with PRISMA, evaluates the efficacy of available math attitudes interventions in school-age children and adolescents and provides an overview of the available literature (PROSPERO Reference: CRD42022332420). The literature research was conducted in ERIC, PsycINFO, MEDLINE, Campbell Library Education Research, Scopus, Web of Science, and ProQuest Digital Dissertations without year or language restriction. A total of 5302 records were initially screened by title and abstract according to inclusion criteria, i.e., sample age (6–19-year-old typically developing students) and study design (intervention vs control group). This produced 196 records, currently under review. Once the coding phase is completed, the analysis will be performed. We aim to examine participants (children's age and sex, mathematics level at baseline) and intervention characteristics (type and modality of intervention, delivery agent, setting and dosage) as moderators related to response to treatment. Publication bias and methodological moderators (publication year, publication status and study origin) will also be evaluated. This study will provide a synthesis of available math attitude interventions for school-age students and inform researchers and teachers about the characteristics of effective programs. Our findings will help to outline suggestions to support positive math attitudes at school and design future intervention studies.

Presentation 2: Doing well and thinking positively about it: The unbalanced bi-directional relationship between math attitudes and math achievement

Michael Slipenkyj*[1], Tsz Tan Lau[2], Ian Lyons[1], Daniel Ansari[1]
[1] Georgetown University [2] University of Western Ontario

Past work shows that children with more positive math attitudes tend to have a higher level of math achievement. However, it is unclear how this relationship manifests across development and in an educational setting. Specifically, do earlier math attitudes predict later math achievement? Does earlier math achievement predict later math attitudes? Or both? In the present study, we investigate the bi-directional longitudinal relationship between math attitudes and math achievement using 4 cohorts from a large (total N = approximately 600,000) Canadian province-wide dataset. Students completed math tests and answered attitude questionnaires in grades 3, 6, and 9. To assess the developmental trajectory of attitudes and achievement, we used a traditional cross-lagged panel model (CLPM), as well as a random intercept cross-lagged panel model (RI-CLPM) to account for between-subject variability.

Results demonstrate improved model fit for the RI-CLPM, with both models showing positive autoregressive and bi-directional paths. Notably, the cross-lagged paths were stronger for earlier attitudes to later achievement compared to the other way around. Broadly, our findings demonstrate that in an educational context, the developmental relationship between math attitudes and math achievement is bi-directional, but with stronger effects from earlier achievement to later attitudes. This study was preregistered on the Open Science Framework.

Presentation 3: Field of study and gender modulation of the effect of personality and math anxiety on numeracy

Maristella Lunardon*[1], Tania Cerni[2], Raffaella Rumiati[1]
[1] Scuola Internazionale Superiore di Studi Avanzati [2] Department of Developmental Psychology and Socialisation, University of Padova [3] Tor Vergata University

Introduction. Non-cognitive factors, such as math anxiety (MA) and personality, are known to influence numeracy, although the nature of their contribution has been overlooked to date. In the present study, we investigated two factors that may shape the effects of MA and personality on numeracy in higher education: field of study and gender.Methods. 201 Humanities (HUM) and 209 Science, Technology, Engineering and Math (STEM) Italian undergraduates remotely completed a battery of standardized tests assessing numeracy, MA, personality traits, intelligence, and basic numerical skills. We ran multivariate regression models to test whether the non-cognitive factors interacted with field of study and gender in predicting numeracy and if these effects held over and above intelligence and basic numerical skills.Results. The only statistically significant interaction, beyond the effect of intelligence and numerical skills, was that between field of study and neuroticism: HUM undergraduates with higher neuroticism levels, i.e., more likely to experience negative feelings and to be sensitive to threats, scored lower in numeracy, whereas STEM undergraduates showed no significant association. Gender did not consistently interact with any of the non-cognitive variables.Conclusions. While MA negatively impacts numeracy regardless of field of study and gender, the effect of personality, especially neuroticism, on numeracy is shaped by individuals' chosen career. The effect of gender is not consistent, suggesting that it may be more sensitive to personal factors that determine career choices rather than to cognitive differences between males and females.

Presentation 4: Gender differences in number line performance for 7- and 8-year-old students

Shuyuan Yu*, Heather Douglas, Jo-Anne LeFevre
Carleton University

Numerical representations are critical to math achievement. Students' accuracy of placing numbers on a number line and their knowledge of the structure of numbers are often used to index numerical representations. Gender differences in numeracy skills tend to be small or non-existent, however, boys often have better number line performance than girls. As part of a large assessment project, 576 students in grades 2 (52% girls, M = 7.44 years, SD = .35) and 3 (45% girls, M = 8.43 years, SD = .34) estimated the position of numbers on a 0-1000 number line. Students also transcoded auditory number words (e.g., two thousand five) into written digits (e.g., 2005). As expected, students' number line and number writing performance were correlated, and both increased with grade. Boys were more accurate than girls in number line estimation in both 2nd and 3rd grade (ß = .23, $p < .001$), even after controlling for school SES ($\chi 2$ (4) = 2.03, p = .730) and number writing performance (ß = .23, $p < .001$). Moreover, number

writing interacted with gender to predict number line performance (ß = .10, p < .05): The relation between number line and number writing performance was stronger for boys than for girls. Thus, although the advantage for boys was moderated by number writing skills, it did not explain the gender difference. Future research is needed to explore potential sources of gender differences, such as spatial ability, in number line performance.

Struggling learners & intervention

Presentation 1: Patterns of network connectivity associated with phonological memory, language, and numerical processing for multilingual first graders

Madison Cook*[1], Lina Shanley[1], Eric Wilkey[2], Ben Clarke[1], Fred Sabb[3]
[1] Center on Teaching and Learning, University of Oregon [2] Vanderbilt University
[3] Lewis Center for Neuroimaging, University of Oregon

Previous research established the association between multilingualism, cognitive functions, and brain functions and structure (Tao et al., 2021). Students with math learning difficulties demonstrate deficits in multiple areas of cognition, particularly in phonological processing (Peng et al., 2018). Understanding how numerical skills develop in relation to phonological processing and the neural architecture that supports this development may inform targeted intervention work, especially for multilingual students. We will examine the relationship between phonological memory and numerical skills as measured by ASPENS and CTOPP. Then we will examine the extent to which this relationship differs for monolingual and bilingual students. Lastly, rs-fcMRI data will be used to examine the patterns of network connectivity associated with individual differences in phonological memory and numerical skills in a matched sample of multilingual and monolingual first grade children (n = 40). We will utilize dual regression to extract subject-specific versions of canonical resting state networks and examine differences for monolingual versus bilingual students. We hypothesize results to show correlations between left frontal brain regions, the inferior parietal cortex and fronto-parietal resting state networks associated with differences in phonological memory, linguistic profile, and mathematics outcomes.

Peng, P., Wang, C., & Namkung, J. (2018). Understanding the cognition related to mathematics difficulties: A meta-analysis on the cognitive deficit profiles and the bottleneck theory. *Review of Educational Research, 88*(3), 434-476.
Tao, L., Wang, G., Zhu, M., & Cai, Q. (2021). Bilingualism and domain-general cognitive functions from a neural perspective: A systematic review. *Neuroscience & Biobehavioral Reviews, 125*, 264-295.

Presentation 2: Identifying struggling students from in-game behaviours: A machine learning approach

Franz Wortha*[1], Korbinian Moeller[1], Kristian Kiili[2], Manuel Ninaus[3]
[1] Centre for Early Mathematics Learning, Loughborough University [2] Faculty of Education and Culture, Tampere University [3] Institute of Psychology, University of Graz

During the digital transformation in education educational games have become increasingly popular in mathematics education and other content domains. A growing body of literature has

indicated significant potential in their ability to foster students' motivation and learning (e.g., Sailer & Homner, 2020). However, less attention has been paid to their diagnostic potential. This study aimed to address this issue by developing a machine learning approach that can identify low-performing students solely through process data from an educational game fostering fraction understanding. To this end, data from a field study with 339 students aged around 12 years from 11 public German schools was evaluated to test whether students at risk of failing their math classes (as indicated by their mathematics grade) could be reliably predicted based on their in-game behaviours. In particular, students' self-reported mathematics grades (dichotomized into reflecting at-risk or typically developing students using the grade cut-off for failing a class) were predicted using in-game features such as average time played, variance of performance across play sessions, etc. Results indicated that the machine learning approach classified at-risk students significantly above chance level despite their rare occurrence (~6% of students in the sample). These findings highlight, that in addition to their potential to facilitate mathematics learning, educational games also have substantial diagnostic capability as stealth assessments. Future research might build upon these findings by identifying struggling students early to allow for timely remediation.

Sailer, M., & Homner, L. (2020). The Gamification of Learning: A Meta-analysis. Educational *Psychology Review, 32*(1), 77–112.

Presentation 3: Counting-focused intervention effects for students with mathematics difficulty: A research synthesis

Syeda Sharjina Akther*
College of Education, The University of Texas at Austin

Counting skills are considered a gateway to other mathematics skills (e.g., cardinality, comparison, simple addition, and subtraction; Nelson & McMaster, 2019). Moreover, proficiency in early numeracy, including counting skills, during preschool and kindergarten accelerates growth in mathematics achievement (Aunola et al., 2004; Aunio et al., 2015). Despite the importance of counting skills, only 60% of students attain proficiency with one-to-one correspondence, and two-thirds of kindergarteners appropriately use cardinality while counting (Stock et al., 2009). It is, therefore, important to synthesize the effects of counting-focused interventions for preschool and kindergarten students to provide instructional recommendations for educators. Through a systematic literature search, eight studies with 12 treatment groups met the following inclusion criteria: 1) Participants had mathematics difficulty (MD) or at-risk for MD, based on clearly defined MD criteria, including (a) cut-off percentile, (b) evidence of persistent low performance in mathematics, (c) identified by teachers, or (d) identified using a screening assessment. 2) The intervention aimed to improve counting and cardinality, and at least 50% of the intervention components focused on the principles of counting skills. Thus, this synthesis examines the effects of counting-focused intervention and associated effective instructional strategies for students in preschool and kindergarten with or at-risk for MD.Results showed that 83% of treatment groups outperformed control conditions. Instructional strategies used in these studies with positive effects incorporated explicit and direct instruction, immediate and corrective feedback, independent practice, and the concrete-representation-abstract framework. It was reported that 50% of the effective treatment groups exhibited explicit instruction and independent practice.

Presentation 4: Experience with equations in sequence enhances problem-solving performance

Lauren E. Anthony*, C. Shawn Green, Martha W. Alibali
University of Wisconsin-Madison

Students' mathematical performance can be enhanced through tasks that afford opportunities to reason about mathematical relationships. Indeed, our prior work has demonstrated that experience with extending mathematical patterns (i.e., stacked equations representing arithmetic sequences) supports adults' abilities to solve equations with similar patterns, relative to experience with explicit instruction. The current study extends past work by 1) using training items intended to promote greater attention to relational structure and deter simple calculation strategies (e.g. if participants are trained with items such as: 255×14+3=3573, 256×14+3=3587, 257×14+3=3601, "Produce the next equation in the sequence", they should be more likely to use the learned pattern than to do the full computation given the question: 212x14+3=2971, 213x14+3 = ?) and 2) including an active control (i.e., a non-mathematical spatial rotation task). We used a three-group pretest-intervention-posttest design. Given previous findings, we hypothesized that experience with patterning tasks would facilitate attention to consistent relationships across equations, thereby improving performance on related tasks, relative to explicit instruction or a control task. Indeed, pattern experience promoted greater problem-solving accuracy than the explicit instruction and control tasks. Surprisingly, explicit instruction with equation-solving practice was not more effective than the non-mathematical control task at promoting problem-solving accuracy. Further, both pattern experience and explicit instruction with equation-solving practice led to faster response times at posttest, compared to the control task; however, pattern experience did not support faster response times than explicit instruction, unlike previous findings. These results provide further insight into the value of patterning tasks for supporting mathematical performance.

Numerosity perception & rational numbers

Presentation 1: Modeling the effect of color entropy and connectedness on numerosity perception throughout development with the diffusion model

Chuyan Qu*[1], Francesca Luzzi[1], Ruining Wang[2], Sam Clarke[1], Elizabeth Brannon[1]
[1] University of Pennsylvania, Department of Psychology [2] Zhejiang University

Understanding if and how visual features systematically bias numerosity perception is central to understanding the processes that give rise to our visual number sense. Recent work demonstrated that increasing color entropy systematically reduces perceived numerosity (Qu, DeWind, & Brannon, 2022). Here we constructed an integrated drift-diffusion model (DDM) to decompose the numerical discrimination decision process and the influence of color entropy on judgments throughout development. We found no significant response bias to make a left or right response at the group level and there was no effect of color entropy on response bias. Boundary separation was also unaffected by color entropy. Color entropy did significantly influence drift rate demonstrating that color entropy distorts numerical calculation through biased accumulation of evidence of quantity. We found that the drift rate increased while

boundary separation decreased from age 5-30 and response bias did not change over development. The effect of entropy on response bias and boundary separation did not change over development, however the effect of entropy on drift rate increased with age. An independent sample of 5-12-year-old children and adults were tested with arrays that induced the connectedness illusion, whereby arrays with elements connected by thin lines are perceived as less numerous than arrays with unconnected elements (Franconeri, Bemis, & Alvarez, 2009). We found that the strength of the connectedness illusion also increased with age. Additional analyses will apply the DDM approach to the connectedness dataset.

Presentation 2: Examining the concurrent validity of extant measures of approximate number system as measured by the dot comparison paradigm

Nathan T.T. Lau*[1], Eric Wilkey[2], Rebekka Cusiac[1], Daniel Ansari[1]
[1] Department of Psychology, University of Western Ontario [2] Psychology & Human Development, Vanderbilt University

The approximate number system (ANS) posits that humans have an innate ability to perceive numbers in an approximate manner. Further, it has been posited that the ANS forms the foundation for later math abilities. There has been a lot of research on the relationship between ANS ability and math achievement, but results have been mixed. It is suggested that these mixed results may be due to differences in how the ANS is measured in different studies. This study examined the performance of 500 participants on commonly used measures of ANS ability, inhibition ability, continuous magnitude discrimination, math fluency, and math problem solving. The study analyzed the degree to which different methods of measuring ANS ability are comparable, and examine the potential impact of inhibition processes and continuous magnitude discrimination on the relationship between ANS ability and math achievement. The results of this study will help determine whether it is appropriate to compare studies using different ANS measurements and whether the addition of confounders is necessary to accurately estimate the link between ANS ability and math achievement.

Presentation 3: Beyond integers: Understanding the cognitive mechanism and neural bases of rational number development

Isabella Starling-Alves*, Eric D. Wilkey
Vanderbilt University

Rational number knowledge is crucial for academic success but becomes more difficult as we progress from integers to other types of rational numbers. This difficulty may be explained by interference from previous knowledge about integers. For example, understanding fractions and decimals requires the learner to use numbers in ways that conflict with existing knowledge about how whole numbers work, often referred to as “whole number bias”. Despite a growing body of literature investigating rational number processing at the behavioral level, its neural underpinnings are not well understood. In particular, it is unclear to what extent the neural mechanisms engaged in processing different types of rational numbers overlap. In this proposed study, we will investigate the neural underpinnings of fractions and decimals, their overlap with nonsymbolic magnitudes and symbolic integer representations, and the neural mechanisms that engage to resolve whole number bias. Ten adults will complete a 7T-fMRI experiment. We will collect a large number of samples of high-resolution data to provide enough power for within-subject analysis. Participants will complete a set of number comparison tasks with different formats: nonsymbolic magnitudes, integers, fractions, and

decimals. We will conduct subject-by-subject univariate ANOVAs to investigate the effects of congruency (incongruent vs. congruent), ratio-of-ratios (hard vs. easy), and number format (nonsymbolic numbers, integers, fractions, and decimals). Additionally, using generalized psycho-physiological models we will investigate how brain regions' connectivity differs by number format and congruency. Finally, we will conduct a representational similarity analysis to investigate how the neural mechanisms are shared across the number formats.

Presentation 4: Do playful math activities support fraction learning in first graders?

Eva Redican*[1], Tamara Turski[1], Alexandria A. Viegut[1], Ilyse Resnick[2], Nora S. Newcombe[3], Nancy C. Jordan[1]
[1] University of Delaware [2] University of Canberra [3] Temple University

Before formal fraction instruction, children develop informal knowledge of fractions, especially with halves and nonsymbolic representations. This informal fraction understanding supports later mathematics achievement (Viegut et al., under review). To support early fraction learning, we designed playful fraction activities that build on children's informal knowledge to help them transition to developing formal fraction skills. Our proposed experiment will use a pretest-training-posttest design to test the extent to which playful fraction activities improve first graders' (6-7 years of age) fraction knowledge relative to an active control group. The fraction activities will include nonsymbolic representations of small-denominators (Viegut et al., under review), continuous linear representations (Siegler et al., 2011), proportional reasoning (Möhring et al., 2016), and introduce fraction symbols. We hypothesize that the experimental group will outperform the control group on: (H1) nonsymbolic and symbolic fraction measures (Viegut et al., under review) and (H2) nonsymbolic proportional reasoning. We will recruit 86 first graders and randomly assign them to the experimental or control condition. Accounting for 5% attrition, 41 children per group will yield 80% power to detect a meaningful effect size (d=.25). During five 15-minute training sessions, the experimental group will complete one-on-one interactive fractions activities. The control group will complete one-on-one interactive activities on another topic. Using ANCOVA we will predict accuracy by condition on fraction understanding (H1) and proportional reasoning (H2), controlling for pretest scores. If our hypotheses are supported, future work could adapt these activities for classroom use to build foundational fraction knowledge.

Early math skills & home environment

Presentation 1: Examining components of early maths skills and inequalities in mathematical development using large-scale secondary data

Dominic Kelly*[1], Sam Sims[1,2], Laura Outhwaite[1]
[1] Centre for Education Policy and Equalising Opportunities, IOE, UCL's Faculty of Education and Society [2] Centre for Early Mathematics Learning, Loughborough University

Evidence suggests early numerical skills significantly predict later maths attainment (Davis-Kean et al., 2022). Other components of early maths, such as spatial, arithmetic, and problem-solving skills, may also play an important role (Hawes et al., 2022; Litkowski et al., 2020).

However, component-based approaches in longitudinal studies for examining mathematical development over time are seldomly considered. Understanding how early maths skills translates into later maths attainment and what inequalities may lead to individual differences in that process is vital in light of educational policies, which places an emphasis on the importance of maths attainment, but also deprioritises spatial skill elements of the curriculum (Gilligan-Lee et al., 2022). Therefore, this registered report study will use a large, nationally representative sample of approximately 8,000 children from the Millennium Cohort Study, which includes detailed measures of socio-economic status (e.g., maternal education) and performance on standardised cognitive tests (e.g., language and maths) at ages 5-7. This dataset is matched to the National Pupil Database, which includes a 27-item teacher observed measure of maths at age 5, as well as curriculum-based standardised mathematical assessments at age 7 and 11. Confirmatory factor analysis will be used to establish components of early maths at age 5. Followed by structural equation modelling to determine inequalities in maths attainment at each timepoint in terms of socioeconomic and special education needs status, gender and their intersections, as well as whether these inequalities change or persist over time, and whether specific elements of early maths skills uniquely predict later outcomes.

Presentation 2: Methodological considerations in number talk measurement

Shirley Duong*[1], Alex Silver[1], Leanne Elliott[2], Heather Bachman[1], Elizabeth Votruba-Drzal[1], Melissa Libertus[1]
[1] University of Pittsburgh [2] American Institutes for Research

Parents' number talk is often associated with children's math performance but has been measured in different ways (e.g., frequency measures at the word, utterance, or exchange level, complexity measures at the utterance or exchange level) leading to some conflicting results. Here we compare methods of calculating number talk from the same caregiver-child interactions to identify: 1) Are measures of number talk correlated? 2) Do all measures of number talk predict math performance in 2-year-olds? And 3) Are the associations between number talk and children's performance specific to math? Toddlers (N=126; Mage = 2.71 years; 66 female) and one caregiver were recorded engaging with a wordless picture book in their homes. Two types of parents' number talk were derived during these interactions: frequency measures (i.e., words, utterances, and exchanges) and complexity measures (i.e., mean length of number utterance (MLNU) and exchange (MLNE)). Toddlers' numerical skills were directly assessed via Give-N, Point-to-X (PTX), and verbal counting tasks, and parents reported children's expressive vocabulary. We found that frequency measures positively correlated with each other and with MLNE. MLNU negatively correlated with number utterances, number exchanges, and MLNE and positively correlated with children's Give-N ($r = .20$, $p = .03$) and PTX performance ($r = .21$, $p = .03$). All other correlations between number talk measures and math and non-math outcomes were non-significant. Thus, different approaches to number talk measurement may explain previous inconsistencies. Our findings suggest that the complexity of parents' number talk is of particular importance for toddlers' numerical skills.

Presentation 3: Parents engage in home mathematics activities the least! Examining the frequency of four home learning environment subdomains

Alexa Ellis*[1], Connor O'Rear[2], Jimena Cosso[3], David Purpura[4]
[1] The University of Alabama [2] University of Notre Dame [3] The Pennsylvania State University [4] Purdue University

Recent studies focus on parenting practices that foster specific areas of academic learning including the Home Literacy Environment (HLitE; McCormick et al., 2020), Home Mathematics Environment (HME; LeFevre et al., 2009), Home Science Environment (HSE; Westerberg et al., 2022), and Home Executive Function Environment (HEFE; Korucu et al., 2019). This study utilizes a public dataset (Ellis et al., 2022) to examine whether parents report spending more time in one subdomain over another. Participants (N = 913) were parents of children between two and six (Mage = 4.28 [1.25]) and were recruited online. Parents completed previously established surveys and were asked to rate how often they engaged in certain activities over the past month. Responses were recorded on a six-point Likert scale ranging from never (1) to multiple times a day (6). A composite score was calculated for each subdomain. A repeated measures ANOVA revealed a significant effect of domain ($F = 587.73$, $p < .001$) and an interaction between subdomain and age ($F = 9.97$, $p < .001$). Parents on average engaged in the HME significantly less often than each of the other subdomains (ps < .001). Analyses showed relative stability in frequency of HLitE activities whereas parents reported engaging in significantly more math and science activities as children got older. Parents reported spending the most time on the HLitE, followed by the HEFE, then HSE and the least amount of time on the HME. The frequency of time spent on the HME and HSE increased across ages.

Presentation 4: Testing the early home environment as a mechanism underlying the effects of paternal education and math and social-emotional outcomes at age nine

Tanya Paes*[1], Irem Korucu[2], Lindsey Bryant[3], Yemimah King[4], Robert Duncan[1], Sara Schmitt[5]
[1] Human Development and Family Science, Purdue University [2] Yale School of Medicine, Connecticut [3] Mathematica [4] Cognition and Temperament Lab, Spelman College [5] The Ballmer Institute for Children's Behavioral Health, University of Oregon

Parental education is a robust predictor of several child outcomes including math, but few studies have explored the relation between paternal education and children's math and social-emotional skills (Mistry et al., 2008; Cabrera et al., 2007), along with the mechanisms that may underlie this relation (Rubio-Codina et al., 2016; Seidler & Ritchie, 2018). Evidence suggests that parental education predicts the home environment (Seidler & Ritchie, 2018), which is related to long-term developmental outcomes (Guo & Mullan, 2000; Hackman et al., 2015; Lugo-Gil & Tamis-LeMonda, 2014; Mistry et al., 2008), and could serve as a possible mechanism that may underlie the effects of parental education on children's outcomes. Aims and Methods: The study aims to use two datasets- the Future of Families and Child Wellbeing Study and the National Institute of Child Health and Development Study of Early Child Care and Youth Development- to examine the longitudinal association between paternal education at 24 months and children's math, behavior problems, and social skills at age 9, and to investigate what aspect of the home environment at 54 months may be driving these potential mediating effects. Hypotheses: We expect that paternal education would predict children's outcomes at age 9 and that the early home environment will mediate these relations. Analytical Strategy: Mediation analyses will be used to examine the direct, indirect, and total effects of paternal education on the children's outcomes with indirect effects working through the overall

home environment score using structural equation modeling. The standardized effects from the model will be interpreted.

Arithmetic & strategies

Presentation 1: Eye movements as an indicator of the strategies recruited to solve arithmetic problems: the case of subtraction by additions

Nicolas Masson*[1], Christine Schiltz[2], Mauro Pesenti[1]
[1] Université Catholique de Louvain [2] University of Luxemburg

Attention is shifted rightward/upward or leftward/downward when participants solve additions and subtractions, respectively. While attentional shifts in both the vertical and horizontal axes co-exist, it is unknown whether the two axes are rooted into identical cognitive mechanisms and mental representations or if they sign critical cognitive differences. To investigate a possible differential role of horizontal and vertical attentional shifts in mental arithmetic, we monitored horizontal and vertical eye movements, as a proxy for attentional shifts, using an eye-tracker while adult participants were orally solving auditorily presented subtraction problems that are known to be typically solved either directly (e.g., 78 – 32 = ?) or using an indirect addition strategy (e.g., 71-68 = ? -> 68 + ? = 71) while looking at a blank screen. Results reveal a dissociation between horizontal and vertical shifts. Horizontal shifts reflected the solving strategy as subtraction by addition problems elicited horizontal shifts more to the right than direct subtraction problems. Vertical eye movements were instead driven by the absolute magnitude of the answer as large answers were associated to upward shifts while small answers were associated to downward shifts. Altogether, this confirms that attentional shifts are part of the solving procedure but suggests that shifts along horizontal and vertical axes reflect distinct cognitive mechanisms. We propose that the horizontal axis is flexibly used according to the solving strategy that is recruited while the vertical axis is merely associated to the magnitude of the answer, irrespective of how it is accessed.

Presentation 2: Inhibition is key: A cognitive approach to successful word problem solving

Joshua Jaffe*, Janice Hong, Michaela Brooks, Donald Bolger
College of Education, University of Maryland College Park

Numerical competency and reading comprehension skills are necessary, but insufficient for word problem success. Inhibitory control plays a significant role in processing and solving word problems. Depending on the word problem structure, successful problem solving may require inhibiting the seemingly obvious and correct answer. For instance, in the problem “John has 4 apples. He has 2 more apples than Mary. How many apples does Mary have?” a solver's association between “more” and addition may lead them to initially believe the resultant is six, and fail to appropriately conceptualize the semantic relations. In this study, we propose an inhibitory performance-based model that posits two approaches to problem solving: 1) an integrated approach where solvers inhibit mathematical associations and form appropriate set schemas to conceptualize semantic relations, and 2) a superficial approach where solvers do

not inhibit associations and therefore may have an inaccurate understanding of semantic relations. To test this model, we aim to recruit 120 undergraduate students during the Spring 2023 semester. The study consists of three sections: inhibitory tasks, word problems, and an interview. The word problem section includes problems that are both consistent and inconsistent with individual associations. The interview aims to examine how individuals process word problems and their beliefs regarding mathematical associations. Quantitative data analysis will include ANOVAs and a cluster analysis. We predict two groups will emerge that are consistent with the proposed model. Further, a coding scheme will be developed and we expect different themes to emerge from the identified groups.

Presentation 3: Encoding and recoding activities for conceptual change

Katarina Gvozdic*, Emmanuel Sander
IDEA lab, Faculty of Psychology and Educational Sciences, University of Geneva

Students' informal solving strategies are the basis for developing formal mathematics knowledge (Baroody & Wilkins, 1999; van den Heuvel-Panhuizen & Drijvers, 2014). In certain contexts, informal knowledge leads to an encoding of the problem favorable for finding the solution (Mcneil & Alibali, 2004), but at other times, it can lead to costly solving strategies and inaccurate answers (Brissiaud & Sander, 2010). The current study investigated the benefits of a pedagogical intervention designed to promote conceptual change through the semantic analysis and semantic recoding of arithmetic word problems, making it possible to overcome informal solving strategies. The principle of semantic recoding is to recode initial representations based on superficial features into representations that make the problem's deep mathematical structure salient. We compared the performance and solving strategies of 5 experimental first-grade classes (103 students, mean age 7.05), to 5 control classes (105 students, mean age 7.03). We used 12 different word problems (coming from 6 different semantic categories). Half of them could be easily solved with informal solving strategies, whereas half would have a high cost if the informal strategy was used and were thus more difficult. Our findings revealed that students from the experimental classes had better performance on high-cost problems (50.48%) than the control group (29.84%) ($\beta=1.22, z=5.41, p<0.001$), and they used formal solving strategies significantly more ($\beta=1.44, z=4.49, p<0.001$). There was no difference between the groups on the control tasks ($t(205.84)=1.88, p>0.05, \eta^2=0.01$). Our findings illustrate a promising path for using students' informal knowledge to foster conceptual change and attain adaptive expertise.

Presentation 4: Neural correlates of subtraction and multiplication in adolescents.

Asya Istomina[*1], Andrei Faber[1], Andrei Manzhurtsev[2], Maxim Ublinskiy[2], Marie Arsalidou[1]
[1] HSE University, Moscow [2] Clinical and Research Institute of Emergency Pediatric Surgery and Trauma, Moscow

Mathematical processes are widely studied using neuroimaging in children and adults (Arsalidou et al., 2018 for meta-analyses), however, little is known about neurofunctional correlates of mathematical operations in adolescents. We examine for the first time using fMRI brain activity associated with subtraction and multiplication in adolescents.Brain activity of 15 adolescents (7 females; 15–17 years) and 15 adults (8 females; 20-30 years) was measured with fMRI while participants performed 2-digit multiplication and subtraction tasks. Conditions appear in blocks that lasts 32 seconds, and during this time-period participants were asked to give as many correct answers as possible. Structural and functional imaging data were collected

with a magnetic resonance Philips Achieva dStream 3.0T scanner. fMRI data analysis were carried out using AFNI software. Behavioural scores were comparable between operations. Subtraction and multiplication activate common brain areas (e.g., left inferior parietal lobule, left superior and inferior frontal gyri). Areas that were specific to multiplication were left middle and inferior temporal gyri. Subtraction activated right inferior parietal lobule, supplementary motor area and middle cingulate cortex. Several areas underlie mathematical performance in adolescents, which are common to both mathematical operation or favor one of the two. The left middle and inferior temporal gyri that favor multiplication was previously linked to language processing (Prado et al., 2014), whereas the supplementary motor area and middle cingulate cortex that favors subtraction was linked to procedural problem solving (Sokolowski et al., 2022). Results of the study add new knowledge on a mapping of mathematical processes in adolescents.

Poster session 3 (1.00 pm – 2.00 pm)

1. Look At It This Way: Equal Sign Position and Blank Position in Multiplication Problems Affect Reaction Time

Taylor-Paige Guba*
University of Delaware, Newark, Delaware

Past research has demonstrated the importance of the ability to process arithmetic problems in multiple formats. This skill is particularly important in higher level STEM courses, such as Algebra, which consists mainly of problems in non-traditional formats. This study examines how different formats of multiplication problems (e.g., __= 3 x 2; 3 x 2 = __; 3 x __ = 6; etc.) affect pre-service teachers' (n = 76) reaction time and accuracy in solving these problems. The main questions addressed are (1) does the placement of the equal sign (right or left) affect reaction time in solving multiplication problems, and (2) does the placement of the blank (i.e., the missing component of the equation) affect reaction time in solving multiplication problems. Participants completed 154 multiplication trials in which problem format was randomized utilizing multiplicands from one to nine. I performed repeated measures ANOVAs to compare the effects of equal sign position and blank position on reaction time and accuracy. There was no significant effect for accuracy. There were significant differences in reaction time for equal sign position ($p < .001$, $\eta 2 = .009$) and blank position ($p < .001$, $\eta 2 = .022$). Pairwise comparisons with Benjamani-Hochberg corrections revealed that participants answered problems with the equal sign on the right significantly faster than when the equal sign was on the left ($p < .001$) and that participants answered problems with the blank in a multiplicand position significantly faster than when the blank was in the product position ($p < .001$).

2. The Effect of Problem Format on Arithmetic Problem-Solving

Iro Xenidou-Dervou*[1], Emine Simsek[1], Sara Rashid[2], Ilona Friso-van den Bos[3], Menno van der Schoot[4], Ruth Trundley[5], Ernest C.D.M. van Lieshout[4]
[1] Loughborough University [2] Cambridge University [3] University of Twente [4] Vrije Universiteit Amsterdam [5] Devon Education Services

In learning materials, arithmetic problems can be presented in various formats, e.g., as symbolic (e.g., 32 + 15 = ?) or word problems, which can be bare or accompanied by illustrations. Berends and van Lieshout (2009) identified three main types of accompanying illustrations: helpful, unhelpful or essential and found that essential illustrations increase children's cognitive load and have a detrimental effect on their arithmetic performance. In this study, we examined the prevalence of these types of problem formats in UK mathematics textbooks, and how they influence young children's mental arithmetic. Our textbook analysis revealed that UK mathematics textbooks include similar problem formats, namely bare word problems and word problems accompanied by helpful, unhelpful, and essential illustrations, which were the most prevalent. To address our second aim, a sample of 220 6- to 10-year-olds completed a mathematics task involving 20 two-digit mental arithmetic problems (addition and subtraction), presented in five different conditions: (1) Symbolic, (2) Bare word problems, and word problems accompanied by (3) an Unhelpful, (4) a Helpful, and (5) an Essential illustration. As expected, we found that children performed best (accuracy and RT) in the Symbolic and were slowest in the Essential condition; the other types of illustrations did not

have an effect. Results are discussed in the context of Cognitive Load Theory and instructional design in mathematics education.
Berends, I. E., & van Lieshout, E. C. D. M. (2009). The effect of illustrations in arithmetic problem-solving: Effects of increased cognitive load. *Learning and Instruction*, *19*(4), 345-353. https://doi.org/10.1016/j.learninstruc.2008.06.012

3. The Role of Creativity in Arithmetic Word Problem-Solving

Gabriella Daroczy*, Hans-Christoph Nuerk
University of Tübingen

Previous research has shown that in the performance of arithmetic word problems – besides several variables (e.g., reading ability, mathematical competencies, working memory, mathematics anxiety etc.) – creativity also plays a role. Nevertheless, it is not yet fully understood how creativity alters performance in different types of word problems. Creativity should increase the likelihood of correct answers especially in non-routine problems – that require heuristics and non-conventional thinking in solving – by facilitating deviations from routine procedures. Therefore, we investigated the role of creativity in word problems, examining both routine (Study 1) and non-routine word problem-solving performance (Study 1 & Study 2) in adults. In an online study with 394 participants (Study 1), we found that creativity influenced mathematical performance in non-routine word problems positively, and mathematics anxiety had a negative effect on performance. Oppositely, neither creativity nor mathematics anxiety had an influence on the performance in routine word problems. To gain a more disentangled view, in Study 2 we differentiated three kinds of creativity: figural, verbal, and numerical creativity. The preliminary results of Study 2, as well as the problems with the operationalization of creativity will be discussed.

4. Executive Function and Mathematical Skills Correlate Differently for Science and Non-Science Secondary School Students

Konstantinos G. Tsigaridis*, Rui Wang, Michelle R. Ellefson
University of Cambridge

Mathematical skills seem to influence academic attainment in secondary education. There is a general consciousness that the core executive function skills of working memory, inhibition, and switching, along with the hybrid executive function skill of planning, correlate with mathematical skills. Our study explores whether this correlation is universal among late secondary school students using a battery of executive function and mathematical skills tasks with a sample of 15- to 17-year-old Greek students (N = 403). The participants are evenly split between science (n = 201, Mage = 16.04 years, SDage = 0.81 years) and non-science students (n = 202, Mage = 15.52 years, SDage = 0.57 years). For simplicity, we identify science students as those who have selected additional courses in mathematics and science and are examined exclusively in these courses for admission to Greek universities. Our analyses indicated two key findings. First, executive function skills correlated with mathematical skills differently between science and non-science students. Second, these correlations were statistically significant for science students only. Our results suggest that the already described links between executive function and mathematical skills are not universal for late secondary school students. Further research should examine if the suggested differences between science and non-science students were present before students engaged with additional science and

mathematics courses or whether they are driven by specialisation within the science and mathematics courses.

5. Co-Development Among Math, Reading, Science, and Working Memory in the Elementary Stage: For Whom and What Triggers?

Peng Peng*
The University of Texas at Austin

Using latent growth models with structured residuals, this study investigated mutualism among reading, math, science, and working memory in a general sample and groups with high or low academic or cognitive abilities from Grades 2 to 5 (N = 859–9,040, 6.27–13.13 years, 49% female, ethnically diverse). Results showed robust longitudinal reciprocal relations among academic skills and working memory only in high academic-ability students, especially those good at math. Results stayed the same with the control of socioeconomic status, gender, and with sensitivity analyses. Together, findings from this study support the heterogenous hypothesis of mutualism theory in education (Peng & Kievit, 2020): The effect of mutualism may be stronger in some contexts and populations than in others. High-ability students, especially high in math, may improve academic performance through efficient knowledge accumulation and academic-cognitive mutualism. Such mutualism seems to be particularly driven by high-quality and intensive academic practice.

6. Symbolic and Non-symbolic Number Format Integration In Adults and Children Probed with Frequency Tagged EEG

Mila Marinova*, Christine Schiltz
University of Luxembourg

The neurocognitive relationship between various numerical formats has been hotly debated in numerical cognition. To shed light on this issue, we used an oddball frequency-tagged EEG technique in adults (aged 18 - 25) and children (aged 7 to 12). In the adult study, we presented the participants with sequences of numbers in single (digits, words, dots) and mixed notation (dots - digits, number words – dots, digits – number words). The sequences were presented at a fast rate of 10Hz – (10 stimuli /sec). The standard stimuli consisted of numbers ranging from 1 to 4. The deviant stimulus (numbers 6 - 9) appeared every 8th item (i.e., 1.25 Hz). The children's study design was similar. Children were presented with only mixed sequences at the standard/deviant frequency rate of 6/1.2Hz. The results showed significant EEG responses tagged on the deviant frequency for adults and children, varying strength according to the format condition and age. For adults, the responses were observed for the single notation condition and only for the digit–words and words – dots. For children, evidence for integration was present in all mixed conditions. These results provide evidence of an automatic integration between some numerical formats and that this integration undergoes gradual developmental changes. From theoretical and methodological perspectives, our findings are among the first to demonstrate that this paradigm can be successfully applied in numerical cognition research. In addition, this method seems promising for studying the automatic numerical processes in vulnerable samples, such as young children.

7. Short-Term Storage of Working Memory Mediates the Relation Between Math Anxiety and Arithmetic Performance

Shiqiao Shen*, Wei Wei
Department of Psychology and Behavioral Sciences, Zhejiang University

Math anxiety is negatively associated with arithmetic performance. Previous studies have addressed that working memory mediates this relation. Although there are many definitions of working memory, it is generally accepted that working memory includes short-term storage. The present study investigated whether short-term memory plays a mediating role in the relation between math anxiety and arithmetic performance. A total of 178 children aged 8 ~ 10 years participated in this study. They completed two questionnaires used to assess math and trait anxiety and a set of cognitive tests measuring arithmetic ability, working memory, and short-term memory (storage). Using structural equation modeling, we first confirmed that working memory mediated the relation between math anxiety and arithmetic ability after controlling for trait anxiety. Second, we found that short-term storage also had a mediating effect. Third, with the component of short-term storage partialled out, working memory could not explain the relation between math anxiety and arithmetic performance. In addition, these results were not influenced by the difficulty of the arithmetic task. These findings indicated that math anxiety impairs arithmetic performance primarily through short-term storage in working memory.

8. Assessment of maths anxiety in early schooling: Emergence, stability and SES differences

Dawn Short*, Janet McLean
School of Psychology & forensic Science, Abertay University

Maths anxiety and SES during the early school years are related to later maths attainment and educational and employment opportunities in adulthood; high maths anxiety and lower SES are associated with poorer maths attainment. Maths anxiety increases with age, but little research focuses on its emergence or early stability. Identifying maths anxiety at the earliest stages of learning may prevent its further development and negative consequences. However, maths anxiety measures appropriate for young schoolchildren are lacking. This study adapted an established measure to assess maths anxiety in children aged 4-7 years old. Lower and higher SES participants were recruited during the first year of formal schooling (N=404, mean age 60 months). Participants completed an adapted Child Maths Anxiety Questionnaire (CMAQ) (Ramirez et al. 2013) and standardised maths assessments in Year 1, Year 2, and Year 3.SES differences in maths anxiety and attainment were apparent from Year 1. Lower SES children reported a higher prevalence of maths anxiety and lower maths attainment than higher SES children. Higher maths anxiety was related to lower math attainment for both SES groups. This pattern persisted throughout the longitudinal study. The adapted CMAQ provided robust results and revealed that maths anxiety was stable for 53% of the children throughout the study; Year 3 maths anxiety equalled Year 1 maths anxiety. However, maths anxiety increased for 30% (mostly lower SES) participants. Identifying and addressing maths anxiety at the beginning of formal education may reduce the negative effects of maths anxiety on later attainment.

9. Using cognitive predictors to predict poor mathematics performance in 7 and 8-year-old children: a feasibility study

Katie Allen*[1], Steve Higgins[2], John Adams[3]
[1] Department of Psychology, Durham University [2] School of Education, Durham University [3] The Open University

There is a large body of literature highlighting the role of working memory in mathematics attainment, however, it is unclear whether this relationship remains stable when other cognitive predictors are included. This study aimed to investigate this by simultaneously measuring working memory, speed of processing, g, and number sense and their ability to predict mathematical performance. 28 children were assessed on all measures. Results show that there were no suggestions of fundamental differences between children who performed poorly in mathematics and their peers. Further, analysis at the individual level revealed a great deal of heterogeneity in the cognitive profiles of children showing a cause for concern in mathematics. We conclude that highlighting children who may develop maths difficulties in the future is feasible as long as the chosen measures thoroughly explore the child's cognitive profile. This will then impact on the remediation strategies adopted to support children at an individual level.

10. Validating a measure of growing pattern understanding in preschool children

Xueliang Chen*, Xiao Zhang
Faculty of Education, The University of Hong Kong

Recent research has pointed to the importance of patterning skills in early mathematics development. However, there is a lack of psychometrically robust instruments to measure patterning skills, especially growing pattern understanding. In this study, we validated an instrument assessing growing pattern understanding among preschool children. Altogether, 138 preschoolers aged approximately five years in Hong Kong were assessed individually on 10 growing pattern items at two time points over a one-year period. Confirmatory factor analysis showed that a two-factor model (i.e., increasing and decreasing patterns) fit best at T1, but a one-factor model (i.e., growing patterns) fit best at T2. Scale reliability was adequate at both time points according to ordinal alpha. At the item level, Rasch analysis showed that although all the items were within an acceptable range of difficulty, most items were relatively difficult at T1. This was corroborated by item and test information curves, which suggested that the test items provided the most information (i.e., had high reliability) at high ability levels at T1 but was a sensitive measure for children of both low and high abilities at T2. No differential item functioning was detected across boys and girls at T1 or T2. Also, children's performance on the growing patterns task was positively correlated with their performance on a repeating patterns task, suggesting convergent validity. Overall, the results suggest that the growing patterns task has sound psychometric properties and is appropriate for use among preschool children approximately six years old.

11. What do teachers in training know about children's conceptual understanding of arithmetic?

Katherine M. Robinson*, Shae Sackman
Departments of Psychology and Philosophy, University of Regina

Inversion (e.g., 4x26÷26), associativity (e.g., 3+24-22), and equivalence (e.g.,2x5x6=2x?) problems are often used to assess children's understanding of the inverse and associative relations between arithmetic operations and the equal sign, respectively. These problems are often unfamiliar to children so their problem-solving strategies can indicate what they understand vs. the rote application of a learned strategy. However, given the importance of conceptual understanding of arithmetic for later mathematical success, direct instruction might be advantageous yet teachers might not realize that it is needed (Sherman, 2007). Undergraduate Education students completed an online study asking them to estimate what percentage of Grade 5 children would apply conceptual knowledge of inversion, associativity, and equivalence during problem solving on both additive and multiplicative problems. Preliminary findings with 28 participants (mean age = 23.8 years) indicate that estimates vary widely within all of the problems. Participants also both overestimated and underestimated children's application of conceptual understanding of arithmetic. For example, participants estimated that 58% of Grade 5 children would solve 8+23–23 by applying their knowledge of the inverse relation between addition and subtraction (cf. 77% of children in Robinson et al., 2018). Conversely, the participants estimated that 44% of Grade 5 children would solve 4x26÷13 by applying their knowledge of the associative relation between multiplication and division (cf. 23%). These preliminary findings suggest that, at least for teachers in training, drawing attention to what children understand or struggle to understand about the relations between arithmetic operations and the equal sign may be beneficial.

12. Worried about transitioning to secondary school? The influence of mathematical skill, confidence and anxiety.

Tatjana Zimasa*[1], Amber Bonser[1], Silke Göbel[1,2]
[1] Department of Psychology, University of York [2] Department of Special Needs Education, University of Oslo

Transition from primary to secondary school is a major life event for many children, with children with higher anxiety reporting more pre-transitional worries. In the current study we investigated the role of mathematics anxiety in pre-transitional worries about mathematics in secondary school, while controlling for mathematical performance and mathematical self-efficacy. We tested 96 children (51 girls, mean age = 11.5 years) in four UK primary schools at the end of their last year in the school. Participants indicated how worried they felt about mathematics in secondary school and completed measures of mathematical performance (WIAT Numerical operations), mathematical self-efficacy and mathematics anxiety (AMAS). We then utilised a hierarchical stepwise linear regression. The first model using mathematical performance as predictor explained 19.3% of the variance. When mathematical self-efficacy was entered in the second step the increase in explained variance was significant. However, while mathematical self-efficacy was a significant predictor, mathematical performance was no longer a significant predictor. In the third step, adding mathematical anxiety led to a further significant increase in explained variance. In the final model (explaining 77.5% of the variance) mathematical self-efficacy and mathematics anxiety were significant predictors of children's worries about mathematics in secondary school, but mathematical performance was not. In line

with previous research on pre-transitional worries, mathematics anxiety emerged as a significant predictor of worries about mathematics in secondary school even when controlling for mathematical performance and mathematical self-efficacy. Thus, pre-transitional worries about mathematics in secondary school are influenced by mathematical self-efficacy and mathematics anxiety.

13. Diagnosing specific learning disorder in mathematics in a multilingual education context

Vera Hilger*[1], Sonja Ugen[1], Linda Romanovska[1], Christine Schiltz[2]
[1] Luxembourg Centre for Educational Testing (LUCET), Faculty of Humanities, Education and Social Sciences (FHSE), University of Luxembourg [2] Institute of Cognitive Science and Assessment (COSA), Department of Behavioural and Cognitive Sciences (DBCS), Faculty of Humanities, Education and Social Sciences (FHSE), University of Luxembourg

Children with learning difficulties or a specific learning disorder in mathematics are entitled to receive support to minimize the impact on their scholastic achievement. This requires accurate identification of individual weaknesses and strengths in an extensive diagnostic process. In general, diagnostic test batteries rely on language, hence, test language proficiency is likely to influence children's test performance. This becomes especially striking in countries with a diverse cultural and linguistic setting. In Luxembourg, for example, most student's home languages are different to the main teaching language (also used in the diagnostic process) and marked differences in school performance based on a child's language background have been observed. In addition, currently used diagnostic test batteries generally do not consider linguistic heterogeneity, questioning the validity of the diagnostic process in a multilingual setting. To optimize this, we have developed a new mathematics test battery for third-grade children, tailored to a multilingual education context. Following diagnostic guidelines and neurocognitive models of number processing, key domains were identified to devise 17 subtests. While all instructions were language-based, only nine tasks included language directly within the items. Results from the pilot study (N = 211) reveal that three of these tasks (number reading, number writing, and verbal counting) show significant performance differences based on language background that favour children most familiar with the test language. This highlights the importance of considering test language proficiency in a diagnostic setting. The present poster will include more detailed information on the test framework and results of the pilot study.

14. Do additional magnitude cues benefit children's number line performance?

Xinhe Zhang*, Kexin Ren, Elizabeth Gunderson
Department of Psychology and Neuroscience, Temple University, USA

Number lines are widely used in mathematics education, and number line estimation skill is tightly linked to math achievement (Schneider et al., 2018). Number lines are typically presented with multiple cues to magnitude, including highlighting of the estimated part and the movement of the marker from zero to the target position. Highlighting the estimated part (the highlighting cue) may emphasize the proportion of the estimated segment's length to the entire number line, facilitating performance. The rightward movement of the marker from zero to a specific location on the number line (the dynamic cue) involves a duration of time that is proportional to the numerical magnitude to be estimated, and may reinforce associations between space, time, and position. The current study examined whether the presence of these

two cues improves children's magnitude estimation. Eighty-two 1st- and 2nd-graders completed the 0-100 position-to-number task. The dynamic cue (versus static) was manipulated within-subjects, and the highlighting cue (versus no highlighting) was manipulated between-subjects. We categorized students' estimates as best fit by a linear, logarithmic, or one-cycle proportional model based on AICs. With highlighting, 59.1% of students were best fit by the linear model (39.8% one-cycle, 1.1% logarithmic), whereas without highlighting, only 30.3% were best fit by the linear model (68.4% one-cycle, 1.3% logarithmic), a significant difference ($\chi^2(2)=13.37$, $p=.001$). The presence of the dynamic cue was not related to the best fit model. This suggests that highlighting the estimated part, but not dynamic movement of the marker, improves the linearity of children's number line estimation.

15. Parents' attitudes and self-efficacy impact children's multiplication fact practice at home.

Natasha Guy*[1], Lucy Cragg[2], Camilla Gilmore[1]
[1] Centre for Mathematical Cognition, Loughborough University, UK [2] School of Psychology, University of Nottingham, UK

Existing literature indicates the important role learning outside of school plays in fostering academic achievement and the effect that role models, including parents, can have in children's learning and perception of mathematics. Educators and researchers recognise the importance of recalling multiplication facts to support fluency, problem solving and later mathematical learning. Consequently, in England, policymakers have introduced a statutory Multiplication Tables Check taken by all 8- to 9-year-old children. Learning outside school may play an important role in children's multiplication fact learning and so we sought to examine the relationship between parent attitudes towards multiplication tables and children's home learning. 194 UK based parents of children aged 7 – 11 years were surveyed online. Parents who placed greater value on children learning multiplication facts reported that their children spent longer practising at home than parents who considered learning multiplication facts as being less important ($p = .002$). Similarly, reported time spent practising multiplication facts at home was higher for parents with greater self-efficacy in supporting their child's learning ($p = 0.02$). A significant difference was also found between parents who were or were not aware of the statutory Multiplication Tables Check and both the frequency and type of practice undertaken by their child (p's < 0.05). Our findings highlight the need for schools to recognise the importance of information they provide to parents, both in communicating the important role that multiplication tables play in the primary curriculum, as well as how to support children's recall practice at home.

16. More is better: Language statistics reveal a bias towards addition

Bodo Winter*[1], Martin Fischer[2], Christoph Scheepers[3], Andriy Myachykov4
[1] University of Birmingham, Department of English Language & Linguistics [2] University of Potsdam [3] University of Glasgow, School of Neuroscience and Psychology [4] Northumbria University, Newcastle-upon-Tyne, Department of Psychology

In behavioral tasks, people have a bias towards adding, systematically overlooking opportunities to perform subtractive changes across a large range of tasks, from improving recipes to revising papers (Adams et al., 2021). Here, we show that this behavioral bias corresponds to a similar bias in language statistics. We find that 1) words related to addition (add, plus, more etc.) are more frequent in the 450 million Corpus of Contemporary American

English than words related to subtraction (subtract, minus, less etc.). Addition-related words also 2) tend to occur first in binomial expressions such as “add and subtract” (as opposed to subtract and add), and 3) they are more positive in emotional valence. Finally, using word embeddings from word2vec (Mikolov et al., 2013), we furthermore 4) show that even simple verbs of change, such as “to change” or “to improve” are closer in meaning to addition-related than to subtraction-related concepts. These results suggest that the English language reflects a bias towards addition (and a relative neglect of subtraction), which also has affects methodology in experiments on subtraction neglect (Fischer et al., 2021).ReferencesAdams, G. S., Converse, B. A., Hales, A. H., & Klotz, L. E. (2021). People systematically overlook subtractive changes. Nature, 592(7853). Fischer, M. H., Winter, B., Felisatti, A., Myachykov, A., Mende, M. A., & Shaki, S. (2021). More instructions make fewer subtractions. Frontiers in Psychology.Mikolov, T., Chen, K., Corrado, G., & Dean, J. (2013). Efficient estimation of word representations in vector space. arXiv.

17. Cross-notation rational number magnitude comparison predicts math college entrance scores

Lauren Schiller[*1], Roberto Abreu-Mendoza[2], Robert Siegler[1], Clarissa Thompson[3], Miriam Rosenberg-Lee[2]
[1] Columbia University, Teachers College [2] Rutgers University, Newark [3] Kent State University

Growing evidence highlights the predictive power of cross-notation comparison (e.g., 2/5 vs. 0.25) for math outcomes, but the underlying mechanisms remain unknown. Here, we hypothesize that the greater predictive power of cross-notation rather than within-notation knowledge (e.g., 2/5 vs. 1/4) derives from its stronger index of magnitude representation. Those who flexibly switch between notations (e.g., 4/16=¼=0.25=25%) can more effectively evaluate the reasonableness of solutions on fraction arithmetic problems by translating to easier-to-process numbers. Across two studies, we investigated undergraduates’ cross-notation and within-notation comparison skills given equivalent fraction, decimal, and percentages (Study 1, N=211 and Study 2, N=183). We found participants did not perceive equivalent rational numbers equivalently. Cluster analyses revealed that approximately one-quarter of undergraduates exhibited a bias to select percentages as larger in cross-notation comparisons. Compared with the cluster who showed no bias, the percentages-are-larger bias cluster performed worse on numberline fraction estimation, fraction arithmetic (exact and approximate) and reported lower SAT/ACT scores, suggesting that cross-notation skill is an important factor in mathematical success. Indeed, hierarchical linear regression analyses demonstrated that cross-notation comparison accuracy accounted for variance in these math outcomes beyond within-notation accuracy. Mediation analyses revealed a potential mechanism: stronger cross-notation rather than within-notation knowledge better equips individuals to evaluate the reasonableness of solutions, which predicts arithmetic accuracy. Together, these results suggest the importance of an integrated understanding of rational number notations, which may not be fully assessed by within-notation measures alone.

18. The Significance of Symbolic Gestures and Pointing Usage in Early Childhood Mathematics Instruction

Melody Mann[*1], Tessa L. Arsenault[2], Sarah R. Powell[2]
[1] Department of Psychology, University of Hawaii, Manoa [2] Department of Special Education, University of Texas, Austin

Word problems appear on formal mathematics assessments and measure how students use mathematics in the real world (Powell et al., 2022). Yet, word problems can be especially complex for students and targeted instruction may be warranted (Van Dooren et al., 2010). Within mathematics instruction, the role of gestures have been included with positive results (Goldin-Meadow et al., 2009). In this study, we examined instructor use of pointing and symbolic gestures within a word-problem intervention: 1)How frequently do instructors use pointing and symbolic gestures? 2)For symbolic gestures, how frequently do instructors use schema gestures compared to other symbolic gestures? 3)How do instructors pair question asking with symbolic gestures? We double coded gestures from 14 recordings sampled from three graduate student instructors from a larger randomized-control trial providing schema instruction one-on-one to third-grade students experiencing mathematics difficulty (Author, 2020). The instructors used both pointing (758 instances) and symbolic (290 instances) gestures across all recordings. On average, instructors used pointing gestures 54.1 times per recording and symbolic gestures 20.7 times per recording. For symbolic gestures across recordings, instructors included schema gestures (i.e., gestures related directly to word-problem schemas; 192 instances) more frequently than other symbolic gestures (98 instances). Additionally, the instructors paired questions with symbolic gestures for 49.7% of the coded gestures. These results indicate that instructors most frequently used pointing gestures but also included schema gestures more regularly than other symbolic gestures. More research is needed to determine how the use of these gestures impacts mathematics instruction efficacy.

19. Frequency-tagging EEG reveals instruction-driven magnitude integration using the numerical distance effect

Cathy Marlair[*1], Aliette Lochy[2], Virginie Crollen[1]
[1] Institute of Psychological Sciences Research (IPSY), University of Louvain, Belgium [2] Institute of Cognitive Science and Assessment, University of Luxembourg, Luxembourg

While humans can readily access the common magnitude of various codes such as digits or dot sets, it is not yet clear whether this integration occurs spontaneously, or only when involved in explicit magnitude processing. We addressed this question by examining the neural distance effect, a robust marker of magnitude processing, with a frequency-tagging approach. By varying the instructions given to participants, we compared spontaneous processing of visually presented numerosities to explicitly oriented processing of magnitude or parity. Electrophysiological responses were recorded while participants were viewing rapid sequences of a base numerosity presented at 6 Hz (e.g., “2”) in randomly mixed codes: digits, number words, canonical dots and fingers. A deviant numerosity either close (e.g., “3”) or distant (e.g., “8”) from the base was inserted every five items. We observed clear discrimination responses of the deviant numerosity despite its code variation. The distance effect (larger responses when base/deviant are distant than close) was present when participants were explicitly oriented to magnitude and parity, but not in simple viewing. We thus argue that abstract magnitude processing is only partly spontaneous. It indeed requires sufficient cognitive resources to be engaged in numerical processing, but occurs whatever semantic aspect of numbers is activated.

20. Place-value understanding in Brazilian children and its relationship to numerical transcoding and arithmetic operations tasks

Paula Carvalho[*1,] Leidiane Caldeira[1], Ricardo Moura[2], Julia Lopes-Silva[1]
[1] Departarment of Psychology, Federal University of Minas Gerais (UFMG) [2] Department of Basic Psychological Processes, University of Brasília (UnB)

Place-value understanding has been related to other mathematics skills in the literature, such as numerical transcoding and arithmetic operations. The present study aimed to investigate the place-value understanding in Brazilian children from second to fifth grade (n=201) and its relationship to the performance at number transcoding and arithmetic operations tasks. For this purpose, we used a task based on a hierarchical model of development place-value understanding (which has 5 levels and has been empirically validated in German, South Africa and Turkey) and 2 other tasks to measure the above-mentioned mathematical skills. Data collection was conducted on cognition.run platform online (n=94, of which 76.60% study in private schools) and in-person (n=107, of which 81.30% study in public schools). The first sample had a higher score in the place-value ($t(199)=2.620$, $p<0.05$) and transcodification ($t(199)=2.124$, $p<0.05$) tasks than the other, and the results of both samples demonstrate a significant influence of procedural and conceptual understanding on numerical transcoding ($F(2.91)=114.990$, $p<0.001$; $F(2.104)=78.029$, $p<0.001$, respectively) and only conceptual understanding on arithmetics operations ($F(1.91)=106.794$, $p<0.001$; $F(1.104)=133.080$, $p<0.001$, respectively). Most of the students are between the second and fourth levels of the place-value model and the results describe that the percentage of children achieving proficiency at each level decreases as the level of proficiency increases. The study does not support the hierarchy of the model in all Brazilian children and the divergence of results between samples might be explained by the modality of the conduction of the experiment or by the type of school system.

21. Pupil Dilation during a Number Line Estimation Task

Hanit Galili[*1,] Avigail Langer[2], Avishai Henik[2]
1 Department of Cognitive and Brain Sciences, Ben-Gurion University of the Negev, Beer-Sheva, Israel 2 Department of Psychology, Ben-Gurion University of the Negev, Beer-Sheva, Israel

In number line estimation tasks, participants are presented with a number (e.g., 435) and asked to estimate this number position on a line between 0 and 1,000 (0 and 100 for young children or 0 and 1 for fractions). Researchers have suggested that this task captures participants' intuitions regarding numbers and their magnitudes. Accuracy on this task, which correlates with math achievement, was higher at specific orientation points (e.g., ends or middle of the line) and for integers than for fractions. We reasoned that the different estimation requirements, for different orientation points and fractions compared to integers, entail different needs of mental manipulation and attention. For example, positioning a number close to one end of the number line might require choice among a small number of alternative positions. In contrast, a number that is distant from an end might require contrasting and weighing more alternatives. However, an opposite expectation might be supported by assymetric eye-movements and fixations (longer and more frequent fixations at orientation points than other points along the line). We examined these expectations in experiments that measured pupil changes. The pupils dilated while participants prepared to respond. In addition, the pupils were larger at the

orientation than other points along the line. This pattern of results suggests that more mental attempts or weighing of alternatives might be required in cases of numbers closer to the ends.

22. Categorical syllogistic reasoning longitudinally predicted mathematics achievement in school-aged children

Charles Chiu Hung Yip*, Terry Tin-Yau Wong
The University of Hong Kong, Hong Kong

Categorical syllogism is a type of logical reasoning that have received considerable attention for its role in children learning. Categorical syllogism takes the form of a three-proposition syllogism, where propositions are related to the categorical relations between different sets or classes (e.g., all A are B, some A are C, therefore some B are C). Previous studies have shown positive associations between categorical syllogistic reasoning and mathematics achievement, but this relation has not been studied longitudinally. The current study was conducted to fill this research gap. A sample of 55 sixth graders completed tasks measuring their categorical syllogistic reasoning and mathematics achievement, as well as potential confounders (i.e., fluid intelligence, verbal working memory, spatial working memory). Three years later, they were assessed again on their mathematics achievement. Results from hierarchical regression showed that participants' categorical syllogistic reasoning longitudinally predicted their mathematics achievement three years later, after controlling for the potential confounders and the autoregressive effects of mathematics achievement. The current findings highlight the potential contribution of categorical syllogism in facilitating mathematics learning. Further research should be conducted to examine the mechanisms through which categorical syllogism can benefit mathematics learning. Intervention strategies may also be explored to enhance students' categorical syllogistic reasoning.

23. Validity of the flexible attention to magnitudes task for young children

Mary Fuhs*, Marissa Brown
Department of Psychology, University of Dayton

The Flexible Attention to Magnitudes (FAM) task assesses young children's explicit ability to shift attention between numerical and spatial magnitudes. FAM ability predicts growth in early mathematical achievement (Fuhs et al., 2022). We examined the concurrent and predictive validity of the FAM task. Children in the study (N = 226) were on average 55 mos old (SD = 8 mos; 51% female; 58% Black/African American, 65% family incomes < 42,000 USD). We hypothesized that FAM task performance would be related to children's number line estimation, proportional reasoning, and non-numerical magnitude approximation abilities, as all three mathematics skills involve attention to both numerical and spatial magnitude information, and that it would not be related to their subitizing performance. Children's FAM task performance was significantly correlated with their number line estimation skills ($r = .30$, $p < .05$), proportional reasoning skills ($r = .25$, $p < .05$), and their non-symbolic numerical magnitude approximation skill ($r = .42$, $p < .05$). Children's FAM task performance was not significantly correlated with their subitizing skills ($r = -.07$, $p > .05$). Children's FAM task performance was marginally correlated with the mathematics achievement ($B = .11$, $p = .07$) above and beyond demographics, language ability, EF skills, and other math skills listed previously. The effect was driven primarily by trials where children had previously switched from focusing on a different dimension for a number of trials ($B = .19$, $p < .05$). Implications for task use and interpretation will be discussed.

24. Parental math skills predict children's math skills and the effect is not mediated via home math environment (HME)

Minna Torppa*[1], Jenni Salminen[1], Maria Psyridou[2], Daria Khanolainen[1], Tuire Koponen[1]
[1] Department of Teacher Education, University of Jyväskylä [2] Department of Psychology, University of Jyväskylä

This study examines the role of parental math skills in children's grade 1-2 math skills. To better understand the mechanisms of the potential association, we examined if the effect of parental math skills on their children's math skills runs via home math environment factors (HME formal and informal) or parental education. HME was measured with parental questionnaires when children were 2, 5, and 7 years (Grade 1), children's skills were measured in classrooms in grades 1 and 2 (age 7-9), and parental skills were measured with questionnaires and tests at the university. Sample size varied across assessment waves and data types, child skills N=834, parental questionnaires in grade 1 N=387, parental tests N=290. For the final regression analyses using full data for mothers and their children N= 135 and for fathers and their children N= 84. The preliminary results suggest associations between children's skills and HME at school age (negative for formal and positive for informal HME) but not with pre-school HME. No associations between child's skills and parental education were found. Parental education and parental skills were also not associated with HME. However, parental skills predicted children's skills and the association did not disappear after controlling for the effects of HME and parental education. Of the variance in children's math skills, 20-29% were predicted by parental skills and HME. The results suggest that parental math skills predict their children's math skills and the effect is not explained by the poorer HME provided by the parents with poorer math skills.

25. Gesture can influence what number you have in mind

Alexandra Lorson*[1], Vinicius MacUch Silva[1], Christopher Hart[2], Bodo Winter[1]
[1] University of Birmingham [2] University of Lancaster

Manual gesture provides a window into spationumerical associations. A corpus analysis of adults in the TV news shows that when people talk about larger quantities, they move their hands outwards, and inwards for smaller quantities (Woodin et al., 2020). Here, we present the results of a pre-registered study (N = 352) to look at whether such gestures matter for comprehension. We compiled 20 scenarios such as — "400 people were at the protest. Several of them got arrested." — and asked people: "How many were arrested?" A mixed beta binomial regression with random intercepts and by-condition random slopes for scenario revealed that estimates were on average 5% higher when participants saw an outwards- as opposed to inwards-moving gesture. Post-hoc analyses revealed that the exact pixel distance between the hands seen in the video affected numerical estimates in a metric fashion (bigger gestures = higher numerical estimates). These results suggest that 1) gesture plays a role in adult numerical communication, in a way that 2) is in line with existing experimental evidence for the mental association between space and number (Wood et al., 2008).
References Wood, G., Willmes, K., Nuerk, H.-C., & Fischer, M. H. (2008). On the cognitive link between space and number: A meta-analysis of the SNARC effect. Psychology Science, 489–525.Woodin, G., Winter, B., Perlman, M., Littlemore, J., & Matlock, T. (2020). "Tiny numbers" are actually tiny: Evidence from gestures in the TV News Archive. PLOS ONE, 15(11), e0242142. https://doi.org/10.1371/journal.pone.0242142

26. A categorization of self-reported strategies in human numerosity estimation

Elisabeth Inge Romijn[*1], Jeremy Hodgen[1,2], Eivind Kaspersen[1], Trygve Solstad[1]
[1] Norwegian University of Science and Technology (NTNU) [2] University College London

Humans use a range of strategies to estimate numerosities (Siegel et al., 1982). Previous research has identified individual differences in the use of these strategies (Yeo & Price, 2021) and that strategy use is influenced by the age of participants and the structure of presentation (Gandini et al., 2008). However, in these studies, participants were either allowed a long time to carry out estimates (up to 6 seconds) or to summarise their strategies at the end of the experiment rather than reporting after each trial. In our current study, participants were presented with numerosities between 2 and 49. We restricted the stimulus duration to either 100ms, 300ms or 600ms and collected strategy reports for each individual trial following a semi-structured interview protocol. Early analysis of the data suggests that participants used some similar strategies to previous research, but, in addition, some participants appeared to use strategies involving approximations based on density or decomposition. We will present analysis of the factors that influence strategy use, and the connection between strategies and behavioural data. In particular, the strategies can be categorized into three cognitive "mechanisms": recognition, direct associative retrieval of a pattern; calculation: performing an arithmetic procedure on the pattern, such as step-counting; and, approximation, such as comparing the similarity of the stimulus pattern to a reference pattern. The cognitive mechanisms appear to be broadly associated with different numerosity ranges which are influenced by presentation time.

27. Does the math anxiety-performance link depend on paradigm?

Xinru Yao*[1], Julia Huber[1], Christina Artemenko[1], Yunfeng He[2], Hans-Christoph Nuerk[1]
[1] Department of Psychology, University of Tuebingen, Germany [2] Liaoning Key Laboratory of Psychological Testing and Behavior Analysis, Liaoning University, China

Researchers investigate arithmetic by using different paradigms. However, performance differs between paradigms. Commonly, this is attributed to the difficulty of the paradigm, but another possibility is that math anxiety affects different paradigms differently. Math anxiety is a negative affective reaction to situations involving math. Recent studies showed the state-trait math anxiety discrepancy, i.e., a negative correlation between state math anxiety and math performance was observed while there was no negative relation between trait math anxiety and performance. These raise questions about whether state and trait math anxiety and its relation to performance differ between paradigms. This preregistered study (https://aspredicted.org/gf8dc.pdf) uses a mental arithmetic task including addition with/without carrying and subtraction with/without borrowing in six different paradigms: verification, choice reaction, delayed choice reaction, computerized production, verbal production with button press, and verbal production with voice key. Trait math anxiety was assessed before and state math anxiety during the arithmetic task. The first results show that state math anxiety is significantly larger for verbal production than computerized production and verification/choice reaction paradigms, suggesting a dissociation between speaking and writing/choosing the answer. These may be because participants are afraid of making mistakes and being negatively appraised in the experimental situation when speaking out the answer in front of an experimenter. We conclude that the corresponding paradigm in a study can be

chosen according to the aim (e.g., if researchers want to induce high math anxiety, then it's better to use verbal production paradigms).

28. When children with developmental coordination disorder use finger-counting: behavioral and 3D motion analyses

Maëlle Neveu*[1], Cédric Schwartz[2], Laurence Rousselle[1]
[1] Research Unit for a life-Course perspective on Health and Education (RUCHE), ULiège, Liège, Belgium [2] LAM-Lab motion, ULiège, Liège, Belgium

Children with Developmental Coordination Disorder (DCD) are known to be at increased risk for mathematical difficulties (Gomez et al., 2015; Pieters et al., 2012). While the severity of their numerical impairments appears to vary with the intensity of their symptoms (Pieters et al., 2012), few studies have attempted to understand how motor deficits affect their numerical abilities. The purpose of this study is to explore the functionality of finger-counting in children with DCD in solving resource-demanding problems in numerical and non-numerical contexts. Seventeen children with DCD matched with TD children on school level and on fluid reasoning abilities were tested. They were asked to identify the nth item after a target item in numerical and alphabetical ordered sequences. Behavioral measures supplemented by 3D motion analyses synchronized to a voice recording were used to assess children's performance and finger-counting functionality. Results showed that, although performing finger-counting gestures comparable to those of their TD peers, children with DCD had more difficulties in solving resource-demanding problems. When added to the model, working memory captures the majority of the variability explaining this group difference. These finding provide evidence that children with DCD do not take advantage of finger-counting to reduce working memory processing load and achieve the same level of performance than their peers.

29. Struggling with single-digit multiplications during primary school. Problem solved?

Juan Antonio Álvarez-Montesinos, Javier García-Orza, Ismael Rodríguez-Montenegro*, Marina Cuadra Jaime
Laboratorio de Cognición Numérica. Universidad de Málaga

Why some children struggle with single-digit multiplication solving is still open to debate. On one hand, some researchers defend that these children lack inhibitory control to manage the interference caused by the similarities among problems in single-digit multiplications (e.g.: 4x3=12 and 6x3=18 has both similar numbers, causing interference during the memorization and retrieval of multiplication tables); on the other hand, another explanation consider that low fluency multiplication children have poor numerical representations. They argue that we need to have robust number representations as bricks to build an efficient single-digit multiplication network that allows us to manage interference effectively. To study both hypotheses, we selected 175 primary school children and grouped them in three grade groups (3rd/4th, 5th and 6th) and in three multiplication fluency levels (Low, Medium and High) using a single-digit multiplication task (60 items in 2 minutes) and a timed multiplication verification task. We ran an Attentional Network Task (ANT) for children to evaluate conflict Attentional Network as a measure of inhibitory control and a group of several numerical tasks to evaluate the quality of number representations: collection comparison task, Arabic number-dot matching task, and two-digit Arabic comparison task. We controlled for intelligence and general speed processing. Results indicated no differences in conflict between fluency groups, on the contrary, differences in numerical knowledge arose in several numerical tasks: children with lower

multiplication fluency showed immature numerical representations. These results provide support for the poor numerical representations hypothesis in explaining the difficulties many children experience in automatizing multiplication retrieval.

30. Concurrent predictors of toddlers' spontaneous math focusing tendencies during a picture description task

Jorge Carvalho Pereira*, Heather Bachman, Elizabeth Votruba-Drzal, Melissa Libertus
University of Pittsburgh, Department of Psychology

Children's early mathematical skills are important predictors of later math achievement and overall educational attainment. However, substantial variation exists in these early skills. Children's spontaneous math focusing tendencies (SMFT), like the tendency to spontaneously focus on numerical information (SFON), rather than other features of a stimulus, predict later math performance. Here, we examined concurrent associations between toddlers' SMFT and their early number knowledge and expressive vocabulary skills. We measured toddlers' (N=86, Mage=3.72, female=50%) number knowledge and expressive vocabulary via an adapted Give-N task and parental report on the Developmental Vocabulary Assessment for Parents respectively. Additionally, toddlers' SMFT was assessed via a picture description task, where toddlers were shown three visually rich images depicting different cartoon-like scenes, each including a variety of mathematical content (e.g., numerals, patterns, countable sets). Toddlers described each image to the researcher in as much detail as they wanted. Researchers coded instances of toddlers' SMFT in three categories: spontaneous number word use; spontaneous spatial talk describing features/locations of both 2D/3D objects and spaces; and spontaneous quantifier talk describing discrete, inexact quantification. Linear regression results indicate that controlling for toddlers' math-related and non-math-related expressive vocabulary, number knowledge significantly predicted concurrent SMFT (b=1.22, SE=0.54, p=.03). Results will be discussed highlighting the importance of further understanding relations between young children's SMFT and their mathematical development. Future work should consider how early SMFT relate to children's performance on other numerical and spatial tasks and whether such associations are observed longitudinally, too.

31. Finger counting, finger montring and their impact on early mathematical skills

Stephanie Roesch*[1], Julia Bahnmueller[2], Roberta Barrocas[3], Korbinian Moeller[2]
[1] University of Tuebingen [2] Loughborough University [3] Leibniz-Institut fuer Wissensmedien, Tuebingen

Introduction Most children use their fingers when learning to calculate. However, it remains unclear (i) whether 4-year-olds already know how to count and show magnitudes on their fingers, (ii) whether they are able to apply these strategies spontaneously, and (iii) whether finger counting and montring are related to early mathematical skills. Methods156 kindergarteners aged 3 to 5 (N=78 female; M=4.33 years, SD=.43) from Germany participated in the study. We evaluated finger counting (i.e., counting to a number with fingers) and montring (i.e., simultaneously extending a number of fingers) and whether children spontaneously applied these strategies to keep track of a list of items (i.e., naming of six animals) or to indicate their age/the age of others. To examine the link to mathematical skills verbal counting, cardinal number knowledge, and word problem-solving was measured. Results Overall, children performed significantly better in finger counting than montring. In particular, 89% of children knew how to use their fingers for counting (solved at least one item

correct), but only 6% applied this strategy spontaneously. By contrast, 59% spontaneously depicted their age with fingers, but only 22% did so to indicate the age of others. Moreover, both finger counting and montring were significantly associated with verbal counting, cardinal number knowledge, and word problem-solving (controlling for cognitive ability and age). Conclusions Results suggest that better finger counting and montring are associated with better early mathematical skills in 4-year-olds. However, children of this age do not yet seem to apply these strategies spontaneously in mathematical contexts.

32. Acquiring the successor function of symbolic numbers: longitudinal comparison of verbal number words and number gestures

Laurence Rousselle*[1], Line Vossius[1], Marie-Pascale Noël[2]
[1] Research Unit for a life-Course perspective on Health and Education (RUCHE), ULiège, Belgium [2] Catholic University of Louvain, Belgium

Several authors claim that children achieve a complete understanding of the cardinal meaning of number words through the discovery of the successor function (i.e. every number word n has a strict successor defined as n + 1; Carey, 2004, 2009; Sarnecka & Carey, 2008). Additionally, converging lines of evidence suggest that children's ability to use their fingers in numerical contexts contributes to the development of basic numerical skills (Fayol & Seron, 2005; Gunderson et al, 2015). In this study, we examined longitudinally when children come to master the successor function of symbolic numbers and how finger representation contribute to the acquisition of the successor function. Sixty preschoolers were tested five times every four months between the age of 36 and 52 months using two tasks assessing the knowledge of the successor functions: one direction task assessing the understanding of direction of numerical changes and a successor task assessing the understanding of successor function. Each task was administered twice, once with number words and once with number gestures. Performance will be analyzed in relationship to their cardinal knowledge level (Give-a-number task). The analyses are in progress.

33. Impact of home mathematical environment on early numeracy skills in Cuban preschoolers

Melissa Alomá Bello*[1], Beatriz Hernández Aguilar[1], Lenna María Crespo Díaz[1], Susana Nuñez Raventós[1], Nancy Estévez Pérez[1], Abigail Cahoon[2], Victoria Simms[2]
[1] Cuban neuroscience center [2] Ulster University

There is evidence supporting the home environment provides experiences for children that significantly influence the acquisition of numerical skills. In contrast, several studies have reported weak relations between these variables. In Cuba, studies that analyze this relationship are insufficient. The present investigation aimed to examine the association between home math environment (HME) and early numerical skills of Cuban 3-4 years old children. Dyads of parents-children were assessed (n=72). Parents completed an adapted version of the home mathematics questionnaire (PHMQ), and children were assess in early numerical abilities and general domain cognitive processes (intellectual capacity, language, and inhibitory control). The Early Numerical Concepts - British Ability Scale III, Statue test - Battery NEPSY II, Oral Language task - Child Neuropsychological Assessment (ENI) and RIST tests were used to assess the children. We found that home activities that involve counting and classifying objects, symbolic representations and sets operations positively correlated with early numerical abilities. Significant positive correlations were also found between parent´s education level and

early numerical abilities. General domain cognitive processes (intellectual capacity and inhibitory control) predicted early numerical abilities, nevertheless home mathematical activities did not. These findings underscore the relations between the HNE and the development of children's mathematical skills.

34. HRV as an index of regulation and cognitive function to predict numeracy performance

Sylvia Gattas*, Alex Fraser, Yixin Chen, Gaia Scerif
Department of Experimental Psychology, University of Oxford

Regulatory mechanisms are essential for the development of abilities foundational to numeracy development such as Executive Functions (Hendry et al., 2016). Importantly, the development of regulatory mechanisms is essential for the development of foundational executive abilities at pivotal stages in early childhood which later help in skills such as those necessary for mathematical cognition. Furthermore, trait heart rate variability (HRV) as a measure of affective regulation has been linked to both behavioural regulation tasks and executive functioning tasks such as self-control and inhibition. While many believe ability is a result of sole performance and practice, this view bypasses the potential underlying regulatory mechanisms that are essential to practice and maintenance of such abilities. Furthermore, studies have explored whether trait HRV or state HRV is the stronger predictor of regulatory mechanisms within an executively demanding task. We examined the effects of trait HRV on mathematical performance in addition to an emotionally evoked maths task in 80 3.5-year-old children. We assessed whether trait HRV predicts numeracy performance on a number identification task. We also further explored whether trait HRV is a stronger predictor of performance within an emotionally evoked maths game or if state HRV is the stronger predictor. Results support evidence for the presence of a mechanism by which children who are anxious might overcome their anxiety and perform well.

35. Identifying general and maths specific anxiety levels in secondary school pupils in the UK

Caroline Peters*, Krzysztof Cipora, Kinga Morsanyi
Centre for Mathematical Cognition, Loughborough University

Mathematics anxiety has been seen in young school children from around the age of 6 (Beilock, Gunderson, Ramirez, & Levine, 2010; Krinzinger, Kaufmann, & Willmes, 2009; Thomas & Dowker, 2000; Vukovic, Kieffer, Bailey, & Harari, 2013). However, negative attitudes towards mathematics and MA appear to increase when children reach secondary school age, persisting into post-secondary education and throughout adulthood (Dowker, Sarkar, & Looi, 2016). Studies with older children and adults suggest that as the difficulty level of the mathematics asked of them increases, there appears to be an associated increase in the MA. Previous research into MA has generally focused on assessing at what age MA begins within primary schools settings or how MA effects other elements of learning, such as performance in older students. Fewer studies have looked at how MA changes at secondary school age. In this study we examined the levels of MA across UK secondary school students aged 10 to 18 ($n > 1400$). We also examined its relation to general anxiety and prior attainment as well as differences related to gender, socioeconomic status, and special educational needs.

36. Students' use of unit coordination when solving school-based place-value tasks (P)

Moritz Herzog*[1], Helena P. Osana[2], Anne Lafay[3]
[1] Institute for Educational Research, University of Wuppertal, Germany [2] Concordia University, Canada
[3] Université Savoie Mont Blanc, France

Unit coordination (e.g., understanding that 1 ten can be composed from and decomposed into 10 units) is considered a central aspect of base-ten numeration. Recently, researchers have used unit coordination as a theoretical framework for studying children's numeration knowledge, which has generated fine-grained descriptions of their place-value understanding (e.g., Herzog et al., 2019). Assessing place-value can be challenging, however; relying on children's performance on school-based tasks may not be sensitive to their understanding of the structure of number. Our objective is to use unit coordination as a theoretical framework to provide insight on children's conceptual understanding of place value. We present a planned study to investigate children's place-value knowledge and unit coordination when performing typical school-based tasks. Second and third graders in Germany and Canada will complete place-value tasks using base-ten blocks, digit cards, and visual representations. We will assess their performance and the extent to which their strategies show an elaborated understanding of unit coordination. We predict that although performance may suggest understanding, their unit coordination strategies will show important lacunae in their conceptual understanding of base-ten numeration. The results will provide researchers with insight on the assessment of place value and inform educators of the types of instructional tasks that can support the development of unit coordination in the early school years. Herzog, M., Ehlert, A., & Fritz, A. (2019). Development of a sustainable place value understanding. In A. Fritz, V. G. Haase, & P. Räsänen (Eds.), International handbook of mathematical learning difficulties (pp. 561–579). Springer.

37. Neural representation of discrete and continuous ratios in the visual and parietal cortex: A preregistered report (P)

Rebekka Lagacé-Cusiac*, Daniel Ansari, Jessica Grahn
University of Western Ontario

We often rely on ratios and proportions to make decisions. For example, we can tell from the battery icon on electronic devices how much charge is left by comparing the length of the filled bar to the length of the full battery icon, regardless of the overall size of the icon. This leaves the question of how humans process ratios across different formats. The aim of this study is to investigate the neural representation of discrete and continuous ratios in the parietal cortex using fMRI. Previous neuroimaging studies on ratio processing have focused on whether symbolic and non-symbolic magnitudes have common neural representation (Bhatia et al., 2022; Mock et al., 2018). However, this assumes the common representations of all non-symbolic formats (e.g., that one half depicted with sets of dots (numerosity) has the same representation as one half depicted with lines (length)). This assumption is currently untested as neuroimaging has only shown a spatial overlap in brain areas processing ratios across different formats (Jacob & Nieder, 2009; Mock et al., 2018). To answer this question, participants will complete a ratio match-to-sample task on discrete (sets of dots) and continuous (line lengths) magnitudes while in the MRI. Using representational similarity analysis, we will test a series of models representing low- and high-level features on a range of areas from primary visual cortex to parietal cortex. We hypothesize that ratios across formats will have

greater similarity in higher-order areas in the parietal cortex than in lower-order areas in the visual cortex.

38. Design and evaluation of 'The Mathematical Strategies Development Test' (P)

Nadir Díaz-Simón*, Jana Menalo, Maya Ghai, Daniel Ansari
Numerical Cognition Laboratory, Department of Psychology, Western University

The mathematical strategies observed in the solution of simple arithmetic problems can be classified into two main types: strategies for direct retrieval of answers from memory and procedural algorithms. Even though arithmetic strategies (AS) have been studied for more than five decades, there still needs to be more theoretical models and standardized methods to describe the development of this process and its relationship with other psychological abilities. The Mathematical Strategies Development Test (MSDT) is a novel paper-and-pencil assessment of self-generated AS of school-age students. MSDT includes five addition problems plus one practice test that students must solve. For each trial, students have two minutes to generate as many alternative solutions as they can. MSDT measures the number and complexity of AS generated by children.This project aims to characterize the development of AS in school-age children (third to five grade). Our specific objectives are: to analyze the psychometric properties of the initial version of the MSDT, to describe the developmental changes in this construct across different age groups, and to evaluate the relationship between AS and divergent thinking, arithmetic fluency, and receptive vocabulary. We plan to include at least one class from each grade (approximately 30 students per grade, 90 students total). An a priori power analysis conducted using G*Power (Faul et al., 2009) shows that an N of 90 is sufficient to yield an alpha level of .05, with a power of .80 to detect a medium effect size (Cohen's f = .335) in a in a one-way ANOVA.

39. NumRisk: number sense and financial decision making in dyscalculic adolescents (P)

Maike Renkert*
Zurich Center for Neuroeconomics (ZNE), University of Zürich, Switzerland

Economists have long tried to understand how people behave under uncertainty, specifically under risk, where most people tend to behave risk averse. While this has been traditionally explained by valuational processes, recent models suggest that it may also emerge from misperceptions of the magnitude of large payoffs [Khaw&Woodford, 2018]. Such a perceptual account of risk aversion directly relates to how the brain represents numerosities, for which the underlying cognitive system is commonly referred to as number sense. Some studies found evidence in favor of it being less precise in Dyscalculia. In the current study, we want to investigate the potential link between behavioral plus neuronal number sense acuity and risk-aversion in control and dyscalculic adolescents. For this, both groups will perform a simple magnitude judgment task while their brain activity is recorded via fMRI and a financial decision-making under risk task outside the scanner. In addition, we will collect some other data to look at dyscalculia as a heterogeneous learning disorder from different angles.The fMRI-data analysis will be based on a generative model, yielding an estimate of neural precision. Perceptual number sense precision and risk-aversion parameters will be derived from fitting a noisy logarithmic coding model to the behavioral data. The three estimates will be put into context by a mediation analysis and compared among groups, with the hypothesis that a) perceptual precision mediates the link between neuronal precision and risk-aversion, and b) the

dyscalculic group will have lower neuronal and behavioral precision and hence be more risk averse.

40. Leveraging a Visuospatial Language to Enhance Quantitative Learning (P)

Rachel Pizzie, Rachel Sortino*, Christina Kim, Lorna Quandt
Gallaudet University, Educational Neuroscience Program, Washington, DC

Deaf and hard-of-hearing (DHH) people are underrepresented in STEM fields and lag behind their hearing peers by two or more grade levels in mathematics. One contributing factor is the use of English or manually-coded English (MCE) to present STEM content to DHH students. This conflicts with DHH students' need for explicit, visual, explanations, especially for abstract, quantitative content. One proposed remedy is leveraging the iconic and spatial nature of American Sign Language (ASL) to present math topics with increased visuospatial depiction. This is supported by research suggesting that embodied learning strengthens understanding of quantitative content, creating a better conceptual foundation. We propose that highly-iconic visuospatial ASL presentations facilitate learning for DHH students because they allow for an embodied understanding of content. In this study, we will compare learning outcomes in response to different types of signed STEM content (i.e., MCE vs. highly-iconic ASL). We will measure content knowledge before and after participants are trained with video-based learning modules. 35 signers will view two modules in MCE, counter-balanced with two highly-iconic modules in ASL. Participants will copy key signs as they watch and summarize what they have learned at the end of each video. We will analyze within-subject improvement on assessments for MCE vs. iconic presentations. We predict that scores will increase more for iconic ASL than MCE modules, indicating improved learning. This study establishes a foundation for future neuroscience research investigating how embodied ASL learning may be processed in the sensorimotor cortex.

41. Studying how ANS numerosity representations are dynamically built (P)

David Gomez*[1,2], Mario Perez[3], Valentina Giaconi[1,2]
[1] Institute of Education Sciences, Universidad de O'Higgins, Chile [2] Millennium Nucleus for the Study of the Development of Early Math Skills (MEMAT), Chile [3] School of Social Sciences, Universidad de O'Higgins, Chile

Introduction: The Approximate Number System (ANS) allows for representing large numerosities of objects in an approximate and quick manner. However, our knowledge of how these representations are dynamically built over time is yet scarce (e.g. Inglis & Gilmore, Cognition, 2013). In this study, we will use data from comparison and estimation tasks with different lengths of stimulus presentation to measure the time course of numerosity judgments. Methods: We will consider two comparison tasks (with spatially overlapping or separate sets of dots) and two estimation tasks (calibrated or uncalibrated). Participants will respond to 2048 items distributed over 4 experimental sessions. Sets of dots will be designed so that total set area and convex hull vary orthogonally to numerosity. Dot color will be either yellow or blue (two shades each). Stimulus presentation will vary from 50 ms to 800 ms. Analysis: We will analyze performance by using logistic mixed-effect regression models (as in DeWind et al., Cognition, 2015). To investigate the evolution of numerosity representations, we will use diffusion decision models (e.g. RatCliff & McKoon, Psych Rev, 2018) to integrate information from response accuracies and response times. In these models, we will consider the effects of numerosity as well as non-numerical variables. We predict that drift rates for numerosity will

increase with stimuli presentation times. Pilot data: We will present preliminary data from one of the comparison tasks with a fixed presentation time of 400 ms, where we tried different parameters for the distance between numerical and non-numerical properties of the stimuli.

Symposia 2.00 pm – 3.15 pm

Numerical development and applied mathematics – from kindergarten to primary school.

Chair: Yarden Gliksman
Ruppin Academic Center

The symposium explores factors that contribute to children's numerical development and math achievement. We present the contribution of domain specific and domain general cognitive factors that predict math achievement and refer to individual differences in young children, from four to nine years of age. Specifically, we present spontaneous focus on numerical order, math fluency measures, numeracy profiles, and domain-general abilities, as spatial processing, and executive functions. Moreover, the symposium includes presentation of new valid and reliable tools to assess numerical profile and math performance. Overall, the symposium aims to provide insights that can help design numerical diagnosis and interventions. The first study examines the role of children's spontaneous focusing on numerical order in their numerical development and finds that it is related to cardinality recognition, ordinality skills, and number sequence skills. The second study investigates the relationship between math fluency in addition and subtraction exercises and symbolic and non-symbolic comparison tasks in primary school children and finds that different measures of math fluency are predicted by different factors. The third study examines the role of domain-general abilities, including spatial abilities, visuospatial working memory, executive functions, attention, and fine motor ability in the development of numerical skills and finds that spatial skills and executive functions are the major factors that affect numerical performance. The fourth study examines the processing of numbers, number relations, and number operations as features of different numeracy profiles among kindergartners and their stability into first grade.

Presentation 1: Spontaneous focusing on numerical order and its relation to numerical skills in 4-year-old children

Heidi Harju*, Jo Van Hoof, Cristina Nanu, Jake McMullen, Minna Hannula-Sormunen
University of Turku

Understanding both cardinal and ordinal properties of numbers is essential for children's mathematical development (Lyons et al., 2016; Spaepen et al., 2018). Moreover, children's ability to spontaneously notice mathematical features in their surroundings supports their mathematical development (Hannula & Lehtinen, 2005). Nonetheless, only children's cardinality skills and the accompanying tendency to spontaneously focus on exact numerosities (SFON) have received ample research attention. The current study investigated the role of children's spontaneous focusing on numerical order (SFONO) in their numerical development. SFONO (three novel tasks), SFON, cardinality and ordinality skills, and number sequence production were measured from 152 3.5 – 4.5-year-olds. Preliminary results show individual differences in SFONO that are significantly related to cardinality recognition ($r = .57$), ordinality skills ($r = .49$, $r = .43$), and number sequence skills ($r = .57$). Moreover, hierarchical regression analysis show that SFONO explains small unique variance in children's ordinality

skills, after controlling for number sequence, cardinality, and SFON. These results suggest that SFONO may be an important, distinguishable feature of early numerical development.

Hannula, M.M., & Lehtinen, E. (2005). Spontaneous focusing on numerosity and mathematical skills of young children. *Learning and Instruction, 15*(3), 237–256.
Lyons, IM, Vogel, S., Ansari, D. (2016). On the Ordinality of Number: A review on neural and behavioral studies. *Progress in Brain Research, 227,* 187-221.
Spaepen, E., Gunderson, E. A., Gibson, D., Goldin-Meadow, S., & Levine, S. C. (2018). Meaning before order: Cardinal principle knowledge predicts improvement in understanding the successor principle and exact ordering. *Cognition, 180,* 59–81.

Presentation 2: Symbolic and non-symbolic comparisons predicts math Fluency in primary school in different ways

Yarden Gliksman*, Shai Falach
Ruppin Academic Center, Israel

Math fluency (MF) is the ability to solve math problems quickly and accurately. MF is an important building block for success in arithmetic achievements and in crucial skill for daily life. The Ben-Gurion University Math Fluency (BGU-MF) test is a 3-minute computerized tool that measures MF by evaluating the number of solved exercises, accuracy rates, and response times for each exercise and operation. Recently, we found that MF improves with age during primary school, but it is not yet understood which factors predict MF. This study investigated the relationship between MF in addition and subtraction exercises and symbolic and non-symbolic comparison tasks in children in grades 1-3. The results showed that different measures of MF are predicted by different factors. Accuracy in MF was predicted by symbolic comparison, while response times in MF were predicted by non-symbolic comparison and grade. The number of solved exercises was predicted by symbolic comparison, non-symbolic comparison, and grade. These results can shed light about the role of non-symbolic processing in MF, and highlight the importance of using different measures of MF and assessing it with a computerized tool.

Gliksman, Y., Berebbi, S., & Henik, A. (2022). Math Fluency during Primary School. *Brain Sciences, 12*(3), 371, 1-16.
Holloway, I. D., & Ansari, D. (2009). Mapping numerical magnitudes onto symbols: The numerical distance effect and individual differences in children's mathematics achievement. Journal of Experimental Child Psychology, 103(1), 17-29.

Presentation 3: The role of domain general factors (spatial, executive function, working memory, attention, and fine motor skills) in numerical processing in early childhood

Sarit Ashkenazi*, Anna Adi
The Seymour Fox School of Education, The Hebrew University of Jerusalem

Numerical skills are a major cognitive foundation of mathematical learning, especially in young children. The role of domain-general factors in explaining individual differences in numerical skills is largely unknown. The current study aims to shed light on the different roles of multiple domain-general abilities, including spatial abilities, visuospatial working memory, executive functions, attention, and fine motor ability in the development of numerical skills. Using an extensive sample of children (n = 339) of varying ages (between 3

and 8 years-old), we examined the influence of domain-general factors on numerical skills (symbolic and non-symbolic). We used factor analysis to cluster tasks into latent variables to analyze the data. Based on the results, we used Structural Equation Modeling with numerical abilities as the outcome variable. Spatial skills directly and strongly affected numerical skills, and executive functions also affected numerical skills. Executive functions made a unique contribution to symbolic numerical skills, dissociating symbolic and non-symbolic numerical skills. These results indicate that multiple factors can affect numerical performance. This conclusion bears significant implications for the early diagnosis of learning disorders and intervention methods for these disorders.

Silverman, S., & Ashkenazi, S. (2022). The differential relationship between visual and spatial working memory in children's mathematics performance. *Trends in Neuroscience and Education*, *29*, 100188.
Ashkenazi, S., & Adi, A. (2022). The role of domain general factors (spatial, executive function, working memory, attention and fine motor skills) in numerical processing in early childhood. *Current Psychology*, 1-13.

Presentation 4: Exploring Individual Differences in Number Sense Development from Kindergarten to First Grade Using Random Intercept Latent Transition Analysis

Haobai Zhang[1] , Brianna L. Devlin[2], Alice Klein[3], Nancy Jordan*[1]
[1]University of Delaware [2]University of Oregon [3]West Ed

Children's number sense competencies at the start of kindergarten predict mathematics growth across elementary school (Jordan et al., 2009). Recently, researchers have turned to person-centered analyses (e.g., latent transition, LTA) to capture individual differences in numerical development (e.g., Cahoon et al., 2021) Using these person-centered approaches, the present study aims to (1) identify empirically distinct numeracy profiles represented by proficiency with three conceptually validated strands: number, number relations, and number operations among kindergartners (N = 150); (2) examine the longitudinal stability of the distinct profiles a year later. Data were collected using the Screener for Early Number Sense (SENS), a reliable and valid researcher-developed tool. LPAs in each grade identified a four-profile solution: a) advanced overall number sense, b) relatively strong number knowledge, c) relatively strong number relations knowledge, and d) underdeveloped overall number sense. Random intercept LTA was performed to examine within-person stability and transitions over time. Profiles were relatively stable from kindergarten to first grade, and no children moved from the underdeveloped number sense group to the advanced group. Those with relatively strong number relations in kindergarten were the most transient group—they had only a .30 probability of remaining in the same group by first grade. Overall, our findings add to an understanding of stability of relative strengths and weaknesses in early number sense over time. Using a person-centered approach can inform where to target specific early number sense intervention work for individual students.

Integrating perspectives on adults' and children's math anxiety

Chair: Carlo Tomasetto
Department of Psychology, University of Bologna

Research in cognitive, developmental, and educational psychology has accumulated over the last decades, highlighting that many individuals experience negative feelings toward numerical information and mathematical problems, and that these feelings interfere with mathematical performance and achievements among both adults and young children. In the present Symposium we will seek to offer new insights from research on populations that are still relatively understudied in math anxiety research, and that span from parents of preschool-aged children to adult learners and to college professors in Europe and in the US. In the first contribution Carlo Tomasetto and colleagues will present data on the longitudinal link between math anxiety among parents of preschool-aged children – as measured when children were aged 3 years – and the development of children's math skills from age 3 to age 8, as well as with children's math anxiety. In the second contribution, Gerardo Ramirez and colleagues will focus on the role of teachers as socializing agents of math anxiety among students, by taking an original perspective on college professors, and by analyzing their validating vs. invalidating responses to students' emotional experience toward math. The contribution of Caterina Primi and Maria Anna Donati will focus on adults as well, although not in the role of socializers but rather of learners. In their research, they will adopt a person-centered approach to characterize students with diverse profiles of math-related and statistics-related anxiety.

Presentation 1: Longitudinal relations between parents' math anxiety and children's mathematical development from age 3 to 8

Carlo Tomasetto*[1], Maria Chiara Passolunghi[2], Chiara De Vita[2], Veronica Guardabassi[3]
[1] Department of Psychology, University of Bologna [2] Department of Life Sciences, University of Trieste
[3] Department of Humanities, University of Macerata

Past studies highlight that parents' math anxiety may be associated to children's math outcomes from as early as the primary school years. In this longitudinal study we investigated the associations between parents' math anxiety - as measured when children were in the first preschool year at age 3 – and the development of children's mathematical skills from age 3 to age 8 (N = 125). At age 8 we also assessed children's math anxiety and math self-concept. Results of longitudinal structural equation models revealed that parents' math anxiety at age 3 was associated with the average level of children's mathematical skills during the preschool years, from age 3 to age 5. In turn, children's mathematical skills during the preschool years were associated with children's mathematical skills and math self-concept, but not with children's math anxiety, at age 8. An indirect effect of parents' math anxiety at age 3 on children's mathematical skills at age 8 also emerged though children's mathematical skills during the preschool years. In sum, these findings suggest that despite not being a direct source of children's math anxiety, parents' math anxiety may have enduring effects on the development of children's early mathematical skills.

Presentation 2: Emotional Validation as a Response to Students Anxiety in Math

Gerardo Ramirez*[1], Annie Daeune Park[2], Christina Yang[2], Rebecca Gold[1], Addison Helsper[1]
[1] Department of Educational Psychology, Ball State University [2] Department of Psychology, Sungkyunkwan University

How professors react to students' vulnerability during math situations is critical to students' subsequent emotion regulation and their academic trajectories in STEM (Lin-Siegler, Ahn, Chen, Fang & Luna-Lucero, 2016). For instance, when students express a strong emotion (e.g., "Solving this equation is hard"), professors can be quick to invalidate (e.g., "no it's not, you just need to know how to properly set up the problem") rather than validate (e.g., "This is a tough problem. These problems give many students difficulties"). A validating response is one in which a student expresses their private experience, and this expression is met with understanding, legitimacy and acceptance (Linehan, 1997). Research with elementary school children and adolescents reveals that validating responses to emotions during educationally challenging activities helps reduce the frequency, intensity and duration of their emotional reaction as well as help build relationships (Shenk & Fruzzeti, 2011; Okonofua et al., 2016). However, there is a theoretical gap in what we know about the use of validation among professors in a college course setting, where emotions run high. I will present research on the value of emotional validation in helping students to regulate their emotions in math.

Presentation 3: Understanding profiles related to math anxiety and statistical anxiety: results from university students

Caterina Primi*, Maria Anna Donati
Neurofarba, University of Florence

Despite the increasing interest in studying math anxiety (MA), little attention has been focused on a person-centered approach, especially with university students attending non-mathematical Schools with introductory stats courses. Understanding possible typologies of individuals based on MA and statistical anxiety (SA), would be useful to better understand the phenomenology of domain-specific anxieties relevant for attending the course and implementing preventive actions to favor achievement. Participants were 240 students (76% females, Mage = 21.35, SD = 4.84) attending the School of Psychology at the University of Florence (Italy). MA and SA were respectively assessed with the Abbreviated Math Anxiety Scale (AMAS) and the Statistics Anxiety Scale (SAS). By entering the z-standardization of the AMAS and SAS subscale scores, a two-step clustering procedure was conducted. The resulting cluster distribution (Cluster 1 = 25%; Cluster 2 = 27%%; Cluster 3 = 48%) indicated that Cluster 1 was characterized by levels of Learning (MA) and Interpretation (SA) about 1.5 SD above the mean; Cluster 2 had all the dimensions below the mean; and Cluster 3 showed all the dimensions approximately at the mean value. Significant differences between the Clusters were found in mathematical ability, probabilistic reasoning ability, cognitive reflection, and attitude towards statistics. Students belonging to Cluster 1 showed the lowest levels in all the variables investigated. Data encourage a further understanding of classification of university students in terms of MA and SA and emphasize the characterization of profiles mostly in terms of anxiety in learning math concepts and anxiety in interpret statistical topics.

Discussant

Erin Maloney
School of Psychology, University of Ottawa

Evidencing the approximate system - findings from different research perspectives

Chair: Anita Lopez-Pedersen
Department of Special Needs Education, University of Oslo, Norway

In a seminal study, Dehaene suggested that humans and animals have an inherent intuitive primitive mental system of nonverbal representations, namely the approximate number system (ANS) (Dehaene, 1997). Purportedly, ANS is the foundation for understanding symbolic numbers and for mathematical development. Dehaene based the notion of this system underpinning mathematics on theories hypothesizing that the foundation of numerical competence lies in preverbal mechanisms for counting and arithmetic reasoning. After Dehaene's pivotal publications, the notion of ANS has attracted much attention. ANS is considered a mental system of approximate number representation that is activated and used during nonsymbolic approximation and number tasks (Mazzocco et al., 2011). In this symposium we aim to highlight and discuss the developmental relationship between ANS and mathematical skills from three different perspectives. We present findings from two longitudinal studies and one meta-analysis. The objective being to challenge the role of ANS as a foundation for mathematical development - in both a domain-general and domain-specific perspective, as well as methodologically. Although, there seems to be a consensus that ANS has a role to play, the discussion is instead whether it explains anything over and beyond other domain-specific skills and which domain-general factors are more or less important in this developmental interplay.

Dehaene, S. (1997). The Number Sense [How the Mind Creates Mathematics]. Oxford University Press. Mazzocco, M. M. M., Feigenson, L., & Halberda, J. (2011). Impaired acuity of the approximate number system underlies mathematical learning disability (dyscalculia). Child Development, 82 (4), 1224-1237.

Presentation 1: Analyzing the Developmental Relationship between the Approximate Number System and Early Mathematics: Different Methodological Approaches Lead to Different Results

Anita Lopez-Pedersen*[1], Arne Lervåg[2], Monica Melby-Lervåg[1]
[1] Department of Special Needs Education, University of Oslo [2] Department of Education, University of Oslo

Using two different data sets, this study examines the hypothesis that the approximate number system has a potential causal influence on mathematical development, and that the converse is also true, i.e. mathematical skills influence ANS. First, we reanalyzed the dataset from a recent study by Elliott et al., (2019). Using a cross-lagged panel model, Elliott et al. (2019) claimed a reciprocal relationship between ANS and early mathematics. However, when reanalyzing this data set using a random-intercept cross-lagged panel model, no evidence of a reciprocal relationship was found. The cross-lagged effects found in Elliott's initial study were not present. Second, in a one-year longitudinal study with three time points, 120 low-performing children were assessed on measures of ANS and addition skills. This dataset was also analyzed using a random-intercept cross-lagged panel model. Results showed no evidence supporting a reciprocal relationship between ANS and mathematical development; no significant cross

effects were found. Thus, these results challenge the notion that ANS plays a vital role in the development of early mathematics, and vice versa.

References Elliott, L., Feigenson, L., Halberda, J., & Libertus, M.E. (2019). Bidirectional, longitudinal associations between math ability and approximate number system precision in childhood. *Journal of Cognition and Development, 20*(1), 56-74

Presentation 2: Early interrelations between spatial skills and Approximate Number System

Ilse E.J.I. Coolen*[1,2], Julie Castronovo[2]
[1] Donders Institute, Radboud University [2] University of Hull

Mathematics consists of an abstract culturally invented system. This system is often thought to have a foundational basis in primitive neural networks. Indeed, the neuronal recycling hypothesis by Dehaene and Cohen (2007) states that culturally invented functions rely on primitive brain areas initially intended for other functions. These primitive brain areas consist of regions (e.g., Intraparietal sulcus; IPS) with domain-specific functions such as the representations and manipulations of numerical quantities (i.e., the Approximate Number System; ANS) and domain-general functions such as visuospatial skills and memory. Indeed, participants with a more precise ANS acuity have been shown to also perform better on visuospatial tasks. Even though both functions have been thoroughly investigated in terms of their relation to mathematics, their respective behavioral interrelations during development are less understood. Therefore, we will investigate whether both processes and their development are related longitudinally and whether their link to mathematics is interrelated or separate. This will be tested in children aged 4 to 7 in a longitudinal behavioral design. We expect to find a bidirectional link between visuospatial skills and the ANS longitudinally and that both processes are equally related to mathematics. Thereby indicating that both foundational networks work together in the development of early mathematics skills.

Presentation 3: A Meta-Analysis of Approximate Number System Acuity as a Predictor of Mathematical Outcomes

Tonje Amland*[1], German Grande Garcia[2], Ronny Scherer[3], Arne Lervåg[2], Monica Melby-Lervåg[1]
[1] Department of Special Needs Education, University of Oslo [2] Department of Education, University of Oslo [3] Centre for Educational Measurement, University of Oslo

Accumulating evidence suggests that humans possess a non-verbal innate system for magnitude processing, commonly labeled the approximate number system (ANS). The acuity of the ANS has been suggested to matter for symbolic number learning and could therefore be an important predictor of mathematical outcomes in early and later school years. However, findings are mixed and only a few meta-analyses have previously assessed the ANS as a predictor of mathematical outcomes. Neither of these have controlled for known domain general predictors such as language and spatial ability. Here, we present a new meta-analysis summarizing cognitive predictors of mathematical skills based on 181 concurrent and 113 longitudinal studies with children, comprising 2019 correlations. Results showed that ANS acuity correlate significantly less with mathematical achievement compared to not only symbolic number skills, but also compared to other cognitive predictors. The concurrent Pearson's r correlation between ANS and mathematical competence was .29. When

mathematical domains and other cognitive abilities were taken into account, we found that ANS concurrently predict arithmetic but not word problem solving. Longitudinally, an initial correlation of .25 between ANS and mathematics disappeared once symbolic number skills were taken into account. The heterogeneity of effect sizes was high, and moderator analyses indicated that some ways of conceptualizing ANS acuity yielded higher correlations with symbolic number skills and mathematical outcomes than others. Nevertheless, we found that the overall contribution of ANS acuity to mathematical outcomes was limited.

Discussant

Silke Göbel*
Department of Psychology, University of York

Parent language input, math attitudes, and family contexts in children's math learning

Chair: Yu Zhang
University of Chicago

Math learning, like many other cognitive processes, is intertwined with everyday learning experiences, which occur within, and are affected by, sociocultural contexts. Yet, we understand little about various contextual factors that relate to children's early math. Three papers examine understudied socio-cultural factors that relate to the early family math environment and children's math learning. These factors include parents' math attitudes in lower-SES African American families, immigrant generation status in Latine families, and frequency of counting in infants' home environment. Paper 1 focuses on how parents from low SES backgrounds use math language when describing common scenes to their 1st graders. Findings show that parent use of math relational language (e.g., math comparisons, definitions) varied depending on parent self-efficacy for supporting their child's math learning but parent math talk did not depend on their math anxiety. Paper 2 focuses on the frequency with which Latine immigrant parents shared books with math content with their young children (2- to 7-year-olds) depending on the recency of their immigration to the United States. First-generation Latine immigrant families prioritize non-math books over math books at home compared to later generation immigrant families. Echoing Paper 1, parent math anxiety did not predict math book sharing. Paper 3 highlights the potential of very early parent math language to affect infant math outcomes, by showing that counting in the home environment predicts 14- to 18-month-old's sensitivity to set size. Together, these papers underline the importance of examining factors that affect the home math environment in particular socio-cultural contexts.

Presentation 1: Parent math attitudes and their use of math relational language in low-SES families

Yu Zhang*, Dania Smithstein, Susan Levine
University of Chicago

Recent research has shown that parents' self-focused math attitudes (e.g., math anxiety) predict parent advanced math talk in middle-class families but not among lower SES families (Berkowitz et al., 2021). The present study examines whether the child-focused math attitudes of parents from low-SES backgrounds (N= 70 dyads; 79% African American) relate to their advanced math talk (math relational language) shared with their 1st grade children. Parent measures included two child-focused math attitudes—math expectations and value for children's math success (MEV) and math self-efficacy for teaching children math (TMSE), and one self-focused attitude—math anxiety (MA). Parents were asked to discuss three scenarios (i.e., a weather report, a train station, and a produce stand) with their child, with conversations recorded via Zoom. A comprehensive coding scheme revealed that parents used more math non-relational language (M=42.06, SD=21.58) than math relational language (M=29.96, SD=19.42; $t(69)=4.47$, $p < .001$) overall. Results replicated Berkowitz's finding that the MA of low SES parents did not predict their math relational language ($\beta=-.16$, $p=.19$). However, parent child-focused attitude, TMSE, predicted their math relational language ($\beta=.28$, $p=.04$) but not their use of math non-relational language ($\beta=.12$, $p=.39$) controlling for child gender, MEV, and parent math education. These findings suggest that parent TMSE is a potential lever for strengthening home math learning experiences for children. We suggest that a strength-based approach for addressing low levels of parent TMSE is likely to be particularly effective way to support math learning opportunities at home.

Presentation 2: Parental math anxiety and reading habits: A comparison of math and non-math books and E-books

Susana Beltran-Grimm*, Avery Closser, David Purpura
Purdue University

Parental engagement in activities such as reading math books with their children can enhance children's mathematical numeracy and literacy proficiency1. Conversely, parents who have high anxiety about math are less likely to engage in advanced math activities with their children2. Additionally, children of first-generation immigrants develop reading skills as early as kindergarten3. Here we examine the role that Latine parents play in creating math-rich home environments, including reading math books and e-books. An online survey of 181 Latine parents with children 2- to 7-year-old was conducted. All parents were Spanish-speaking living in the US; 75% were foreign born, with at least some college or technical education. A multiple regression analysis was conducted to examine the relation between reading frequency (measured by non-math book, non-math e-books, math books, and math e-books) and parent math anxiety (measured by a 14-item math anxiety scale), controlling for gender, education level, and immigrant generation (measured as first-generation or not). Immigrant generation was a positive and statistically significant predictor of reading frequency of non-math books ($\beta = .27$, $p < .001$) such that first-generation Latine parents living in the US read more non-math related books to their children than later-generation parents whereas there was no difference in the frequency of math book reading as a function of recency of immigration. These findings suggest that first-generation Latine parents prioritize literacy over math in their home learning

environment to support children's reading and writing skills to help them adjust academically in a new country.

Presentation 3: Sources of individual differences in infants' recognition of counting: The role of home learning environment

Kathleen Cracknell*, Jingjing (Jenny) Wang
Rutgers University

Recent studies suggest that watching an experimenter count helps infants better remember sets of objects in person and online (Wang, 2022; Wang & Feigenson, 2019). This kind of counting input may underlie individual differences in later number knowledge (Gunderson & Levine, 2011). Infants aged 14 to 18 months (n = 111; 54 girls; mean age 15.6 months; SD = 1.6 months) participated in this study. To explore potential effects of individual differences on task performance, caregivers were asked to complete an online survey detailing frequency of number related, literature related, and general home activities within the past week and month. We measured infants' memory for hidden objects with an online violation of expectation paradigm, comparing infants' looking time when there was a Match between the number of objects hidden and revealed (e.g., two objects hidden, two objects revealed) or a Mismatch (e.g., four objects hidden, two objects revealed). Infants watched the objects counted in English (Counting condition) and labeled without counting (No Counting condition) before being hidden. To ask what factors predict how much infants benefit from Counting or No Counting, individual preference scores were calculated between the conditions. Preliminary ANOVA results suggest a significant effect of weekly home counting frequency on preference for the Mismatch event in the Counting condition ($\beta = -.21$, $p = .04$), and a significant effect of monthly home number activities for the Mismatch preference in the Counting condition controlling for literary and general activities ($\beta = -.47$, $p = .05$).

Discussant

Susan Levine*
University of Chicago

"Everything I know I learned after I was thirty.": the past, the present, and the future of Spatial-Numerical Associations

Chair: Krzysztof Cipora
Centre for Mathematical Cognition, Loughborough University, UK

Thirty years ago, in 1993 Stanislas Dehaene and colleagues published a seminal paper demonstrating that numbers are associated with directions in space: small numbers are associated with left-hand side while large magnitude numbers – with the right-hand side. This observation was named Spatial-Numerical Association of Response Codes (SNARC). The SNARC effect has been replicated numerous times in various settings, and while its presence is well-established and not disputed, there is still no consensus on where the SNARC effect comes from, what it means, and whether it plays any functional role. In this session we will reflect on the history of the SNARC (Wim Fias), go over current theoretical models aimed at

explaining it (Jean-Philippe van Dijck), discuss its potential functional role (Carrie Georges & Christine Schiltz), and recent empirical observations (Krzysztof Cipora). At the end of the session, we will try to think of the future of the SNARC (whether the quote in the title of this symposium may be valid for the SNARC too) while enjoying the special "birthday cake".

Presentation 1: Three decades of research on the SNARC effect: A synthesis

Wim Fias*
Department of Experimental Psychology, Ghent University

Since the original SNARC publication in 1993, hundreds of papers have been published on this phenomenon. This makes a complete historical overview a difficult if not impossible task. Therefore, rather than focusing on chronology, I will discuss a number of thematical issues along which research on the SNARC effect has developed over the last three decades.First, the SNARC effect has been used as a tool to test theories of the structure and organisation of the numerical and mathematical cognitive system. Second, the SNARC effect has been a research topic on itself. The goal of this research line has been to understand which underlying cognitive mechanisms give rise to the effect. Third, a broader research focus have been taken when other paradigms and effects were sought and found that also reflect associations between numbers and space. Fourth, research efforts have concentrated on the SNARC effect (and related phenomena) as a possible determinant of mathematical abilities. Significant progress has been realised along each of these four research lines. Yet, work remains to be done and, undoubtably, there is more exciting research to come.

Presentation 2: An overview of different theoretical accounts of the SNARC effect

Jean-Philippe van Dijck*
Department of Applied Psychology, Unit: Assessment and Intervention, Thomas More University of Applied Sciences

In the 30 years after the discovery of the SNARC effect, a large bulk of studies has been published, providing us with detailed insights in the origin and nature of this effect. Several attempts have been made to reconcile these findings to overarching theoretical accounts. Here, we give an overview of the most popular and influential theoretical accounts of the SNARC effect and bring them to the test in the context of recent empirical developments in the field. We will show that each account has its strengths but that none of the existing accounts is able to explain the large collection of existing empirical data. We will end the talk by discussing some pointers which can help us to direct future theoretical developments.

Presentation 3: The SNARC effect and its functional role in mathematical development

Carrie Georges*, Christine Schiltz
Institute of Cognitive Science and Assessment, Department of Behavioral and Cognitive Science, University of Luxembourg

The intuitive idea that the use of space as a building block for numerical representations is underlying math skills has sparked interest in research about a potential functional link. Could the SNARC effect prove useful in the diagnosis of math difficulties and the training of math skills? Unfortunately, the pattern of results is far from conclusive. While some positive and

negative relations between the SNARC effect and math skills have been reported in children and adults, respectively, most studies did not find a significant link. Discrepancies were ultimately explained by differences in sample characteristics (e.g., age range) and the operationalization of math skills, which has sparked discussions about the cognitive mechanisms involved. Various candidate factors were suggested based on empirical findings and theoretical considerations, including automatic number processing, selective attention, representational abstractness/flexibility, spatial skills, as well as inhibition, interference control, processing efficiency and anxiety. Recently, methodological concerns pertaining to the reliability of the SNARC effect, its prevalence at the individual level and the use of correlation analysis with robust cognitive phenomena have also been considered in explaining conflicting results regarding relations to math skills. In the future, working around these issues in large-scale studies including different age groups and math tasks should help us make further sense of the puzzling results presented in the literature and deepen our understanding of the role of the SNARC effect in math development as well as the cognitive mechanisms at play.

Presentation 4: The present of the SNARC

Krzysztof Cipora*
Centre for Mathematical Cognition, Loughborough University

The SNARC effect is doing very well at its thirty. It has been well proven robust against replication crisis in psychology: it was observed in several setups and cultures. It also successfully moved online. The overall effect is also fairly robust to variations in data preprocessing. At the same time, across the years it turned out that there is quite some inter-individual variation in the SNARC, and effect is present above chance only in minority of individuals. It also turned out that the internal consistency of the effect may be suboptimal, but there are ways to improve it, for instance by including more trials in the experimental task. We also found that the SNARC can be relatively easy manipulated by situated influences. At the same time, new evidence shows that even if no specific manipulation is implemented, the intra-individual stability of the SNARC effect turns out to be surprisingly low. However, given all these inter- and intra-individual variability SNARC remains robust at the group level. Being named at its birth after Snark, a hard-to-capture creature sneaking out from individuals trying to hunt it, SNARC keeps up to the expectations raised by the heritage of its name. There is still long hunt ahead of us, but it is also about the friends we make along the way.

Symposia 4.45 pm – 6.00 pm

Foundational number skills and early assessment

Chair: Heather Douglas
Department of Cognitive Science, Carleton University

Mathematical learning is cumulative and builds on early foundations in number knowledge, number relations, and number operations. The goal of this symposium is to discuss how these skills are assessed and applied to support student learning. Devlin will discuss a literature review of models of early numeracy. Douglas will describe the development and implementation of a numeracy screener that taps into students' (ages 5-9) developing knowledge of number, number relations, and number operations. Peake will focus on comparison of two measures of number relations that involve number ordering, for students in kindergarten. Finally, McElveen will describe an intervention to help students interpret the relations among numbers and apply their knowledge of number operations to improve their problem solving skills.

Presentation 1: What factors comprise "early numeracy" and why does no one agree?

Declan Devlin*, Francesco Sella, Korbinian Moeller
Centre for Mathematical Cognition, Loughborough University

Early numeracy is a multi-dimensional construct that is frequently associated with both later mathematics performance and life outcomes more generally. However, despite its importance, there remains little consensus on exactly which skills comprise this construct. In this presentation, I review recent studies that investigated the factor structure of early numeracy using either confirmatory or exploratory factor analysis. I highlight both the commonalities and differences across proposed models. Furthermore, I discuss possible explanations for these differences, including variations in research aims, methodology, and assessment tools used. I conclude by highlighting the need for future research to evaluate the structure of early numeracy in a more systematic and coordinated way to increase comparability and coherence across studies.

Presentation 2: The EMA@School Numeracy Screener - Assessment for Learning

Heather Douglas*[1], Jo-Anne LeFevre[2]
[1] Department of Cognitive Science, Carleton University [2] Departments of Cognitive Science and Psychology, Carleton University

A comprehensive numeracy screening program can help educators intervene appropriately so students' early math challenges do not become ongoing difficulties. The early math assessment tool (EMA@School) is a research-based numeracy screener developed at Carleton University. The EMA@School has been used with over 60 000 students aged 5 to 9 (Kindergarten to grade 4). The component measures focus on students' understanding of number, number relations and number operations. The measures are grade-specific and reflect students' developing knowledge of number. In this presentation, I will provide an overview of the structure of the assessment, include data on the reliability, validity, and

norming of the assessment, and discuss how the screener is currently being used. I will conclude the talk with a discussion on next steps for further development and implementation of the EMA@School.

Presentation 3: Underlying mechanisms of ordinality measures: comparing the order verification task and the ordering task

Christian Peake*[1], María Francisca del Río[2], María Inés Susperreguy[1]
[1] Faculty of Education, Universidad Diego Portales [2] Millennium Nucleus for the Study of the Development of Early Math Skills

Ordinality skills are a crucial predictor of early arithmetic skills. It is common to use the order verification task to measure ordinality. This task reveals the reverse distance effect, which is assumed to be based on strategy selection (either by retrieving numerical sequences from memory or by performing cardinal judgments). This finding raises the debate about which cognitive mechanisms underlie the order verification task. Moreover, this task has been questioned as a predictor of arithmetic skills, highlighting the need for alternative tasks. The present study included a small sample of Chilean kindergarteners (n = 34) who completed an ordering task (where they had to set three symbolic numbers in order) and the order verification task. Cardinality, oral counting, and early arithmetic skills were also measured to study their relations with both measures of ordinality. Results showed a significant correlation between accuracy in the ordering task and in the order verification task and a significant correlation between both of them and early arithmetic skills. A reverse distance effect was only found in the accuracy measure of the order verification task. Strategy exploration showed 1-distance items to be easier than 2-distance ones and related to oral counting as well as to cardinality. Accuracy in 2-distance items was correlated only with cardinality. These results show that the ordering task and the order verification task are similarly reasonable measures associated with early arithmetic in kindergarten. They support the proposal of memory retrieval and cardinal judgment as underlying mechanisms when making ordinal decisions.

Presentation 4: Using PULSE to Improve Problem Solving With The Four Operations

Tamika L. McElveen*[1], Sarah Powell[2], Caroline Hornburg[3], Amanda Mayes[1], Jisun Kim[4], Katie Quinn[4], Sara Schmitt[5], Michael Eiland[1], Ma Bernadette Andres-Salgarino[6], David Purpura[1]
[1] Department of Human Development and Family Science, Purdue University [2] Department of Special Education, University of Texas at Austin [3] Learning and Development Lab, Virginia Tech [4] Department of Human Development and Family Science, Virginia Tech [5] Department of Education and Clinical Sciences, University of Oregon [6] Santa Clara County Office of Education

In the elementary grades, students often rely on non-evidenced based strategies to set up and solve addition, subtraction, multiplication, and division word problems. To solve a word problem, students must read the problem, interpret the relations among the numbers, and apply operation(s) to answer the word-problem question. One research-based strategy for helping students understand the relations among the information in word problems and to determine a solution pathway is through an attack strategy (Freeman-Green et al., 2015; Montague et al., 2011). Whereas attack strategies primarily focus on interpreting and problem-solving steps, metacognition is also key. In this study, we extended prior work on addition and subtraction word problems and implemented an attack strategy (PULSE) that accounted for the role of executive functioning in word-problem solving. “With PULSE, students (1) Pause, (2) Understand and remember, (3) Lay out the equation, (4) Solve, and (5) Evaluate the solution."

We introduced PULSE through a 9-week supplemental curriculum. Teachers (grades 3-5) used PULSE as they practiced setting up and solving word-problems with their students. We assessed growth in word-problem solving (N=77, 42%-White, 31%-Latine, 50%-Parental Education beyond HS). We identified significant change in students' overall scores ($t(76) = 3.60$, $p = .001$) including their performance on single-step ($t(76) = 2.55$, $p = .013$) and multi-step ($t(76) = 3.17$, $p = .002$) problems. Our continued evaluation shows promise for PULSE as it supports students in their understanding of the relations in word problems and use of operations to solve word problems.

The multiple aspects of dyscalculia and calculation difficulties

Chair: Dror Dotan
Mathematical Thinking Lab, School of Education and School of Neuroscience, Tel Aviv University, Israel

Calculation is a challenging cognitive activity. In certain cases, estimated to occur in 3%-6% of the population, the difficulty is severe to the extent of a learning disorder – dyscalculia; but even for people without dyscalculia, calculation is often very hard. This symposium aims to examine why is calculation so hard, and whether it is possible to diagnose this difficulty reliably. We will present different origins of difficulty in calculation and examine how they affect individuals with and without dyscalculia. In line with recent studies that highlight the heterogeneity of dyscalculia and of the calculation-related cognitive skills, the talks will cover several cognitive aspects of calculation, focusing on domain-general factors such as long-term memory, short-term memory, and interference, as well as conceptual understanding, ordinal processing, and brain connectivity. We will also examine different techniques to assess calculation skills and the existence of dyscalculia.

Presentation 1: Dyscalculia: perhaps it's not a calculation deficit after all

Dror Dotan*
Mathematical Thinking Lab, School of Education and School of Neuroscience, Tel Aviv University

Memory functions predict arithmetic skills, but the mechanisms underlying this relation are still poorly understood. Here, I will present some of these mechanisms, and show how memory deficits can induce dyscalculia. I will first discuss how working memory (WM) is involved in multi-digit mental calculation, by describing the calculation patterns of individuals with different developmental deficits. Their errors point at several different arithmetic-relevant WM processes. First, a specific process that removes items from WM. A deficit in this process results in a highly specific error pattern: errors occur mainly in number-words that were removed from WM and then reactivated. Second, a WM process that binds each digit with its decimal role (unit, decade, etc.). A deficit in this process results in morphological errors (e.g., three thirty). Third, I show how participants came up with a simple but well-planned combination of visual and phonological memory strategies in order to increase their effective WM capacity.I will also show how memory is involved in learning arithmetic facts. We examined the origin of dyscalculia in 19 adults with poor multiplication-table knowledge. The results were extremely heterogeneous, pointing at deficits in long-term, short-term, and

working-memory; attention disorders; and even at some participants with no cognitive deficits, who apparently just didn't try hard enough at school. Overall, I aim to show how different memory deficits give rise to highly specific subtypes of dyscalculia, identifiable via detailed error analysis; and to exemplify some of the multiple ways in which memory underlies mental calculation.

Presentation 2: Numerical Comparison of Exponential Expressions

Ami Feder*, Michal Pinhas
Department of Psychology, Ariel University

Exponential expressions (EE) symbolically instantiate the mathematical operation of exponentiation. Previously, we discovered that people automatically focus more on the physically larger component of the expression (i.e., base) than on the component which in most cases is more significant mathematically because of its exponent status (i.e., power). The present study examined whether a similar type of processing occurs when people numerically compare EEs. In two experiments, participants were presented with pairs of EEs and were instructed to choose the larger one. Experiment 1 included base-power compatible (i.e., both base and power in one pair were larger than the other) and incompatible (i.e., the base was larger in one pair, while the power was smaller) Pairs. Importantly, in both pair types, the EE with the larger power led to the larger result. In Experiment 2 however, in half of the base-power incompatible pairs, the larger power led to the larger result (i.e., power-result congruent), while in the remaining half, the larger power led to the smaller result (i.e., base-result congruent). Our findings from both experiments revealed faster and more accurate responses for the base-power compatible than incompatible pairs. Namely, a base-power compatibility effect. Moreover, this effect grew with larger distances between the base/power components. Furthermore, in Experiment 2, base-result congruent pairs were responded to faster and more accurately than power-result congruent pairs. Overall, these results show that although participants were able to process both EE components', they relied mostly on the base, demonstrating poor understanding of EE.

Presentation 3: The development of an adult dyscalculia checklist

Kinga Morsanyi*
Centre for Mathematical Cognition, Loughborough University

Dyscalculia (specific learning disorder in mathematics) affects between 3-6% of the population. Although it has a similar prevalence to dyslexia, and can lead to even more detrimental consequences for life prospects, it is a notoriously underdiagnosed condition. Self-report clinical checklists can support the initial screening of participants for developmental disorders, and such checklists already exist for a variety of developmental conditions, including dyslexia, ADHD and autism. Nevertheless, no such instrument exists for dyscalculia, although some unvalidated checklists can be found online. The aim of this project was to develop a short instrument which could be used to screen adults for dyscalculia. Based on the results of pilot studies, a 15-item clinical questionnaire was created (Cronbach's alpha .93), which asked participants to report on some everyday numerical (e.g., "Difficulty with grasping and remembering maths concepts, rules and formulas") and non-numerical difficulties (e.g., "Difficulty with learning movement sequences, for example, when learning to play a musical instrument or practicing dance moves."). The questionnaire was administered to a sample of 241 adult participants. Scores on the clinical questionnaire showed a strong negative correlation

with performance on a numeracy test, self-reported numerical skills, and general wellbeing, and moderate negative correlations with general academic ability (but no correlation with literacy skills). A regression analysis showed that the clinical questionnaire still predicted performance on the numeracy test, even after controlling for the effect of a number of demographic factors and general academic ability, reading ability and self-reported serious difficulties with mathematics.

Presentation 4: Effective brain connectivity in children with and without developmental dyscalculia

Simone Schwizer Ashkenazi*[1], Ursina McCaskey[2], Ruth O'Gorman Tuura[2], Karin Kucian[2]
[1] Department of Psychology, University of Zurich [2] Center for MR-Research, University Children's Hospital Zurich

Numerical ordinality has been identified as a strong predictor for arithmetic abilities in children and for complex mathematical abilities in adults. Furthermore, children with Developmental Dyscalculia (DD) show difficulties in numerical order tasks. On the neuronal level, in particular frontal and parietal regions are involved in number processing. In addition, the insula and the cerebellum have been associated with monitoring, speed and sequential processing during the operation with numbers. Previous studies demonstrated that children with and without DD show different brain responses in those regions. However, knowledge about connectivity between regions involved in number processing is sparse.The aim of the present work was to understand how brain regions that are commonly activated in both, children with and without DD, during a symbolic number order and number identification task, interact. We conducted effective connectivity analyses using dynamic causal modelling (DCM). We defined six regions of interest (ROI) located in the right parietal, frontal and insular cortex and in the cerebellum. Task average connectivity analyses revealed that activation in the insula and precentral gyrus led to increased activation in all other regions, whereas activation in the intraparietal sulcus and posterior medial frontal gyrus (pMFG) led to decreased activation to all regions except of the vermis and the superior frontal gyrus. DD and controls differed in the extrinsic connectivity from the pMFG to all other ROIs. Our results show that connectivity of brain regions involved in symbolic number processing differs between children with and without DD and possible interpretations will be discussed.

Algorithmic foundations of mathematical development

Chair: Joshua Rule
University of California, Berkeley

From counting to computing derivatives, the mathematical skills that students master are often algorithmic: they require learning, following, and conceptualizing well-defined sequences of steps. Previous research characterizes procedural learning in mathematical domains [1-3] and the dynamics of variation, selection, and change in children's algorithms during mathematical development [4]. There has, however, been relatively little integration between that work and modern cognitive models that learn logical structures [5] and mathematical algorithms [6] by discovering computational expressions encoding their behavior [7]. In this symposium, we begin to close this gap by presenting work at the intersection of artificial intelligence,

information theory, and cognitive psychology—particularly the psychology of mathematical development. We discuss empirical evidence for the importance of geometric representations throughout mathematics as well as the key role which global information capacity plays in making mathematics possible. We also present recent computational models of the algorithmic substrates on which early mathematics might be built. Together, these talks demonstrate how better characterizing children's algorithmic abilities is a productive step towards a comprehensive account of mathematical development.
[1]: R. Siegler & E. Jenkins, How children discover new strategies, 1989.[2]: D. W. Braithwaite, A. A. Pyke, and R. Siegler, Psychological Review, 2017.[3]: J. Chu, et al., Cognitive Science, 2020.[4]: R. Siegler, Emerging minds, 1996.[5]: S. T. Piantadosi, N. D. Goodman, and J. B. Tenenbaum, Psychological Review, 2016.[6]: N. D. Goodman, et al., Cognitive Science, 2008.[7]: J. S. Rule, S. T. Piantadosi, and J. B. Tenenbaum, Trends in Cognitive Sciences, 2020.

Presentation 1: Deep learning models of mathematical symbol grounding

Alberto Testolin*
General Psychology, University of Padova

Mathematical reasoning is one of the human intellect's most impressive achievements but remains a formidable challenge for artificial intelligence (AI). In this talk, I argue that deep neural networks could nevertheless provide unique insights toward a computational theory of mathematical symbol grounding. Symbolic reasoning is notoriously difficult for connectionist models, and despite recent progress, deep networks still struggle with tasks requiring procedural and compositional knowledge, such as arithmetic calculation [1]. Taking inspiration from constructivist theories in developmental psychology, I argue that simulating the acquisition of symbolic numerical concepts requires more sophisticated deep learning agents which learn by actively manipulating their environment. Such agents might exploit external tools to create powerful representational systems that can be manipulated in simple ways to answer difficult problems. For example, counting on virtual fingers might allow agents to gradually grasp the meaning of number words, and learning to manipulate a virtual abacus might allow them to ground arithmetic knowledge into concrete visuospatial representations. I present recent modeling work in this direction, exploring how simulated agents learn to solve arithmetic problems by interacting with a virtual abacus [2] or carry out multi-digit addition and generalize to novel (out-of-distribution) problems using an external, grid-like memory [3].[1] A. Testolin, Frontiers in Human Neuroscience, 2020.[2] F. Petruzzellis, L. X. Chen, and A. Testolin, in Proceedings of the Northern Lights Deep Learning Workshop, 2023.[3] S. Cognolato and A. Testolin, in Proceedings of the International Joint Conference on Neural Networks, 2022.

Presentation 2: On the foundational role of geometric representations in mathematics

Marie Amalric*
Psychology, Harvard University

Previous fMRI work has shown that advanced math thinking does not seem to rely on language processes in the human brain. Instead, math knowledge activates a set of regions that overlaps with the neural substrates for number and visuospatial processing. Behavioral studies suggest that the human brain is endowed with basic numeric and geometric representations. Together,

these findings suggest that the edifice of mathematics is constructed on both numeric and geometric foundational concepts. While the study of numeric intuitions is extensive in the literature, still little is known about the role of geometric intuitions in shaping advanced math knowledge. In this talk, I will present two cases (from arithmetic and geometry) in which geometric representations and simulations seem to play a fundamental role in understanding math concepts. A first study suggests that 2-dimensional rectangular representations give precursory understanding of the commutative principle of multiplication to 5-year-old children, long before they formally know what the concepts of multiplication and commutativity are. In contrast, a second study reveals that systematic errors arise in geometric reasoning when adults fail to spontaneously use scaling to reason about spatial relations between geometric objects. Both findings highlight the essential role of geometric intuitions in math activity: spatial transformations generally help math thinking and the lack of certain geometric primitives leads to detrimental counter-intuitions.

Presentation 3: An artificial intelligence model of rapidly learning reusable concepts

Kevin Ellis*
Computer Science, Cornell University

This talk concerns a computational model of how human learners acquire concepts from ordinary amounts of experience, and then deploy those concepts in new situations. I present DreamCoder [1,2], an artificial intelligence system which gradually grows a library of reusable concepts that it uses to solve new problems, and which also uses neural network methods to simultaneously get faster at solving new problems. I present several studies of human behavior which suggest that core DreamCoder mechanisms could have analogues in human cognition, particularly for representing and producing geometric constructions [3,4].
[1] K. Ellis, et al., https://arxiv.org/abs/2006.08381, 2020.[2] C. Wong, et al., https://arxiv.org/abs/2106.11053, 2022.[3] L. Tian, et al., in Proceedings of the Conference on Neural Information Processing Systems, 2020.[4] M. Sable-Meyer, et al., https://psyarxiv.com/28mg4, 2021.

Presentation 4: Mathematical logic: What sets humans apart

Jessica Cantlon*
Carnegie Mellon University

It is no secret that humans have a knack for using mathematical logic—it underlies uniquely human feats like building computers and flying to the moon. Our special abilities, however, do not simply start when we are adults; they begin to emerge as early as three years old, when we can grasp basic math and logic. The question we must then ask is: what early cognitive and neural processes do humans have in common with other primates, and which processes make us unique? In this talk, I look at the logical abilities we have in common with other primates and how global information capacity—the raw amount of information mental algorithms can reason about at any one time—determines whether or not humans and other primates have similar "inner programs" for mathematical logic.

Gesture's role in numerical development

Chair: Madeleine Oswald
University of Chicago

Gestures are a powerful tool for learning and have been implicated in mathematics learning (Goldin-Meadow, Levine & Jacobs, 2014). Using fingers to represent numbers has the potential to support many early number concepts such as cardinality and calculation. But the extent to which children take advantage of such affordances, and whether it is important to view or to produce gestures when acquiring number concepts remains unclear. We present four papers demonstrating the benefit of both viewing and producing number gestures at different stages of number development. Paper 1 shows that viewing cardinal number gestures increases 1-3-year-old children's focus on number. Children were more likely to produce number words after viewing a speaker produce a number word with an iconic-number-gesture than after hearing a number word without a number gesture. Paper 2 shows that encouraging 3-year-old children to produce cardinal-number gestures as compared to pointing gestures leads to increased accuracy when labeling sets. Paper 3 examines individual variation in gesture use by considering gender as a factor alongside inhibitory control and working memory in predicting 4-7-year-old children's gesture use while solving arithmetic problems, finding that gender is a significant predictor. Finally, paper 4 shows that training 7-year-olds to use finger-counting when solving addition operations that sum to numbers greater than 10 (e.g., 9+5) results in increased arithmetic competencies. Taken together, these papers show the utility of finger gestures across a broad range of numerical concepts and competencies.

Presentation 1: Iconic Number Gestures Increase Talk About Number

Madeleine Oswald*, Susan Goldin-Meadow, Susan C. Levine
University of Chicago

Number words are difficult to learn, in part, because they do not describe an attribute of any individual item but rather the property of a set. We hypothesized that iconic number gestures, raising fingers to represent set size, could lead to more child number talk by highlighting the relevant numerical feature of the set. Using two paradigms we show that viewing an iconic number gesture engenders more numerically relevant responses from children than hearing a number word without a gesture. Study 1 used a longitudinal sample of parent-child dyads (N=34, child ages 14-30 months) engaged in naturalistic interactions. When parents used an iconic number gesture compared to a number word alone, proportionally more child responses contained numerical information (β = -1.32, SE = 0.18, $z(34)$ = -7.18, $p < 0.001$).To test causality, children in Study 2 (N=118, Mage=35.7 months) were primed with either an iconic number gesture accompanying a number word or a number word alone. Children were then asked to label a set of objects (e.g., 3 blue fish). Children in the gesture+speech condition produced a number word on more trials than children in the speech-alone condition $t(117) = 2.58$, $p < 0.05$. Moreover, children in the gesture+speech condition labeled the set with the correct number word more than children in the speech-alone condition $t(117) = 2.04$, $p < 0.05$.These studies demonstrate that iconic number gestures promote child number talk likely by making numerical information more salient.

Presentation 2: Grasping Number: Can Number Gestures Facilitate Children's Verbal Number Labels

Jacob R. Butts*[1], Dominic J. Gibson[2], Susan Goldin-Meadow[1], Susan C. Levine[1]
[1] University of Chicago [2] foundry10

Children can accurately label sets of objects using cardinal number gestures (e.g., raising three fingers to reference three objects) and can also accurately label cardinal number gestures with number words (e.g. describing three fingers as "three") before they can accurately label sets of objects with number words (e.g., describing three objects as "three"; Butts et al., forthcoming). This raises the possibility that cardinal number gestures could serve as a helpful bridge between number words and the quantities they represent, but also that children do not automatically connect number words to quantities via number gestures. To examine this possibility, in the current study we prompted children to use cardinal number gestures before verbally labeling the number of items in a set. We found that children who received such prompting were able to more accurately label quantities using number words than children who were prompted to just point at the sets ($t(86)=2.94$, $p<.01$, $d=0.64$). Differences in verbal number accuracy were most pronounced for larger set sizes (e.g. 3-5). These findings provide evidence that children's number gesture knowledge can support their ability to accurately use number words, which in turn, may accelerate their number learning trajectories.

Presentation 3: The impact of inhibitory control and gender on young children's gesture use during arithmetic problem solving

Raychel Barkin*, Geetha B. Ramani
University of Maryland

Gestures are one of several overtly observable strategies in math contexts (e.g., finger counting). Their ability to reduce the user's working memory (WM) load makes them uniquely useful (Goldin-Meadow & Wagner, 2005). Less is known about how differences in children's concurrent domain-general (e.g., inhibitory control; IC) and domain-specific abilities (e.g., math) impact children's use of gestures during problem solving. The current study assessed the interrelations of these factors and investigated whether IC moderates the relation between WM and gesture use. One-hundred-thirty-seven 4- to 7-year-old children and their parents participated in the current study. Children completed two sessions; an autonomous online-game assessment and a video recorded Zoom session. Children's problem-solving gestures were recorded during one arithmetic measure. Parents also completed a standardized assessment of their child's IC and WM abilities, for a total of two measures for each factor (IC, WM, and math). Using the Gestures in Mathematics model (GME; Gordon & Ramani, 2021), relations between children's age and gender on each factor and the outcome (gestures) were tested. Results showed a significant gender difference in gesture, favoring females, $t(115.13) = 2.872$, $p = 0.005$, $d = 0.489$. Accounting for this difference, structural equation modeling was used to investigate the factor structure, interrelations, and their impact on gesture use. While there was not sufficient evidence to support the role of IC as a moderator of WM on gesture use, a modification to the GME model with the addition of gender is discussed.

Presentation 4: Extending the efficiency of finger-counting to addition operations beyond 10 in 7 year-old children

Virginie Crollen*, Dounia Berger
Université Catholique de Louvain

Because fingers are readily available, easy to manipulate and exist in sufficient quantity to sustain the understanding of the base 10 numerical system, they are often used by children while learning the conventional sequence of counting words and basic arithmetic operations. However, although the role of finger-counting in performing operations whose results range from 1 to 10 is largely acknowledged, little is known about the efficiency of this procedure in solving larger addition operations. These operations however present several learning challenges. They indeed require, in opaque languages, the knowledge of several non-transparent number words (e.g., "sixteen" and not "ten six") but also require the mastery of the carry-over procedure. In the present study, we therefore examined whether a specific finger-counting training could improve the resolution of addition operations whose results exceed 10 (e.g., 9 + 5). To do so, we taught 7-year-old children how to decompose, with the hands and the fingers, each addition into an easiest one always involving "10 (or 2 full hands of 5 fingers) + something" (e.g, 9 + 5 = 2 full hands + 4 fingers = 14). Results demonstrated that this arithmetic training increased children's arithmetic competencies much more than a control training involving stories reading. Fingers can therefore support the decomposition of additions by allowing children to immediately perceive the operands and the result of the operation.

Numerical cognition in healthy and pathological aging

Chair: Hannah D. Loenneker
Psychological Department, Tübingen University, Tübingen, Germany

Numerical and arithmetic skills play a crucial role for daily life up to old age. Arithmetic difficulties have serious consequences on the well-being of individuals and their ability to live independently, especially in old age. Therefore, research should adopt a lifespan approach to investigate healthy and pathological aging in numerical cognition and to understand how numerical processing changes during aging. Following this idea, the current symposium brings together four talks differing in study design, samples, and experimental tasks. Study designs range from a meta-analytical approach over a training study, a comparison of paper-pencil and web-based settings, to a clinical study. These studies have been conducted with different samples including younger adults, healthy older adults, and even patients. It contains a broad range of numerical and arithmetic tasks as well as tasks of number line bisection and arithmetic learning. Consequently, we aim to provide insights into how elderly process numbers, which components of numerical cognition are preserved and which difficulties occur during healthy and pathological aging. This symposium contributes to an emerging research field of aging in numerical cognition.

Presentation 1: Changes in numerical cognition across aging – a meta-analysis

Mine Avcil*[1], Christina Artemenko[1], Patrick Lemaire[2], Hannah D. Loenneker[1]
[1] Psychological Department, Tübingen University [2] Department of Psychology, Aix-Marseille Université & CNRS

Numerical cognition involves a variety of tasks and underlying representations. The developmental approach classically focuses on child development and stops at young adulthood. However, numerical cognition is important for everyday life up to old age. In a lifespan approach, aging effects in numerical cognition should be investigated systematically to test the generalizability of models of numerical cognition and extend the perspective of numerical development to the whole lifespan. This meta-analysis compares younger and older adults in a wide range of numerical and arithmetic tasks with the aim to examine age-related changes in numerical cognition. This preregistered project follows the PRISMA-criteria and predefined terms are searched in electronic databases according to the review protocol (https://osf.io/5rmgb). Included studies enabled comparisons of young and older adults in numerical and/or arithmetic task performance or reported performance of older adults in a standardized numerical or arithmetic test with age-specific reference norms. Out of 18184 studies being found during screening, 86 studies were eventually included. Meta-analytic effect size estimates of the different tasks reveal a differential pattern of aging effects: While older adults perform better than younger adults in certain standardized arithmetic tests (e.g., FrenchKit arithmetic fluency test), younger adults are typically better than older adults in numerical tasks when considering speed measures (e.g., reaction times in magnitude comparison). These results hint at a distinct pattern of preserved, impaired, or even improved function of numerical cognition over the lifespan, suggesting specific age-related changes in numerical cognition beyond the general cognitive decline.

Presentation 2: Numbers, lines, and the effect of test mode in the elderly

Elise Klein*[1,2], Roman J. Janssen[2,3], Stefanie Jung[2,4]
[1] Université Paris Cité, CNRS, LaPsyDÉ [2] Leibniz-Institut für Wissensmedien, Tübingen [3] Psychological Institute, University of Innsbruck [4] Department of Computer Science/Therapy Science, Trier University of Applied Science

Digital diagnostic approaches such as web-based testing are becoming increasingly important in clinical and neuropsychological assessments. However, older people have been shown to often not reach full adoption of technology. This raises the question whether age-related influences and less familiar handling of digital technology result in a lack of equivalence between web- and paper-based test scores due to the testing environment (i.e., the mode effect).This study evaluated whether the bias in visuospatial (number) line bisection tasks (e.g., the size of the pseudoneglect) is equivalent between a supervised paper-pencil assessment and a web-based at-home assessment in the elderly. 77 participants above 60 years performed the following tasks either as paper-pencil or web-based assessment: A typical line bisection task, a line proportion task, in which the line had to be subdivided into identical large segments, a number bisection task and number line estimation tasks for integers and fractions. While we found the pseudoneglect in all psychophysical tasks, neither the systematic perceptual bias nor its variance was affected by test mode. Only when examining whether responses for fractions were systematically skewed, we found an s-curved skew which differed by mode: across all three number-line-related tasks, participants in the online group revealed a slightly greater bias, i.e. the curvature in their responses was greater (more s-curved). Our study suggests that elderly participants had slightly more trouble using the computer for estimating fractions on the

number line. However, when examining only line bisection tasks, the test mode did not seem to make a difference.

Presentation 3: Aging effects on the acquisition of new arithmetic competence

Valentina Mayr[1], Elisabeth Göttfried[1], Manuela Piazza[2], Demis Basso[3], Laura Zamarian*[1]
[1] Medical University Innsbruck, Neurological Clinic [2] Center for Mind/Brain Sciences, University of Trento [3] Cognitive and Educational Sciences (CES) Lab, Faculty of Education, Free University of Bolzano-Bozen

Being competent with numbers and calculation is essential at any age to comply successfully with the demands of our modern society. Individuals with difficulties in number processing and calculation face indeed limitations in their autonomy in everyday situations (e.g., difficulty to interpret medical information). In a first study (Zamarian et al., 2018), we required young and older adults to intensely train on complex multiplication problems (e.g., 28x3=?; training by using routine procedures). Results showed for both groups significant improvements in accuracy and response times following training. However, transfer effects to untrained related division problems (e.g., 84:3=?) as well as training effects were lower for older adults than for young adults. In a second study (ongoing), we investigate whether training-related performance improvements depend on the learning method and are associated with specific cognitive factors. Young and older adults train at the same time on two sets of new, invented problems. One set has to be learned by memorising the associations between problem and solution (memory condition; e.g., 3#11=20), the other set by applying a new invented procedure (strategy condition; e.g., 3§13="[(2ndop+1stop)-10]+2ndop"=19). Both groups show performance improvements with both learning methods. Furthermore, training effects are modulated by age, prior arithmetic competence, and domain-general cognitive factors (memory and executive functions). In general, our results contribute to a better understanding of the acquisition of new number proficiency in advanced age. Acknowledgements: The second work is supported by FWF IPN 135-B.

Presentation 4: Basic numerical cognition, arithmetic, and numerical activities of daily living in Parkinson's Disease

Hannah D. Loenneker*[1], Christina Artemenko[1], Inga Liepelt-Scarfone[2,3], Klaus Willmes[4], Hans-Christoph Nuerk[1]
[1] Psychological Department, Tübingen University [2] Hertie Institute for Clinical Brain Research and German Center for Neurodegenerative Diseases (DZNE), Department of Neurodegenerative Diseases, Tübingen University [3] IB-Hochschule [4] Department of Neurology, RWTH Aachen University, University Hospital

In the elderly, neurodegenerative diseases like Alzheimer's Disease (AD) or Parkinson's Disease (PD) are increasingly prevalent. Patients with AD show specific deficits in numerical cognition, affecting activities of daily living such as financial matters even in early disease stages. General cognitive impairment is frequent in PD ranging from mild cognitive impairment (PD-MCI) to dementia, reflected by difficulties in everyday function. Despite its importance, there is a lack of systematic research on basic numerical cognition, arithmetic, and numerical activities of daily living in PD. Therefore, the current project compares performance in numerical cognition and numerical activities of daily living between PD patients (n = 80) with mild cognitive impairment (PD-MCI), with normal cognition (PD-NC), and healthy elderly (HC, n = 40).In two sessions, participants went through a comprehensive numerical (transcoding, number line estimation, non-symbolic magnitude comparison, symbolic

magnitude comparison, addition, subtraction, multiplication, division, numerical activities of daily living) and neuropsychological test battery, as well as sociodemographic and clinical questionnaires. While controlling for confounders, we find evidence for group differences in some tasks (e.g., transcoding, symbolic magnitude comparison), but not in others (e.g., number line estimation, non-symbolic magnitude comparison). This differential picture suggests that PD leads to specific impairments in numerical cognition, going beyond domain-general cognitive deficits. For instance, non-symbolic magnitude representation seems to be preserved while symbolic and verbal number processing seems to be impaired. This pattern of results is explained within the framework of current neurocognitive models of numerical cognition.

THURSDAY 8 JUNE

Symposia 9.00 am – 10.15 am

The role of perception in arithmetic cognition

Chair: Josh Medrano
University of Maryland, College Park

In this symposium, speakers will speak on how perceptual features in the spatial and numerical environment (spacing between numbers and symbols, problem format, notations, and spatial representations) facilitate or hinder mathematical outcomes and representations. The first two speakers investigated the role of perception in multi-operand problem solving. In the first talk, Josh Medrano (University of Maryland) will speak on how physical spacing between operands and operators may interact with working memory. While recent research has shown that spacing can affect accuracy and response times in problem solving (Landy & Goldstone, 2008), it is not known whether this effect interacts with working memory, a cognitive process key in arithmetic (DeStefano & LeFevre, 2004; Peng et al., 2016). In the second talk, Jeffrey Bye (University of Minnesota) and Jenny Yun-Chen Chan (The Education University of Hong Kong) will speak on how the position of operators elicit a type of error that is then predicted by their ability to perceive equivalent expressions. In the third talk, Qiushan Liu (Florida State University) will speak on how children may use strategies for certain notations (multiplication with decimals and addition with fractions). In the final talk, Alison Tellos (Concordia University) will speak on how perceptual features of LEGO® bricks may provide a qualitative description of children's mental representations of multiplicative structures.

Presentation 1: Integrating Physical and Cognitive Processes in Mental Arithmetic

Josh Medrano*, Richard Prather
University of Maryland

Decades of research have established the importance of working memory in arithmetic computation (DeStefano & LeFevre, 2004). More recently, research has also shown that a formally-irrelevant perceptual cue—spacing—can influence problem-solving (Landy & Goldstone, 2007). In a multi-operand problem, individuals solve less accurately and more slowly when the spacing between operands and operators is inconsistent with the order of operations (e.g., 2 x 3+4) compared to when spacing is consistent (e.g., 2x3 + 4). While this effect of physical spacing is widely demonstrated, it is not known whether this perceptual cue also influences working memory. To examine this, we will use a dual-task paradigm, wherein participants (N=114 adults) evaluate an expression while completing either a visuospatial (dot pattern) or phonological (letter span) memory task. There will be three conditions. In each condition, the working memory stimuli will vary by load (low and high) and type (visuospatial and phonological). Between conditions, the arithmetic stimuli will vary. In the first condition, spacing will be neutral for all arithmetic expressions; in the second condition, spacing will be neutral, consistent, or inconsistent; in the third condition, spacing will also vary, but there will be parenthesis around multiplied operands (e.g., (2 x 3)+4). We predict that the arithmetic performance (through response times and accuracy) will vary by spacing and by working

memory load, replicating previous studies. We also predict that spacing and working memory will also interact, confirming the hypothesis that perceptual cues have an effect on working memory.

Presentation 2: Perceiving Precedence: Adherence to Order of Operations is Predicted by Students' Perception of Equivalent Expressions

Jeffrey K. Bye*[1], Jenny Yun-Chen Chan[2], Avery H. Closser[3], Ji-Eun Lee[4], Stacy T. Shaw[4], Erin Ottmar[4]
[1] University of Minnesota [2] The Education University of Hong Kong [3] Purdue University
[4] Worcester Polytechnic Institute

Given mathematical ambiguity in problems containing multiplicative and additive operations (e.g., 5+2*3), students must learn an (arbitrary) order of operations (i.e., rules of precedence): namely, that higher-order arithmetic operations are performed first by convention (e.g., multiplication before addition). Fluency with precedence is essential for students' transition from arithmetic to algebra. However, when faced with expressions like 5+2*3, precedence conflicts with many students' learned tendencies to solve problems from left to right. We examined log data from an initial sample of 1139 U.S. middle schoolers' (ages 12 to 13) performance in a mathematics game. We found that, consistent with prior work, a higher percentage of students made a precedence error when the higher-order operator was on the right (5+2*3) vs. left (5*2+3), suggesting the influence of operator position on students' problem solving performance. Further, students who made more precedence errors over a series of six problems were also less likely to correctly perceive equivalent expressions in a separate speeded assessment. Students' scores on this and other assessments (e.g., algebra knowledge, math anxiety) provide novel insights into predictors of their moment-to-moment behavior in the interactive game. These results are important for understanding what factors may be involved in understanding precedence, and how to support students' learning as they transition from arithmetic to algebra.

Presentation 3: Impact of Notation on Arithmetic Accuracy

Qiushan Liu*, David Braithwaite
Florida State University

Unlike whole numbers, rational numbers are commonly represented by three symbolic notations—fractions, decimals, and percentages. An adaptive strategy choice perspective (Siegler, 1996) suggested that fractions should be preferred to decimals for multiplication, but decimals should be preferred to fractions for addition. This hypothesis was supported in two previous studies with adults using a revealed preference paradigm. The present study will employ a choice-no choice paradigm to test whether 6th and 8th graders display the same preferences as adults and whether their accuracies align with their preferences. Children will be presented 12 pairs of equivalent fraction and decimal problems involving either addition (e.g., 2/5+4/5, 0.4+0.8) or multiplication (e.g, 3/4×1/2, 0.75×0.5). In the choice task, the pair of equivalent problems will be presented together for each trial, participants will be asked to indicate which of the two problems they would prefer to solve. We predict that participants will prefer fraction problem on trials involving multiplication and will prefer decimal problem on trials involving addition. In the no-choice task, the problems will be presented one by one in random order, participants will be asked to solve all the problems using the notation presented in the problem. We predict that accuracy on multiplication problems will be higher

with fractions and accuracy on addition problems will be higher with decimals. If our prediction was confirmed, it will provide further support to the adaptive strategy choice model (Siegler, 1996).

Presentation 4: What Makes an Array? How Perceptual Features of LEGO® Bricks Influence Children's Interpretations of Multiplicative Structures

Alison Tellos*, Helena P. Osana
Concordia University

The perceptual features of concrete objects (i.e., manipulatives) have affordances that constrain and guide children's performance on mathematical tasks. Identifying such affordances can inform the design of instructional materials for use in the mathematics classroom. The overarching aim of our research program is to examine the impact of perceptual features of LEGO® bricks on children's interpretations of visual representations of multiplicative structures. To this end, we will present children with multiplication expressions (e.g., 2 x 3 = 6), each of which will be paired with a visual display of LEGO® bricks. Each display will represent one of several models of multiplication, including array (e.g., 2 rows and 3 columns), equal groups (e.g., 2 groups of 3 bricks), and product (e.g., one set of 6 randomly-arranged bricks), and the children will rate the extent to which the display is representative of the target expression. Our symposium presentation will be based on preliminary data that will inform the design of the array stimuli used in the study. Thirty (N = 30) fourth-grade students will rate visual representations of arrays created with LEGO® bricks on a scale from 1 (very "array like") to 7 (not at all "array like"). The arrays will vary by the number of columns, the space between the columns, and the size of the bricks. The data will serve to identify the perceptual features of LEGO® configurations that children rate as most array-like and will be used in a descriptive analysis of children's mental representations of multiplicative structures.

Mathematics attitudes and performance: importance of self-concept and self-efficacy

Chair: Ann Dowker
Department of Experimental Psychology, Oxford University

Mathematics anxiety is common, and often found to correlate negatively with mathematics performance. Most studies suggest a bidirectional relationship between anxiety and performance. Much of the research in the area has focused on mathematics anxiety, but other attitudes such as those involving mathematics self-concept are increasingly seen as important to study. Self-concept can include self-rating; perception of one's own level of involvement in mathematics; and mathematics self-efficacy. Self-efficacy involves regarding oneself as able both to perform mathematical tasks and to play an active role in improving one's performance. The main objective of the symposium is to explore the effects of mathematical self-concept, including self-efficacy, on mathematical performance and STEM career choice, in the context of other mathematics-related attitudes and emotions. The first talk, by Mariuche Gomides and colleagues, investigates factors influencing undergraduate students' choice whether to pursue STEM careers. After controlling for math fluency, math self-efficacy, trait anxiety, and gender, mathematics anxiety was not a significant predictor of career choice. However, mathematics self-efficacy was a significant independent predictor. The second talk, by Ann Dowker and

Poppy Holmes, investigates relationships between mathematics performance and attitude measures in a group of university students. Mathematics anxiety did not correlate significantly with performance, but self-efficacy did, as did mathematics enjoyment. Th third talk, by Sara Caviola and colleagues, investigate primary school children's emotions toward mathematics. Only negative ones contributed to their mathematical performance. Expectancies for success and task values moderated participants' feelings towards mathematics and their perceived abilities. Colleen Ganley will discuss implications.

Presentation 1: Barriers to a career choice in STEM: untangling maths anxiety and maths' self-efficacy

Mariuche Gomides*[1], Claire Elliott[1], Sara Caviola[2,3], Krzysztof Cipora[4], Flavia Santos[1]
[1] School of Psychology, University College Dublin [2] Department of Developmental Psychology and Socialisation, University of Padova [3] School of Psychology, University of Leeds [4] Centre for mathematical Cognition, Loughborough University

Math anxiety might steer way students from pursuing careers in STEM. Previous research showed that highly math-anxious students are more likely to avoid math-related courses and activities. When investigating the association between math anxiety and career choice, very few studies have controlled for other possible confounding factors (e.g., math ability and math self-efficacy). The current study examined how math anxiety affected undergraduates' likelihood of pursuing a career in STEM, their attitudes towards mathematics, and their perceived mathematics abilities. Data from 180 Irish and English undergraduate students were analyzed. Math anxiety was not a significant predictor of undergraduates' likelihood of pursuing a career in STEM after accounting for the effects of math fluency, math self-efficacy, trait anxiety, and gender. However, further regression models indicated that math anxiety significantly predicted participants' attitudes towards mathematics and their perceived mathematics abilities. At odds with previous research, math-anxious individuals were not less likely to avoid a career in STEM. Interestingly, math self-efficacy, which was highly correlated with math anxiety, was a significant predictor of career choice. Nonetheless, math anxiety explained participants' attitudes towards math and their perceived math abilities. The present findings might suggest that math anxiety might play an indirect role in the association between beliefs and attitudes towards math and career choice.

Presentation 2: University students' attitudes and performance in mathematics: the importance of self-efficacy

Ann Dowker*, Poppy Holmes
Department of Experimental Psychology, Oxford University

32 undergraduate students (13 male, 19 female) were given an extended form of Hitch's (1978) Numerical Abilities Test 2 to assess mathematics performance, and four measures of attitudes and emotions relating to mathematics and tests. These included Aiken's (1974) Mathematics Enjoyment Scale; Hopko et al.'s (2003)'s Abbreviated Mathematics Anxiety Scale; Sarason's (1978) Test Anxiety Scale; and Betz & Hackett's (1983) Mathematics Self-Efficacy Scale. Spearman rank correlations were highly significant between mathematics performance and enjoyment of mathematics, and between mathematics performance and mathematics self-efficacy, but did not approach significance between mathematics performance and mathematics anxiety A regression model using mathematics anxiety, test anxiety, and

mathematics self-efficacy to predict mathematics test score was significant. Self-efficacy turned out to be the only significant predictor, contradicting hypotheses about the key importance of mathematics anxiety and test anxiety. Males showed significantly higher mathematics self-efficacy than females but there were no gender differences approaching significance on any other measure. Further research should include larger numbers of students and compare results from students in different disciplines.

Presentation 3: Children's emotions in mathematic domains: the moderating role of expectancy-value profiles

Sara Caviola*[1,2], Enrica Donolato[3], Irene Mammarella[1]
[1] Department of Developmental Psychology and Socialisation, University of Padova [2] School of Psychology, University of Leeds [3] Department of Education, University of Oslo

Recently, Eccles and Wigfield (2020) provided a detailed discussion of what are – according to them – the main issues of the expectancy-value theory, a framework frequently used to understand the motivational processes involved in achievement-related outcomes. The authors re-discussed definitions of the major psychological constructs in the model, focusing on the task value component, and tackled the individuals' interpretations of their own performance. Following this critical review of the literature, in the current study, we tested children's expectancies for success in different mathematical outcomes. We also assessed children's self-concept, task value and emotions related to mathematics. About 560 primary school students, attending third-to-fifth grades, were tested. Results showed that, after controlling for age and gender, self-concept and task values resulted as significant predictors of different mathematical outcomes. Nonetheless, among the tested emotions, only the negative ones (i.e., anxiety and boredom) contribute to explained mathematical performance in children. Interestingly, expectancies for success and task values moderate participants' feelings towards mathematics and their perceived abilities, indicating that children seem to engage in the weighting of task value components along with their ability-expectancy beliefs and emotions

Discussant

Colleen Ganley
School of Psychology, Florida State University

Symbolic and non-symbolic number processing in dyscalculia

Chair: Michael Andres
Numerical Cognition Lab, Psychological Sciences Research Institute, UC Louvain

Developmental dyscalculia is characterized by difficulties in the ability to process numerical symbols and to solve arithmetic problems fluently. The three studies in this symposium aim to evaluate a series of non-mutually exclusive hypotheses about the deficits that may underlie the difficulties of children and adults with dyscalculia. A first hypothesis is that dyscalculia stems from a core number-sense deficit affecting both symbolic and non-symbolic skills. A second hypothesis is that dyscalculia involves lexico-semantic deficits affecting the recognition of symbols, specifically the integration of magnitude information from decades and units. A third

hypothesis is that dyscalculia is associated with a lack of automaticity in number magnitude processing and arithmetic fact retrieval. In examining these hypotheses, particular attention will be paid to the influence of severity, comorbidity, and age. The discussant will synthesize the three presentations and assess the plausibility of the various hypotheses in relation to what is known about typical numerical development.

Presentation 1: Domain-specific deficits in developmental dyscalculia

Marco Zorzi*[1,2], Gisella Decarli[3], Maristella Lunardon[4], Serena Dolfi[1], Michele De Filippo De Grazia[1], Silvia Gerola[5], Giuseppe Cossu[5], Silvia Lanfranchi[1], Alberto Testolin[1], Francesco Sella[6]
[1] University of Padova [2] IRCCS San Camillo Hospital [3] University of Trento [4] International School for Advanced Studies [5] Centro Medico di Foniatria [6] Loughborough University

A long-standing debate on developmental dyscalculia (DD) is whether it originates from a deficit in perceiving the numerosity of object sets (i.e., non-symbolic number system deficit), or a difficulty in processing the meaning of number symbols (i.e., symbolic number system deficit), or even from domain-general cognitive weaknesses (e.g., working memory deficit). Heterogeneity in recruitment and diagnostic criteria make it difficult to disentangle this issue. We will discuss our recent studies in which DD children were identified within a clinical sample referred for assessment of learning disability using a stringent 2-SD cutoff in a standardized numeracy battery and then compared to control children without DD from the same sample. Our findings can be summarized as follows: i) a multivariate pattern of domain-general measures (WISC subscales, visuospatial working memory) does not reliably discriminate DD from non-DD children, thereby showing that DD is a domain-specific deficit; ii) DD children show deficits in both non-symbolic and symbolic number sense tasks, which reliably discriminate them from non-DD in cross-validated logistic regression; iii) lower non-symbolic number acuity in DD is a domain-specific deficit that cannot be explained by increased interference from (or reliance on) non-numerical visual cues. We also show how the non-symbolic deficit can be explained within a leading computational model of numerosity perception. Overall, we conclude that DD is a domain-specific deficit affecting both non-symbolic and symbolic number sense. These results may inform early screening for the identification of at-risk children.

Presentation 2: Difficulties in the ability to process symbolic numbers: where do they come from?

Michael Andres*, Nicolas Masson, Samuel Lepoittevin
Numerical Cognition Lab, Psychological Sciences Research Institute, UCLouvain

Children with developmental dyscalculia (DD) seem to experience difficulties whenever they have to process numerical symbols. It has been hypothesized that these difficulties might result from impairments in accessing numerical magnitude from symbols. However, the nature of these impairments remain a matter of conjecture. In principle, the deficit could affect any process between the recognition of the symbol and the representation of its magnitude. Moreover, it is unclear whether such a deficit effectively persists after schooling. In the present research, we recruited adults with long-lasting mathematical difficulties and a performance below the normative mean in standardized arithmetic tests (-1.5 SD). We found they also experience difficulties in basic numerical tasks, such as the comparison of Arabic digits or

auditory number words. Their slower performance could not be explained by a failure to recognize numerical symbols efficiently, as they showed normal performance in a lexical decision task, nor by a failure to access magnitude automatically, as they showed typical stroop-like interference from irrelevant numerical cues in a physical size judgement. As an alternative, we will consider the hypothesis of a higher-level deficit affecting the learning of ordinal relations between symbols or the integration of magnitude information from decades and units. In light of these new data, we will try to specify the cognitive processes behind the observed difficulties of adults with DD and discuss how these difficulties might differ from those observed in children with DD.

Presentation 3: Arithmetic and sustained attention in populations with typical development and subgroups of developmental dyscalculia

Liat Goldfarb*, Ram Naaman
University of Haifa

The present talk examines the interrelations between sustained attention and arithmetic performance while differentiating, between automatic and procedural arithmetic problem solving, and between various groups diagnosed with difficulties in the numerical domain. The data of 506 students from the national diagnostic system for learning disabilities were used in order to examine this relationship in typically developed population and different groups with developmental dyscalculia (DD): pure DD and DD with attention deficiency. The results demonstrate a differential relationship between arithmetic and sustained attention depending on the automaticity of the arithmetic task, as strong links were found under automatic arithmetic tasks when compared to under procedural ones. Furthermore, although the DD groups with attention difficulties presented similar patterns of correlations to those seen among the typically developed group, the pure DD showed no correlation between sustained attention and automatic arithmetic. The talk will discuss the different role sustained attention plays in automatic and procedural arithmetic. In addition, it will discuss the notion that pure DD might not achieve automaticity in arithmetic and therefore do not rely on the sustained attention system even under simple automatic situations in arithmetic.

Discussant

Bert De Smedt
Faculty of Psychology and Educational Sciences, KULeuven

Data based individualization in mathematics for struggling learners

Chair: Stephanie Hopkins
University of Missouri, Columbia

According to the latest Nation's Report Card, 9% of Grade 8 students with disabilities and 37% of Grade 8 students without disabilities are at or above a proficient level in mathematics (National Center for Education Statistics, 2019), suggesting the need for intervention within mathematics. Data Based Individualization (DBI) is a hypothesis-driven, empirical approach

in which the teacher utilizes a framework for intensifying intervention in which systematic student-level formative assessment data are used to determine when and how a student's intervention should be modified (NCII, 2013). Research demonstrates that students who have intensive needs benefit from more practice and different instructional approaches to learn new information. As part of the DBI process, teachers collect and analyze progress monitoring data to determine student response to instruction. If progress is insufficient, the teacher uses diagnostic data and their knowledge of the student to modify the intervention while continuing to assess. The teacher continues to adjust the intervention to meet the student's individual needs and facilitate progress. In most cases, DBI is not a quick fix, but an ongoing process requires multiple iterative adaptations over a sustained period (Powell et al., 2020). Objectives: (1) Participants will learn about three different research projects in which DBI was integrated as a component to impact student mathematics outcomes. (2) Participants will understand the variety of implementation methods and data collection that can be used within DBI. (3) Participants will engage in discussion around DBI in mathematics specifically, middle school math teacher support, coaching, and classroom observations.

Presentation 1: The Beginning of Supporting Teaching of Algebra: Individual Readiness 2.0

Erica Lembke*, Stephanie Hopkins
University of Missouri

The COVID-19 pandemic disrupted learning across the US and created new challenges for educators and students. For example, state-wide data from Texas indicated that 34% of Grade 6 students Did Not Meet Grade Level standards on the state test in 2021 compared to 21% in 2019 (Educational Testing Service, 2021). Supporting Teaching of Algebra: Individual Readiness 2.0 is an Institute of Education Sciences IES funded grant funded to accelerate pandemic recovery in special education. This 3-year SMART (sequential multiple assignment randomized trial) research design allows researchers to examine the effects of two different types of coaching for middle school mathematics teachers. SMART is an experimental design to evaluate timing, sequencing, and adaptive selection of STAIR 2.0 treatments and involves cluster randomization at two stages. Stage 1 includes Intense coaching, which includes teachers meeting one-on-one with a coach on a weekly basis and using a clear coaching routine. Light coaching teachers receive core professional development and meet with coaches every other week and do more learning independently. Stage 2, non-responder teachers will be identified and re randomly assigned to receive one of two enhanced treatments—peer mentoring or booster sessions. In this presentation, the scope of project will be presented along with stage 1 findings (teacher n= 37, students n=79), lessons learned, and plans for stage 2 implementation which will begin in Fall 2023.

Presentation 2: From Research to Practice: Implementation of Data-Based Individualization

Sarah King*, Sarah Powell
University of Texas at Austin

Despite ongoing efforts to improve mathematics outcomes for students with mathematics difficulties (MD), practitioners across the U.S struggle to provide adequate intervention support. Addressing this issue has been challenging due to the level of individualized

instruction necessary to improve outcomes for students with persistent academic difficulties as well as limited access to evidence-based resources (Fuchs & Fuchs, 2015; Lemons et al., 2019; Powell et al., 2022). One potential solution is Data-Based Individualization (DBI), an iterative process of collecting and examining student data to inform instructional decision-making (National Center for Intensive Intervention, 2013). Through Project STAIR (Supporting Teaching of Algebra: Individual Readiness), we implemented DBI with special educators to increase the algebra readiness of middle school students with MD. By providing on-going, tailored professional development and instructional coaching, participating teachers learned to effectively deliver targeted just-in-time intervention support utilizing evidence-based mathematics practices. In this presentation, we connect research to practice and aim to demystify implementation of DBI in the classroom. We present five evidence-based instructional practices that can be integrated into the DBI framework and implemented with students with MD: (a) systematic and explicit instruction, (b) multiple representations, (c) precise mathematics language, (d) mnemonics, and (e) fluency-building. We describe our focus on each practice through professional development and coaching. We share how these efforts in STAIR led to improved teacher outcomes on a measure of teacher instructional practices in terms of understanding (ES = 0.63), confidence (ES = 0.41), and frequency of strategy use (ES = 0.45; Powell et al., 2021).

Presentation 3: Diagnostic Data to Inform Intervention Design

Leanne Ketterlin-Geller*, Elizabeth Thomas, Joanne Joo
Southern Methodist University

The process of using data to individualize instruction for students experiencing difficulty requires access to instructionally relevant and sensitive information from various sources. Progress monitoring data are used to evaluate students' responsiveness to instruction, and support teachers' decisions about changes to the level of intensity of instruction students need to reach their learning goals. Diagnostic data are used to understand students' current level of knowledge and prior conceptualizations of the content. These data can provide rich insights into areas of strength that can serve as the foundation for future learning, and provide teachers with a roadmap of the content students have yet to master. Although data from diagnostic assessments can provide useful information to guide the design of interventions, limited research and practice focuses on how to gain meaning from these data sources. In this presentation, we examine data from a larger project in which students completed a fraction magnitude comparison measure prior to receiving intervention. The measure was designed to support diagnostic inferences about students' understanding of fraction magnitude and the presence of possible misconceptions, including a natural number bias. The instrument included 4 sets of 10 items each in which students identified the magnitude relationship between two fractions (<,>,=). Each set targeted a different fraction magnitude misconception. We present data from a sample of over 300 students in grade 4, including subscores based on misconceptions. We discuss how these data can inform inferences about students' prior conceptualizations of fractions to guide intervention design.

Discussant

Glenn Fahey
Education Policy Centre for Independent Studies Sydney Australia

The role of inhibitory control in mathematics: Beyond correlations

Chair: Lucy Cragg
School of Psychology, University of Nottingham

There is a growing body of evidence from cross-sectional and longitudinal correlational studies indicating that individuals with better inhibitory control, the ability to ignore distractions and suppress incorrect responses, perform better on mathematics assessments. However, the mechanisms by which inhibitory control might support mathematics learning, and whether these inhibitory control mechanisms are domain-general or domain-specific, remain unclear. In this symposium we present findings from four different labs aiming to address these issues. The first two talks showcase the use of negative priming and conflict adaptation paradigms to investigate the transfer of inhibitory control across trials and task domains in the context of comparing numerosities (Talk 1) and retrieving multiplication facts (Talk 2). In contrast, the second two projects employ an intervention design to provide specific evidence of a role of inhibitory control, and the mechanisms that might be at play, in suppressing incorrect but intuitive mathematical concepts (Talk 3) and real-life mathematical word problems (Talk 4). Together these projects highlight the myriad of ways in which inhibitory control supports the learning and performance of mathematics and begin to uncover the specific mechanisms through which this is achieved.

Presentation 1: Better characterizing inhibitory control processes in numerical cognition using priming paradigms

Arnaud Viarouge*
Université de Paris

Inhibitory control plays an important role in multiple aspects of math, from basic numerical abilities to more complex procedural and conceptual knowledge. At the perceptual level, several studies have suggested that representing and comparing the numerosities of sets of objects require an ability to selectively attend to numerical information, in part by inhibiting conflicting non-numerical dimensions of magnitude. However, experimental studies aimed at better characterizing the inhibitory control processes at play in this context are scarce. Priming paradigms can shed light on these inhibitory control processes. Negative priming can provide evidence for the causal role of inhibitory control in a task by investigating the cognitive cost of inhibiting conflicting information on a subsequent congruent trial. When adapted to a non-symbolic comparison task, we observed significant negative priming effects in a group of 7-8-year-olds and a group of adults. In the context of inter-task paradigms, negative priming can also be used to better identify the nature of the inhibited information. For instance, in a group of 7th Graders, performance in a length comparison task was lower when preceded by an incongruent decimal number comparison (e.g. 0.563 vs. 0.64), providing evidence for the inhibition of the physical length of numbers in this task. Finally, conflict adaptation paradigms allow investigating the question of the generality or specificity of inhibitory control processes. Using this method in adults, we were able to show that the inhibitory control processes at play when comparing numerosities were specific to the conflicting dimension of magnitude.

Presentation 2: Evidence that retrieval of multiplication facts requires inhibitory control

Joanne Eaves*[1], Camilla Gilmore[2], Lucy Cragg[1]
[1] School of Psychology, University of Nottingham [2] Loughborough University

The mechanism(s) underlying the relationship between inhibition and mathematics is currently unclear. We used an experimental approach to test the proposal that inhibitory control is required when retrieving multiplication facts to resolve interference between related facts. For example, for the problem '6 × 7', some people might incorrectly answer '48' because it is the correct answer to the neighbouring problem '6 × 8'. In a pre-registered, online experiment with 450 adult participants, we interleaved trials of animal-Stroop and number-Stroop tasks (well established inhibitory control tasks) with trials where participants were presented with a multiplication fact ('6 × 7') and two possible answers, one that was correct and one that was incorrect (a foil). Foils were either drawn from the times table of one of the operands (generating interference) or was unrelated to the operands (generating less interference). We found that the interference generated on the multiplication trials was influenced by the interference generated on the previous Stroop trials (a congruency effect) indicating that inhibitory control transferred between trials, and between tasks. This reveals that inhibitory control is involved when resolving interference between related multiplication facts. The nature of the Stroop task (animal or number) did not affect the transfer of inhibitory control, demonstrating that the inhibitory control operated in a domain-general way. Our findings suggest that retrieving knowledge of multiplication facts might be difficult for some individuals not because they lack mathematical knowledge of those facts, but because they have insufficient inhibitory control, or a difficulty deploying it.

Presentation 3: Stop & Think – development and evaluation of a primary school-based mathematics and science intervention

Iroise Dumontheil*
Centre for Brain and Cognitive Development, Department of Psychological Sciences, Birkbeck, University of London

Science and mathematics learning requires the integration of new evidence about the world into one's existing theories. In science education, it can be a real challenge for children to acquire knowledge that goes beyond popular beliefs or perception. In mathematics children need to go beyond the perceptually obvious solutions, or previously learned simplified concepts, to uncover formal logical solutions to a problem. Behavioural and neuroimaging research suggests that old theories remain even when new ones are learnt. Correctly solving counterintuitive science and mathematics problems is associated with slower reaction times and increased activation in fronto-parietal cortex regions. These findings are thought to reflect the recruitment of inhibitory control to suppress incorrect intuitive concepts. Building on this research, the "Stop & Think" intervention was designed to encourage children to use their inhibitory control skills when solving potentially counterintuitive science and mathematics problems. The computerised whole-class 10-week-long intervention was delivered by teachers and evaluated in a large-scale randomised controlled trial in Year 3 (7–8-year-olds) and Year 5 (9–10-year-olds) children. The trial showed improvements in performance of standardised mathematics and science tests in Year 5 children when Stop and Think was compared to an active training intervention focusing on socio-emotional skills. While these results are promising and are consistent with the proposed role of inhibitory control in science and

mathematics reasoning, further analyses in subsamples with cognitive and neuroimaging data were not able to provide clear evidence of the mechanism of impact of the intervention.

Presentation 4: Teacher-student web-based platform for real-life math problems – focusing on cognitive control and inhibition

Michal Gilstron Wolk*, Orly Rubinsten
Edmond J. Safra Brain Research Center for the Study of Learning Disabilities, University of Haifa

Mathematical literacy allows people to put math principles into practice in real-life scenarios. However, real-life math problems are often complex and accompanied by a lot of verbal information and a large amount of data displayed in various ways. For children to convert verbal instructions into the mathematical calculations they need to perform to solve a problem, high level cognitive abilities are required, such as being able to arrange the data, compare it, plan, and implement math concepts. Therefore, high level cognitive control abilities are necessary in order to monitor, inhibit irrelevant information and pay attention to details. We conducted an intervention program with about 80 8th graders and about 80 other 8th graders in a control group. For the intervention group, we developed a web-based learning platform for real-life math problems that focuses on specific cognitive control and inhibition. For that we manipulated cognitive control abilities specific to math such as identifying math mistakes, suppressing irrelevant numerical information, considering background stories, and paying attention to details. The children were motivated by being given 'brain points' for every cognitive control behavior that they expressed. Initial pilot results are showing a near transfer of cognitive control abilities in real-life math problems in the intervention group and as a result their performance is improving. However, a far transfer of cognitive control to other general tasks was not seen. To conclude, we suggest that intervention programs focusing on cognitive control abilities are essential for improving math performance, especially in complex, real-life math problems.

Symposia 10.45 am – 12.00 pm

Automatic number processing: Features, measurement, and links to individual characteristics

Chair: Lilly Roth
Department of Psychology, University of Tübingen

Numbers are often processed automatically. Some of their most crucial features such as ordinality, cardinality, or parity can influence the behavior of participants, even if processing of these features is not required by task demands. Much research is being dedicated to investigating effects that reflect automatic number processing, such as the SNARC (Spatial-Numerical Associations of Response Codes) effect, the numerical distance effect, the reverse distance effect, the ordinal position effect, and the MARC (Linguistic Markedness of Response Codes) effect. In this symposium, we wish to present recent evidence on automatic number processing: features, measurement, boundary conditions, and links to individual characteristics.

Presentation 1: Playing cards: A novel kind of stimuli to investigate the SNARC effect

Serena Mingolo*[1], Valter Prpic[2], Krzysztof Cipora[3], Alberto Mariconda[1], Eleonora Bilotta[4], Tiziano Agostini[1], Mauro Murgia[1]
[1] Department of Life Sciences, University of Trieste [2] Department of Philosophy and Communication Studies, University of Bologna [3] Centre for Mathematical Cognition, Loughborough University [4] Department of Physics, University of Calabria

The Spatial-Numerical Association of Response Codes (SNARC) effect (Dehaene et al., 1993) indicates a left-to-right mapping of numbers, as in a mental number line. Accumulating evidence suggests that this effect could be attributed both to the cardinality (magnitude) or to the ordinality (order) of numbers; their roles are still not clear, however. This study investigated the SNARC effect using playing cards as stimuli. During card games, some people dispose cards in ascending order (AO), as in the mental number line, but other people dispose them in descending order (DO). Thus, according to the way in which they order cards, DO people should spontaneously associate low magnitude cards (e.g., 2) to the right and high magnitude cards (e.g., 6) to the left. Therefore, in DO individuals, cards' order and magnitude would elicit opposite spatial mappings. Participants belonging to the DO group performed magnitude classification on simple numerals and on playing cards as stimuli. This group showed a regular SNARC effect only when classifying numbers while showing no SNARC effect when classifying cards. Conversely, participants belonging to the AO group showed a regular SNARC effect when classifying cards. Results thus suggest that the different cards' arrangements determined different results in the two groups, and this probably indicates that ordinality plays a bigger role than cardinality in determining SNARC-like effects. Yet, when DO individuals classified cards, the SNARC effect disappeared but was not reversed, indicating that an interference of cardinality might still have occurred.

Presentation 2: True colors SNARCing: Automaticity of the SNARC effect observed in color judgment tasks

Lilly Roth*[1], John Caffier[2], Ulf-Dietrich Reips[2], Krzysztof Cipora[3], Hans-Christoph Nuerk[1]
[1] Department of Psychology, University of Tübingen [2] Department of Psychology, University of Konstanz [3] Centre for Mathematical Cognition, Loughborough University

Numbers are associated with space, but it remains unclear how automatic these associations are. One highly automatic effect indicating semantic processing of number properties is the SNARC (Spatial-Numerical Association of Response Codes; Dehaene et al., 1993) effect, which describes faster responses to smaller/larger magnitude numbers with the left/right hand, respectively. It occurs both when number magnitude is relevant (e.g., magnitude classification) and irrelevant (e.g., parity judgment) to the task. Regarding judgments of non-semantic properties, the SNARC effect has been found in orientation judgment, but evidence from color judgment is mixed. A less automatic effect is the MARC (Linguistic Markedness of Response Codes; Nuerk et al., 2004) effect, which describes faster responses to odd/even numbers with the left/right hand, respectively. It typically arises in parity judgment but not magnitude classification and has so far not been tested in judgments of non-semantic properties. In two highly powered online experiments, we investigated the degree of automaticity of the SNARC and MARC effects in nominal color judgment (blue vs. yellow) and color intensity judgment (light cyan vs. dark cyan) of Arabic digits. We found a small but significant SNARC effect in both experiments, suggesting high automaticity of spatial mapping of number magnitude, and a small but significant MARC effect in nominal color judgment. Ultimately, number magnitude is processed automatically and mapped onto space even if participants are tasked to attend to perceptual non-semantic features of presented numbers. The processing of number parity is less automatic and depends on the task.

Presentation 3: Examining the Roles of Sequence Familiarity and Inter-Element Distances in Order Judgment Task Performance

James Vellan*[1], Jo-Anne LeFevre[2]
[1] Department of Psychology, Carleton University [2] Department of Cognitive Science, Carleton University

When people are asked to decide if sequences of numbers are in order, they usually respond faster to ordered counting sequences with differences of 1 (e.g., 1 2 3) than to sequences with larger inter-element distances, regardless of whether these other sequences are ordered or unordered (e.g., 2 4 6 or 3 1 2). This effect has been labeled the 'reverse' distance effect (RDE). However, in two studies reported by Vos et al. (2021), there was no RDE and minimal evidence for canonical distance effects. Vos et al. argued that the RDE depends on the stimulus set, but never found an RDE in any conditions, and little evidence for canonical distance effects. We hypothesized that the RDE was absent because they omitted the two most familiar counting sequences (i.e., 1 2 3 and 2 3 4), potentially shifting the strategies used by participants. In the present research, we used a more typical stimulus set and defined 'ordered' as ascending sequences only, with the primary goal of first replicating the RDE. We manipulated only whether the two most familiar counting sequences were included in the stimulus set. In Experiment 1 (N = 48), where these familiar sequences were included, we replicated the typical RDE for ordered sequences and the canonical distance effect for all other sequences. In Experiment 2 (N = 63), where these familiar sequences were excluded, there was no RDE.

Order judgment task performance was negatively related to arithmetic performance only when highly familiar counting sequences were excluded.

Presentation 4: The mental number line and the mental memory line in primary school children: Developmental trajectories and relationship with math achievement

Jolien Moorkens*, Jean-Philippe van Dijck, Wim Fias
Department of Experimental Psychology, Ghent University

The spatial-numerical association of response codes (SNARC) effect characterizes numerical magnitude as being represented as a position on the mental number line. Similarily, serial order in working memory is also associated with space: The ordinal position effect (OPE) describes ordinality to be represented as a position on the mental memory line. It remains unknown how the SNARC effect and the OPE relate to each other, whether they follow the same developmental trajectory, and how they relate to the acquisition of mathematical skills. In a cross-sectional study of third (n = 292) and fifth (n = 254) graders, we tested the degree of spatialization of numbers with the parity judgement task and of serial order working memory with the Ordinal Position Task (van Dijck et al., 2011). We correlated these measures with scores on a standardized math test. The results show that a substantial number of third and fifth graders use space to mentally represent numbers and working memory position. However, the SNARC effect and the OPE are independent of each other: Only few children consistently showed both effects. Furthermore, the relationship of SNARC and OPE to academic skills is completely different; the OPE does not correlate with math skill. In third grade, there is no relationship between SNARC and math ability. In fifth grade, the SNARC effect is associated with better mathematical skills. Further analyses by mathematical subdomains show that these correlations are driven by the domain of numerical knowledge, but are absent for geometry, measurement, and mental arithmetic.

Developmental pathways of mathematical abilities: Evidence from typical and atypically developing populations

Chair: Jo Van Herwegen
Psychology and Human Development, University College London, IOE's Faculty of Education and Society

The development of good mathematical abilities rely on a number of domain general and domain specific skills that come together over developmental time. However, the developmental pathways of mathematical abilities are not well understood. Atypical populations have uneven cognitive profiles, with cognitive strengths and difficulties, and thus can provide further insight into the developmental impact of one ability onto another one. This symposium examines the developmental pathways of a range of domain specific abilities using evidence from a meta-synthesis of intervention studies in typically developing children as well as systematic reviews of research in atypical populations such as Down syndrome, Williams syndrome and autism, in order to obtain a fuller understanding of how domain specific abilities impact overall mathematical abilities over time as well as evaluate the current state of the evidence.

Presentation 1: Creating early mathematical developmental pathways (EMDP): Evidence from meta-review methodologies

Zahra Siddiqui*[1], Laura Outhwaite[2], Jo Van Herwegen[1]
[1] Psychology and Human Development, University College London, IOE's Faculty of Education and Society [2] Centre for Education Policy and Equalising Opportunities, University College London, IOE's Faculty of Education and Society

Good mathematical abilities in the early years are vital for future educational success (Davis-Kean et al., 2021). However, mathematical development includes many different skills, concepts and knowledge. It is thus important to understand developmental pathways of all of these mathematical abilities in the early years (i.e., 3-7 years) and how these influence each other. The present study collated, via a meta-review, relevant domain-specific intervention studies to plot a mechanistic visual representation of the developmental pathways of different mathematical abilities. The protocol was preregistered on the Open Science Framework (https://osf.io/n4dys/). The meta-review identified 190 relevant systematic reviews, meta-analyses, and narrative reviews. All references from these reviews were collated, and 38 interventions studies were identified. These 38 studies contained 2,033 individual participants and 30 different domain-specific abilities were targeted in the interventions. Cumulatively, this resulted in 86 individual strands that were used to construct multiple pathways of mathematical abilities that were plotted. The most common domain-specific strand was symbolic number line training, which showed links to abilities such as cardinality (45 months), symbolic magnitude comparison (59 months), and arithmetic (56 months). Our evidence-based model (EMDP – Early Mathematical Developmental Pathways) demonstrates how training of certain domain-specific abilities at particular ages is effective to raise outcomes and informs theoretical models of mathematical development. It also highlights areas where further intervention data is needed to further confirm these proposed developmental pathways.

Presentation 2: Systematic review of mathematical abilities in Down syndrome

Unta Taiwo*[1], Vic Simms[2], Michael S. C. Thomas[3], Jo Van Herwegen[1]
[1] Psychology and Human Development, University College London, IOE's Faculty of Education and Society [2] School of Psychology, Ulster University [3] Centre for Educational Neuroscience, Birkbeck, University of London

Understanding the mathematical abilities of individuals with Down syndrome (DS) and what abilities relate to good mathematical abilities has been of increasing interest since the 1980s (Casey et al., 1988; Caycho et al., 1991; Gelman, 1988; Lister et al., 1989). Recently, several review papers have attempted to systematically synthesize this topic to examine the ability of individuals with DS to discriminate magnitudes (Porter, 2019), how mathematical abilities in DS compare to other populations (King et al., 2017) and what mathematical interventions might be successful (Lemons et al., 2015). However, reviews thus far have not considered how abilities change over age and time. Furthermore, there is a need for studies to focus on the underlying mechanisms associated with mathematical abilities in DS across the developmental trajectory. This systematic review addresses these gaps and reviews what types of mathematical skills in DS have been examined, the nature of mathematical development in DS, the quality of research, and identified further gaps. Our pre-registered (https://osf.io/gcqxv/?view_only=693c2bd13ea541fba3f13a7c39ef25f5) systematic review has identified 45 articles that will be summarised. Of the fifty studies 3149 individuals with DS participated across the studies, ages ranged from 2 to 53 years (mean age = 11,7 years).

Counting was the most common outcome measured used in 80% of the studies, followed by magnitude comparison (47%) and then arithmetic (27%). Five studies examine the relationship between different domain-specific abilities, whereas 9 studies (20%) investigate associations between domain-general and -specific abilities. We will present the theoretical and practical implications from these findings.

Presentation 3: Mathematical abilities in autism: A systematic review

Erica Ranzato*, Andy Tolmie, Jo Van Herwegen
Psychology and Human Development, University College London, IOE's Faculty of Education and Society

Autism is a common neurodevelopmental condition that results in a number of strengths and difficulties (American Psychiatric Association, 2022). The public notion of mathematical ability in autism is of relative strength. However, there is a growing body of research suggesting that mathematics is an area of difficulty for autistic students. Moreover, autism can be associated with intellectual disability, that is characterised by a delayed and slower development of mathematical abilities (Bashash et al., 2003; Brankaer et al., 2011). Our understanding about different areas of mathematical abilities in autism is limited. Therefore, the aim of this systematic review was to synthesise the research that investigated different mathematical abilities in autism with emphasis on the assessments used, the samples included and the overall quality of these studies.Ninety-three studies were included in the review. Implications for research and practice will be discussed, with focus on the gaps of the current research to develop tailored interventions and to target specific abilities to build mathematical competence on the strengths of autistic students. The systematic review protocol was pre-registered on OSF (10.17605/OSF.IO/Q3D7C).

Discussant

Jo Van Herwegen
Psychology and Human Development, University College London, IOE's Faculty of Education and Society

Perspectives and influences on math engagement in early childhood: The role of family math

Chair: Mary DePascale
Boston College

Family math engagement includes math activities and interactions, attitudes and beliefs, and characteristics of the home learning environment that can support children's math development. Evidence from prior theoretical and empirical work indicates that family math engagement in early childhood is important for young children's mathematical learning and knowledge. This symposium considers family math engagement in early childhood (preschool to first grade) from multiple perspectives, including qualitative, quantitative, and theoretical approaches, and using data from multiple regions of the United States and Brazil. The first two papers consider opportunities for early math learning and engagement, including dimensions

of and approaches to studying math engagement from a family strengths perspective (paper 1) and caregiver perspectives on math learning opportunities that support early math development (paper 2). The second two papers consider parent engagement and child outcomes, including parent math language styles and relations to children's math talk (paper 3) and the impact of home learning experiences, including resources and parent education, on children's math outcomes (paper 4). Together, these four studies provide qualitative and quantitative evidence and descriptive information about math engagement of families with young children. Findings highlight opportunities for math learning in everyday life and the importance of the home learning environment, including parents' math language and resources for children's math outcomes, with implications for children's math learning and development.

Presentation 1: Strengths-based approaches to investigating early math development and family math engagement

Mary DePascale*, Eric Dearing
Boston College

The importance of family engagement in early math development is supported by classic theoretical perspectives (Bronfenbrenner, 1979; Vygotsky, 1978). Empirical evidence also demonstrates links between math learning chances at home and math achievement, contemporaneously and longer-term (Daucourt et al., 2021; Eason et al., 2022). However, there is wide variability in the extent to which families engage in math at home (Levine et al., 2010). Increasingly, researchers and practitioners have begun to consider how interventions that capitalize on families' strengths (e.g., family cultural assets, knowledge, talents, experiences) may be uniquely positioned to improve children's math learning chances at home. Yet, there is little specificity in the field as to what it means to take a strengths-based approach or what the primary dimensions of family strengths in early math are. Building from the funds of knowledge framework (Moll et al., 1992), empirical work in early math, and strengths-based approaches in early learning, we developed a conceptual framework for studying early math from a family strengths perspective. We identified four dimensions of strengths centered around math in everyday life (family knowledge/skills, community knowledge, family routines, family interests) and two dimensions of strengths-based approaches to studying early math (co-design and adaptability/malleability of resources). We then classified studies (n=12) along these dimensions by coding their use of strengths in each. Coding ranged from 0 (no/low use) to 3 (thorough/direct use). Findings demonstrate qualitative and quantitative variability in the use of strengths in early math research, with implications for researchers and strengths-based work in early math.

Presentation 2: Caregivers' recognition of math learning opportunities for preschoolers

Sarah Eason*[1], Siqi Zhang[1], Kathryn Leech[2]
[1] Purdue University [2] University of North Carolina

Caregivers' attitudes about mathematics and early learning appear to account for variation in preschoolers' mathematical experiences in the home, which promote foundational mathematical skills. Understanding this variation is critical for explaining differences in mathematical skills and developing supports aligning with families' perspectives. We examined caregivers' views of opportunities for early mathematics, mathematical content they

most frequently consider, and how mathematics attitudes may relate to ideas about mathematics in the home. We surveyed 180 caregivers of 3- to 5-year-olds in the Midwest and Southern United States an open-ended question about how they can support preschoolers' mathematics learning. We coded responses for settings (context) and type of mathematics (content) they described. We also asked questions regarding caregivers' attitudes about mathematics learning. Most parents mentioned math opportunities within everyday activities (e.g., mealtimes, 37.8%) or using household objects (37.2%) and placed less emphasis on playful contexts (15.0%). For math content, counting was identified as the most popular math opportunity (63.3%). Caregivers who highly rated the importance of their own involvement in preschoolers' mathematics learning were more likely to report everyday opportunities, B=0.31, SE=0.12, p=.007. These findings highlight how caregivers' perspectives may inform how young children experience mathematics in the home. We will further discuss findings regarding caregivers' recognition of mathematics learning opportunities and how these relate to dimensions of caregiver mathematics beliefs. We will then discuss implications for understanding variation in early mathematics experiences and building on caregivers' current mathematical engagement with preschoolers.

Presentation 3: Is parental math language context- and domain-specific?

Rebecca McGregor*, Diana Leyva, Melissa Libertus
University of Pittsburgh

Prior work suggests that parents adopt certain language styles when talking about math with their preschool children during a picture-sharing task and these styles relate to children's math talk. However, it is unclear whether these same styles are present when parents and children engage in other tasks (context-specificity question) and talk about non-math topics (domain-specificity question). The current study addresses this gap by exploring the specificity or generality of parental language styles across two contexts and two domains. Participants were 76 mostly middle-income, White parents and their four-year-old children (M age = 53.32 months; 45% girls) in the U.S. Dyads were videotaped in picture-sharing and free-play tasks and their utterances were transcribed and coded for math and non-math (general language) content. Across the two contexts (picture-sharing and free-play) and two domains (math and general language), the same three parental language styles emerged using cluster analyses: Discussers, who used a combination of language types, Commentators, who used mostly statements, and Elicitors, who used mostly questions. Parents did not always use the same style across contexts and domains. While parental math language styles in both the picture-sharing and free-play tasks were associated with child math talk (but not general language talk) during the task, parental general language styles did not relate to children's math or general language talk in either task. Findings suggest that the relations between parental math language styles and children's math talk are context- and domain-specific.

Presentation 4: Home learning experiences and math abilities relationship in Brazilian students: Mediation of parents' education and income

Angélica Trassi[1], Flávia Santos*[2]
[1] São Paulo State University [2] University College Dublin

Home Learning Experiences (HLE) are defined as parents' behaviour and home resources available to boost children's learning. Studies focused on the relationship between HLE and maths abilities show controversial results due to confounding variables, such as demographic,

cultural, and individual differences (Soto-Clavo et al., 2019; Hornburg et al., 2021). The present study investigated the interaction between HLE and maths abilities in children from a disadvantaged educational context. Participants were 97 Brazilian first graders (Mage=6.12 years; SD=0.52) and their parents. Children completed tests that assessed numerical cognition, arithmetic, and math achievement. Parents answered scales about HLE, math anxiety, generalized anxiety, beliefs, and parental attitudes toward math. Most parents had a primary or secondary school, and the monthly family income is 1 to 3 wages. Linear regression indicated that HLE, parents' math anxiety, beliefs, and attitudes were not related to the three maths measures. However, mediation parents' education level was positively related to numerical cognition (p=0.016), math performance (p=0.001) and arithmetic (p=0.022). Income 1-3 wages (p= 0.002) was negatively related only to numerical cognition. In conclusion, parents' income and education level was associated with higher maths abilities. These results could indicate that parents' resources play a crucial role in children's math learning in the Brazilian educational context. Support: CAPES

Number games in the real world: Factors influencing play-based interventions at home and school

Francesco Sella
Centre for Mathematical Cognition and Centre for Early Mathematics Learning,
Loughborough University

Games can stimulate children's learning by prompting active engagement, enjoyment, and social interaction with peers and adults. In this light, playing number games has the potential to improve early numeracy in a diverse sample of young children to better pave the way for their future mathematical learning. Games are particularly promising interventions as they are low-cost and can be widely used in homes and schools. Nevertheless, multiple factors may influence the efficacy of number game interventions. In the first talk, Ramani and colleagues explore the role of math talk and gestures when parents play number games or read a math-related book with preschool children. In the second talk, Shusterman and colleagues present a 5-month study on the implementation of numeracy games in the classroom, considering the fidelity of the intervention, teachers' perspectives on the games and gender-based enjoyment. In the last talk, James-Brabham and colleagues present the co-development of a number line board game in collaboration with expert practitioners and the evaluation of its effectiveness in a randomised controlled trial in primary school children. They show a lack of game efficacy beyond what children are already learning in school. The symposium provides an overview of the factors that can lead to a successful translation of educational games into different learning contexts. Parents' actions, teachers' beliefs, and children's learning-as-usual will be particularly considered with the aim of raising awareness of these real-life influencing factors and other moderators of the effectiveness of game-based interventions on early numeracy.

Presentation 1: Parents' and Children's Math Talk and Gesture Use During Board Game Play and Book Reading Activities

Geetha Ramani*, Raychel Barkin, Gillian Grose, Neela Krishnasamy
University of Maryland

Math communication in the home environment benefits children's early math skills (Levine et al., 2010). Informal activities can be used to engage children in math-related talk and math-related gestures, although less is known about how nonverbal communication is used during such activities. We examined parents' and children's math talk and gestures during board game play and book reading. We also examined the effects of a short intervention on the benefits of gesture use. Three- to five-year-old children and their parents (n=52) were randomly assigned to watch one of two videos: 1) a video on the benefits of using gestures during math activities (e.g., counting on fingers); 2) a video about how to promote learning during play. Dyads then recorded themselves playing a number-based board game and reading a math-related book. Videos were transcribed for the math talk and gesture use. Across both conditions, parents used more math talk during the board game play than during the book reading ($t(51)=11.94$, $p<.001$, $d=2.21$), and used more math-related gestures during board game play than during book reading ($t(51)=3.74$, $p<.001$, $d=0.55$). Between conditions, parents who watched the gesture-focused video used a higher proportion of gestures highlighting higher-level math content (e.g., cardinality) during board game play ($t(31.938)=1.81$, $p=0.04$, $d=0.53$), and during book reading ($t(35.46)=2.85$, $p=.047$, $d=0.82$) compared to those in the play-focused condition. This suggests a number-based board game can elicit math talk and math-related gestures during parent-child interactions. Further, information about the benefits of gestures can help promote parents' gesture use during informal activities.

Presentation 2: Implementation of a Play-Based Early Numeracy Intervention: Pitfalls of the Real World

Anna Shusterman*, Sophie Williamson, Talia Berkowitz, Pritha Sengupta, Andi Wiley, Remi Feuerman, Madeline Pelz
Wesleyan University

Children receive limited support for math in preschool (Hindman, 2013), and guided play might be optimal for increasing mathematical content in early childhood classrooms (Skene et al., 2022). To address this, we designed and piloted flexible, engaging numeracy games. 30 preschool teachers were then trained to incorporate the games into classrooms using a framework informed by cognitive science and guided play (23 teachers were assigned to a control group.) The 5-month intervention was assessed by pre- and post-test measures of teachers and children, 11 structured observations (using a new instrument that yielded high inter-rater reliability and convergent validity with teacher self-report), and focus group data. Here we address lessons learned from the field trial. Across observed classrooms, game materials were seen in classrooms but missing the critical mathematical component: for instance, a classroom might display a pizza and toppings, but not the dice that tell how many toppings to add. The focus group yielded a shared perspective that the games were 'too easy'; however, the baseline assessments indicated that most children did not understand cardinality and needed practice opportunities. Teachers also reported that boys enjoyed the games more than girls, which conflicted with pilot observations and the games' gender-neutral themes. Thus, although the training addressed the importance of early numeracy, the distinction between rote counting and cardinality, and the need to remove gender bias, there were

misalignments between teachers' experiences and the intervention framework. These misalignments are likely to diminish intervention benefits. Considerations for improving research-implementer alignment will be discussed.

Presentation 3: No evidence that playing a number line game improves numerical skills: a randomised controlled trial

Ella James-Brabham*, Tim Jay, Francesco Sella
Centre for Mathematical Cognition and Centre for Early Mathematics Learning, Loughborough University

Numeracy skills in the first year of formal schooling predict mathematical outcomes at the end of school, as well as numerous life outcomes, including health, income, and quality of life. Therefore, it is important to support the development of numerical skills at the start of school, especially in children from a low socioeconomic background who are most at risk of falling behind. Some studies have highlighted the efficacy of linear number board games in improving early numerical skills, as well as the beneficial effect of counting forward and backwards. We designed a number board game which entailed placing number cards in order on a line either forward or backwards while allowing children to play in small groups with minimal adult supervision. We evaluated the effectiveness of the game in a randomised control trial with four- to five-year-old children from schools located in low socioeconomic areas. Children were randomly allocated to one of three conditions: playing the number game only forward (n = 82), playing the number game forward and backwards (i.e., bidirectional condition; n = 82), or playing an alphabet game (n = 85). Children attended eight gameplay sessions across five weeks. Children's numerical skills and letter-sound knowledge were measured at baseline and post-test. Children improved between pre-test and post-test, but there was no significant effect of intervention conditions. This indicates that neither the forward nor bidirectional version of the number game improved numeracy beyond regular teaching.

Discussant

Francesco Sella*
Centre for Mathematical Cognition & Centre for Early Mathematics Learning, Loughborough University

Early math and motor skills: Evidence from around the world

Chair: Carolina Jiménez-Lira
Autonomous University of Chihuahua

The development of early math skills involves a multiplicity of factors, specifically, motor skills, the use of fingers when counting and manual dexterity are aspects that have recently received much attention in relation to children's mathematical performance. This symposium integrates four studies conducted by recognized researchers, early career academics and doctoral students that analyze this association through correlational, longitudinal and experimental research methods. The studies, conducted in Mexico, South Africa, Switzerland and France bring together a wealth of evidence on the association between early maths, fine-

and perceptual-motor skills and of how finger use evolves and enhances children's ability to solve arithmetic problems. The first presentation examines the relationship between early math skills and gross, fine, and perceptual motor skills in Mexican three-to-five-year-old children. The second presentation analyzes three-to-five-year-old South African children's motor skills, information about caregivers' education, household socio-economic status and whether the child had started early childhood education and care as predictors of numeracy skills. The third presentation focuses on how finger counting influences arithmetic problem solving in five-to-eight-year-old children. The study compared performance in children's ability to solve mental addition problems across three conditions: spontaneous finger use, no finger use and finger use. Finally, the fourth presentation shows the results of a longitudinal study that followed children across one year beginning at age 4.5. Researchers observed children's use of fingers while performing calculation across three measurement points.

Presentation 1: Symbolic numeracy in relation to Mexican preschoolers' gross, fine, and perceptual-motor skills.

Carolina Jiménez-Lira*[1], Elia Verónica Benavides-Pando[1], María Inés Susperreguy[2], Daniela Susana Paz[1], Lucía Consepción Palma-Gardea[1], Fernando Mondaca-Fernández[1]
[1] Autonomous University of Chihuahua [2] Pontificia Universidad Católica de Chile

Researchers have analyzed gross (Lopes et al., 2013), fine, and perceptual-motor skills (Escolano-Pérez et al., 2022), as predictors of children's early math skills with mixed findings. The goal of the present research was to analyze the relationship between early math and gross, fine, and perceptual-motor skills in a sample of Mexican preschoolers. A total of 123 three-to-five-year-old children completed assessments of symbolic number comparison and applied problem solving (Muñoz-Sandoval et al., 2005), the gross, fine, and perceptual-motor subtests of the Battelle Developmental Inventory (Newborg, 2005), four measures of precursor symbolic numeracy skills (i.e., verbal counting, digit recognition, verbal and written cardinality) and two measures of executive function (inhibitory control and visual-spatial working memory). Results from hierarchical linear regressions show that symbolic number comparison was predicted by both perceptual-motor and precursor numeracy skills while applied problem solving was predicted only by precursor skills. Thus, distinct components of motor skills may be relevant for specific math skills.

Escolano-Pérez, E., Herrero-Nivela, M. L., & Losada, J. L. (2020). Association between preschoolers' specific fine (but not gross) motor skills and later academic competencies: Educational implications. Frontiers in Psychology, 11, 1044.
Lopes, L., Santos, R., Pereira, B., & Lopes, V. P. (2013). Associations between gross motor coordination and academic achievement in elementary school children. Human movement science, 32(1), 9-20.
Muñoz-Sandoval, A. F., Woodcock, R. W., McGrew, K. S.,& Mather, N. (2005).Woodcock-Muñoz achievement battery III: Tests of achievement. Itasca, IL: Riverside.Newborg, J. (2005). Battelle Developmental Inventory. Riverside Publishing.

Presentation 2: Motor skills and emergent numeracy in South African preschool-age children from low-income settings

Caylee J. Cook*[1], Steven J. Howard[2], Hleliwe Makaulaa[1], Rebecca Merkley[3], Mbulelo Mshudulu[1], Nosibusiso Tshetu[1], Gaia Scerifd[4], Catherine E. Drapera[1]
[1]SAMRC/Wits Developmental Pathways for Health Research Unit, School of Clinical Medicine, Faculty of Health Sciences, University of the Witwatersrand [2] Early Start and School of Education, University of Wollongong [3] Department of Cognitive Science, Carleton University [4] Department of Experimental Psychology, University of Oxford

Evidence has shown a beneficial association between motor skills and numeracy in the preschool years. However, much of this evidence is based on research from Minority World countries, or as high-income (often Western) countries. Therefore, more research is needed on these topics before applying these findings and interventions in Majority World settings. This study aimed to address this lack of research by exploring the concurrent associations between motor skills and numeracy in a sample of 189 3–5-year-old children from low-income communities in Cape Town, South Africa. Motor skills and numeracy were measured using the International Development Education and Learning Assessment (IDELA). Information about the caregiver education, household socio-economic status and whether the child had started early childhood education and care (ECCE: Grade R, preschool, etc.) were collected using a questionnaire. Linear regressions revealed that child age ($\beta = 0.56$, $p = 0.01$), being enrolled in ECCE ($\beta = 8.45$, $p = 0.01$), and having higher scores for copying a shape ($\beta = 0.12$, $p = 0.001$), and folding paper ($\beta = 0.13$, $p = 0.002$) was associated with better numeracy. However, hopping and drawing a person was not significantly associated. These results not only suggest a positive relationship between fine motor skills and numeracy skills, but also highlight the vulnerability of children who do not have access to ECCE. Further research is needed to determine whether interventions involving motor skills have the potential to improve foundational numeracy skills, particularly in vulnerable children without access to ECCE.

Presentation 3: When and how does finger use enhance arithmetic performance in 5 to 8-year-old children?

Fanny Ollivier*[1], Patrick Patrick Lemaire[2]
[1] Université Angers, Nantes Université
[2] Aix-Marseille Université & CNRS

Arithmetic performance and finger counting are positively correlated in the early stages of math learning (e.g., Jordan et al., 2008). Moreover, finger counting is related to dexterity, working memory, and verbal counting (e.g., Poletti et al., 2022; Suggate et al., 2017). However, unknown are the mechanisms responsible for these relations. To further our understanding of how finger counting influences addition problem solving, we adopted the "choice-no choice" method (Siegler & Lemaire, 1997). Specifically, we compared 5 to 8-year-old children's performance while solving mental addition problems in three conditions: (a) spontaneous finger use (i.e., "choice" condition), (b) no-choice/finger use (i.e., children were required to use fingers on each trial), and (c) no-choice/no-finger use. (i.e., children were not allowed to use fingers). Also, measures of individuals' working memory, dexterity, and verbal counting were collected. The data speak to (a) how performance differ whether finger use is allowed or not, (b) how often children use fingers, (c) relations between performance benefits of using fingers and how often fingers are used. The data also speak to age-related differences in these issues. All in all, our findings further our understanding of how finger use enhances children's

arithmetic fluency, and the role of moderating factors in this enhancement at different points in children's cognitive development.
Jordan, N. C., Kaplan, D., Ramineni, C., & Locuniak, M. N. (2008). https://doi.org/10.1111/j.1467-7687.2008.00715.xPoletti, C., Krenger, M., Dupont-Boime, J., & Thevenot, C. (2022). https://doi.org/10.3390/children9020132Siegler, R. S., & Lemaire, P. (1997). https://doi.org/10.1037/0096-3445.126.1.71Suggate, S., Stoeger, H., & Fischer, U. (2017). https://doi.org/10.1177/0031512517727405

Presentation 4: The use of finger in addition: a study in children from the age of 4.5 to the age of 5.5

Marie Krenger*, Catherine Thevenot
University of Lausanne

It is already established that the frequency of finger use to calculate in 5- to 6-year-olds correlates positively with accuracy in arithmetic. Whether or not this relation is also observed in younger children was still unknown until the present study, in which we observed the behavior of 173 children aged 4.5 years in an addition task. These children were followed longitudinally over one year across three testing points. At the first testing point, 31 children calculated on their fingers, they were 50 at the second testing point (i.e., 5 years) and 66 at the third (i.e., 5.5 years). At each testing point, children who used their fingers to calculate were more accurate than children who did not, which replicates the results obtained with older children. Addition performance was also dependent on whether children had used their fingers or not in a previous testing point. More precisely, children performed better in the addition task when they had used their fingers at a previous point than if they had never used them before. Moreover, children improved their addition performance between two testing points almost only when they continued or started to use their fingers. In fact, when fingers were not used at a specific point, the difference in addition performance with the previous testing point was at best very small, if not null. Overall, those results suggest that use of fingers in addition solving is a tool that allows children to maximize their chances of developing good arithmetic skills.

Poster session 4 (1.00 pm – 2.00 pm)

1. Development and validity of the QIF-M, a scale assessing children's self-perceptions of their daily numeracy activities

Anne Lafay*[1], Emeline Gentelet[2]
[1] Université Savoie Mont Blanc, LPNC-UMR CNRS 5105 [2] Université de Neuchâtel

According to the DSM-5, a child with mathematics learning disabilities presents with number sense, calculation, and reasoning difficulties that persist for at least six months, despite the provision of interventions that target those difficulties. The difficulties cause significant interference with academic performance and with activities of daily living. To date, no tool assesses the consequences of mathematics difficulties on the daily numeracy activities. The current study had two goals: (1) developing a questionnaire on daily numeracy activities related to mathematics skills and (2) assessing the validity of this tool. French-speaking Swiss children (N = 127) from grade 1 to grade 7 were administered the QIF-M (Questionnaire des Impacts Fonctionnels en Mathématiques, that is Questionnaire of Functional Impacts in Mathematics) and the Numerical Operations subtest of the Wechsler Individual Achievement Test (Wechsler, 2005). The results showed acceptable reliability (alpha de Cronbach = .70), excellent social validity (children found the questionnaire easy to fill out, mean = 4/5 on a 5-point Likert scale), excellent validity of construct (the QIF-M score significantly increased with grade), and excellent predictive validity (the QIF-M score is significantly, positively, and strongly correlated with the mathematics skills, r = .79). In conclusion, the QIF-M may become a useful tool to contribute to the diagnosis of mathematics learning disabilities. Future research should investigate more deeply the validity and fidelity of the QIF-M (e.g., sensitivity). The investigation also continues with the development of two similar questionnaires that parents and teachers fill out about the child.

2. Is spatial language an important predictor of early math knowledge?

Carrie Georges*[1], Véronique Cornu[2], Christine Schiltz[1]
[1]University of Luxembourg [2] Centre pour le développement des apprentissages Grande-Duchesse Maria Teresa

Recent evidence suggests that spatial language in preschool plays an important role in the development of verbal number skills, as indexed by aggregated performances on counting and number naming tasks (Georges et al., 2021; Lindner et al., 2022). We aimed to determine whether spatial language significantly predicts both of these measures or whether the aforementioned relation was driven by either counting or naming Arabic numerals. Moreover, we assessed whether the role of spatial language extends beyond verbal number skills to other numerical subdomains (i.e., number writing, cardinal and ordinal judgments, numerosity comparison), and as such affects mathematical development more broadly. Regression analyses including data from n=155 preschool children (mean age=6.36 years) showed that spatial language significantly predicted both forward and backward counting even when controlling for cognitive (phonological awareness, intrinsic and extrinsic spatial skills) and sociodemographic (age, SES, mother tongue) variables previously shown to influence mathematical learning. It did, however, not relate to number naming or writing, which were solely predicted by phonological awareness and extrinsic spatial skills, respectively. Spatial language did also not affect numerosity comparisons. Conversely, it significantly predicted

symbolic cardinal judgments alongside intrinsic spatial skills, age and SES and was the only predictor of ordinal judgments. Altogether, these findings highlight the importance of spatial language for numerical development beyond verbal number skills and suggest that the knowledge of spatial terms might be specifically relevant for (verbally) classifying symbolic numbers in terms of their positions with respect to other numbers on a potentially spatially oriented mental number line.

3. Developing and Validating a Measure of Parental Knowledge About Early Math Development

Camille Msall*, Ashli-Ann Douglas, Bethany Rittle-Johnson
Peabody College of Education & Human Development, Vanderbilt University

Parents' knowledge about the math skills that most preschool-aged children can develop might be an important component of the Home Math Environment (HME) as it might shape their math beliefs and efforts to support their preschoolers' math development. This study aimed to systematically develop measures of parents' knowledge about two critical early math topics, numeracy, and patterning, across five studies conducted with a total of 616 U.S. parents of 3- to 5-year-olds (66% mothers, 54% sons, 73% White, 60% college-educated). Parents were recruited via CloudResearch or a university database. Study 1 focused on item generation to revise a previous measure to capture a wider set of children's early math skills and analysis of the psychometric properties of the measure after it was completed by 161 parents via a survey. Study 2 included an analysis of a new sample of parents (n = 21) who responded to the measures twice across two weeks to explore test-retest reliability. The measures were iteratively revised, administered to new samples, and analyzed in Studies 3 (n = 45), 4 (n = 46), and 5 (n = 344). The measures demonstrated adequate internal consistency and validity (construct, convergent, and discriminant) in Study 5 such as being positively related to parents' numeracy and patterning beliefs about their children. Overall, the newly developed measures satisfy standards for the development of an adequate measure and can be used to better understand what parents know about early math development and how this relates to the HME that they facilitate.

4. Developing a Patterning Lens to Improve Early Numeracy Knowledge: A Pilot Study

Bethany Rittle-Johnson*, Jake Kaufman
Vanderbilt University

Developing a patterning lens – the ability and tendency to look for and make use of predictable sequences – is one promising way to improve young children's numeracy knowledge (Zippert et al., 2020; Wijns et al., 2019). However, theory and evidence for underlying mechanisms is very limited. A pilot study explored the potential of playful patterning and numeracy activities designed to develop young children's patterning lens, based on our emerging theory. Nineteen 5- and 6-year old's (M = 6.43 years) attending a public or private kindergarten in a large U.S. city met individually with an experimenter for seven sessions over 3 weeks. At pretest and posttest, participants' numeracy knowledge, encoding of numeric patterns, and patterning lens (repeating pattern knowledge and spontaneous focusing on patterns (SFOP)) were assessed. In sessions 2-6, children engaged in repeating patterning activities within a patterning book and played a numeracy board game (from Laski & Siegler, 2014). From pretest to posttest, children's scores increased significantly on SFOP (2.21 to 2.52), repeating patterning (11.89 to 15.89), and numeracy (16.33 to 17.21), as did encoding of the structure of a 0-50 number chart (4.74 to 6.44). Further, our new repeating patterning knowledge measure was reliable and

valid. Our learning activities are promising. The next steps are to test if children who are randomly assigned to receive this training show greater gains in numeracy knowledge than children who receive numeracy training without a patterning lens and to refine our theory for how patterning might support numeracy knowledge.

5. Integrating Dynamic Mathematical Technology into the Classroom: The Cases of Three Teachers Teaching Geometric Similarity

Ali Simsek*
UCL's Faculty of Education and Society

The potential of dynamic mathematical technology (DMT) (such as GeoGebra) on pupils' outcomes, engagement, experience and enjoyment of mathematics has been well acknowledged in the literature. However, the complex process of technology integration has resulted in teachers confronting difficulties using DMT in their practice. Identifying the characteristics of teachers' DMT-integrated practice is vital to promote successful integration of DMT into the classroom. The aim of this research is to investigate lower secondary teachers' integration of DMT into classroom practice with a particular focus on geometric similarity (GS). The lens of the Structuring Features of Classroom Practice (SFCP) framework (Ruthven, 2009) guided data collection and analysis. The study adopted a multiple case study approach with three English lower secondary mathematics teachers who had different levels of experience and expertise in using digital technology and committed to develop their students' understanding of GS with DMT. Data were created through video-recorded classroom observations (including the teacher's eye view) (23 lessons in total), audio-recorded post-lesson teacher interviews (20 interviews in total), and teachers' resource and students' work. In this poster, I will present the findings identified through the within- and cross-case analysis of the cases that revealed salient differences and some commonalities between the teachers. These findings point to key characteristics of classroom practices involving DMT not just for teaching GS in particular but also for mathematics in general.

Ruthven, K. (2009). Towards a naturalistic conceptualisation of technology integration in classroom practice: The example of school mathematics. Education & Didactique, 3(1), 131–159.

6. The effect of short-term memory and magnitude processing in single-digit multiplication solving

Mei Ling Soh*[1], Alejandro J. Estudillo[2]
[1] University of Nottingham Malaysia [2] Bournemouth University

Studies in children have found that inhibition, numerical magnitude processing and short-term memory predict individual differences in single-digit multiplication solving. However, results in adults are less clear. In two online studies, 356 adult Malaysians with varying multiplication fluency were evaluated with processing, digit span, visual pattern, and numerical Stroop comparison tasks. Results show moderate positive correlations between short-term memory and multiplication performance as well as between numerical comparison and multiplication fluency. However, these correlations disappeared after controlling for processing speed and problem size. Therefore, although short-term memory and magnitude processing might be important for the acquisition of single digit multiplications, they did not account for individual differences in multiplication solving in adulthood.

7. Inhibition of the "add zero(s)" heuristic is needed to multiply by 10, 100, 1000 decimal numbers: a developmental conflict adaptation paradigm study

Maria Ghazi*, Grégoire Borst
Laboratory of Developmental Psychology and Child Education, Université Paris Cité

Introduction: Growing evidence shows that mathematical learning relies not only on mastering the appropriate rules, but also on inhibiting heuristics that might prevent students from applying these rules. We investigate whether the process of multiplying by 10, 100 or 1000 decimal numbers requires to inhibit the “adding zero(s) after the last digit” heuristic. Methods: 49 adults (aged 18-40 years, Mage = 32.5±6.6 years) and 34 adolescents (7th to 9th grade, Mage = 14.2±0.9 years) were included. We designed a conflict adaptation (CA) paradigm task involving 72 prime-probe trials. Primes and probes consisted of multiplications by 10, 100 or 1000 of integers or decimals. Results: Analyses on the probes show that participants were faster and more accurate to multiply by 10, 100 or 1000 integers than decimal numbers. Also, the difference in RTs between the two types of probes was larger following primes that required to multiply integers by 10, 100, 1000 than following primes that required to perform similar operations on decimal numbers; reflecting the CA effect. Finally, this CA effect was more pronounced in adolescents than adults. Conclusions: Adolescents, and to a lesser extent adults, should inhibit the “adding zero(s) after the last digit” heuristic when multiplying decimals by 10, 100, 1000, which could explain why such multiplications are more difficult than similar ones on integers. This finding suggests that to avoid errors, students need to be aware that such errors stem from the “adding zero(s) after the last digit” heuristic and that they need to inhibit this heuristic.

8. Mathematics Interventions for Secondary Students with Emotional and Behavioral Disorders: A Research Synthesis

Katie Barnicle*
The University of Texas at Austin

Students with emotional and behavioral disorders (EBD) often demonstrate poor academic outcomes, most notably in mathematics (Bradley et al., 2008; Hott & Brigham, 2020; Mulcahy et al., 2014). Deficit areas in prerequisite algebra skills often contribute to students' delayed growth in overall mathematical learning and tend to increase as students reach middle and high school. This synthesis analyzed the effectiveness of mathematics interventions for secondary students with EBD. The number of students receiving special education services for EBD is increasing, and research focused on effective mathematics interventions for these students is limited. Due to the significant academic and behavioral needs of students with EBD, quality interventions are necessary to support their academic and social development. These interventions are particularly important for increasing conceptual knowledge and algebra readiness. Despite common knowledge that students with EBD exhibit mathematics deficits, few studies have investigated the effectiveness of interventions designed to improve the mathematics performance of secondary students with EBD (Mulcahy et al., 2014). Ten studies met inclusion criteria for this synthesis. In this poster presentation, I will present the mathematics interventions included in these studies and their potential effects on mathematics outcomes for secondary students with EBD.

9. Shared neural resources for math and reading in children and adults

Aymee Alvarez-Rivero*, Lien Peters, Daniel Ansari
University of Western Ontario

Despite the robust evidence about the correlations between reading and math performance, these domains have largely been investigated in isolation from each other. More specifically, previous studies have suggested that phonological decoding -a critical ability for reading- also plays a role in arithmetic fact retrieval. However, the neuroimaging evidence to support common neural correlates between reading and arithmetic is still scarce. Specifically, studies looking at shared neural resources across both domains within the same group of participants are severely lacking. In the current study, we contribute to filling this gap by providing evidence about areas of the brain that are recruited for both reading and arithmetic in children and adults. fMRI data was collected while participants completed a rhyming task and an arithmetic task that included small and large addition facts. Preliminary univariate results point to clusters of common activation along inferior frontal gyrus and middle temporal gyrus in adults; as well as multiple clusters along the frontal gyrus in children. Moreover, we hypothesize that small problems that are typically solved using a retrieval strategy should display a larger neural similarity to phonological decoding processes than large problems, which are typically solved using numerical computations. We will use Representational Similarity Analysis to test this hypothesis. These multivariate results will be further discussed in our poster. Overall, our study will have implications for our understanding of neural resources between reading and arithmetic and the role of phonological decoding in this relationship.

10. Math Anxiety, Spatial Anxiety, and Spatial Language Experience

Rachel Pizzie* [1], Christina Kim[1], Rachel Sortino[1], Rachel Inghram[2]
[1] Gallaudet University, Educational Neuroscience Program, Washington, DC [2] Gallaudet University, Clinical Psychology Program, Washington, DC

Visuospatial skills have been identified as important targets for improving STEM performance, as increased mathematical skills are often associated with increased performance on visuospatial tasks. However, a significant challenge for improving math and spatial skills is anxiety associated with each domain. Math anxiety (MA) refers to increased negative feelings toward mathematical tasks and decreased mathematics performance. Similarly, spatial anxiety (SA) involves increased anxiety toward skills that require spatial thinking, such as navigation, mental rotation, or recognizing and understanding visuospatial patterns. Increased SA is related to decreases in spatial task performance and increased MA. Prior research has suggested that math and spatial skills practice can improve performance in both domains. One potential way to practice spatial skills is through the use of a visuospatial language, like American Sign Language (ASL). We propose that more experience with ASL may ameliorate some of the negative effects of MA and SA on performance in these domains. In this online study, deaf, hard of hearing, and hearing participants completed questionnaires on MA, SA, and language background. Participants completed arithmetic and mental rotation tasks, measuring mathematics and spatial skills, respectively. Preliminary results suggest that increased math anxiety is associated with decreased spatial thinking. However, increased ASL proficiency is associated with increased spatial thinking. Continued analysis will explore the relationship between MA, SA, and performance in each domain, and how increased ASL experience may ameliorate these relationships between anxiety and performance.

11. Stronger neural response to canonical finger-number configurations in deaf compared to hearing adults revealed by FPVS-EEG

Margot Buyle*[1], Aliette Lochy[2], Valentina Vencato[1], Virginie Crollen[1]
[1] Psychological Sciences Research Institute (IPSY) and Institute of NeuroScience (IoNS), Université Catholique de Louvain, Louvain-la-Neuve, [2] Psychological Sciences Research Institute (IPSY) and Institute of NeuroScience (IoNS), Université Catholique de Louvain, Louvain-la-Neuve and Department of Behavioural and Cognitive Sciences, Faculty of Humanities, Social and Educational Sciences

The linguistic counting system of deaf signers consists of a manual counting format that uses specific structures for number words. Interestingly, the number signs from 1 to 4 in the Belgian sign languages correspond to the finger-montring habits of hearing individuals. These hand configurations could therefore be considered as signs (i.e., part of a language system) for deaf while they would be simply counting handshapes (not linguistic) for hearing controls. A Fast Periodic Visual Stimulation design was used with EEG recordings to examine whether these finger-number configurations are differently processed by the brain when they are signs (in deaf signers) as compared to when they are a counting-tool (in hearing controls). Results showed that deaf signers show stronger discrimination responses to canonical finger-montring configurations compared to hearing controls. A second control experiment furthermore demonstrated that this finding was not merely due to the experience deaf signers have with the processing of hand configurations, as brain responses did not differ between groups for finger-counting configurations. Interpreting these findings leads us to suggest that finger-number configurations corresponding to sign language are processed differently in deaf signers than in hearing controls.

12. Functional lateralization of number processing

Narjes Bahreini*, Christina Artemenko, Hans-Christoph Neurk
Department of Psychology, University of Tuebingen

Functional lateralization was previously established for various cognitive domains; however, it has not been systematically investigated for number processing. Although numbers are considered to be bilaterally represented in the intraparietal sulcus (IPS), there are some indications of different functional roles of the left vs. right IPS in processing number pairs with small vs. large distance, respectively. This evidence was mainly obtained by studying single-digit number processing which raises the question whether number size plays a distinct role in neural underpinning of number processing. Our preregistered study aims to test the functional lateralization of single-digit vs. two-digit number processing within the IPS. By applying anodal transcranial direct current stimulation (tDCS) over the left vs. right IPS, we investigate stimulation effects on small vs. large distance effect as compared to sham, in both single-digit and two-digit number comparison. We expect anodal tDCS over the left IPS vs. sham decreases reaction time more in number pairs with small distance, while anodal tDCS over the right IPS vs. sham decreases reaction time more in number pairs with large distance. Data collection is in progress now and we will present and discuss the results of our preregistered analyses at the MCLS. Keywords Functional lateralization, Number processing, IPS, tDCS.

13. Young Children's Understanding of Symbolic Fractions: Do Part-Whole Labels and Active Subdividing Interventions Help?

Karina Kling*, Susan Levine
Department of Psychology, The University of Chicago

Children encounter significant challenges in understanding fractions. For example, they struggle to map symbolic fractions onto correct pictorial representations because they misunderstand the roles played by a fraction's numerator and denominator. Two types of interventions have been shown to improve children's performance on adaptations of Miura's (1999) mapping task. First, use of part-whole fraction labels like "two-of-three-parts" rather than the traditional label "two-thirds" increased children's performance in mapping a symbolic fraction to a discretized fraction picture (a pre-divided and shaded shape; Paik & Mix, 2003). Second, having children actively divide fractions composed of continuous parts into units improved mapping of fraction symbols to discretized fraction pictures (Hurst et al., 2022). In the current study, we test whether these intervention strategies - part-whole labels and subdividing - improve mapping performance with continuous fraction depictions separately and/or in combination. On the online platform Lookit, 6-7 year-old participants (N=140 total, partial sample of 92 collected/analyzed) matched verbal labels to continuously shaded rectangles representing fractions, given different label types (part-whole vs. traditional) and action strategies (subdividing vs. not subdividing). Findings show a significant main effect of subdividing ($F(1) = 8.333$, $p<0.01$), where subdividing promotes higher performance ($M=0.55$; $SD= 0.30$) than not subdividing ($M=0.43$; $SD=0.27$). However, there was no main effect of language and no language by subdividing interaction. Thus, subdividing continuous fractions into units appears to be a robust way to address children's difficulty with mapping symbolic fractions onto nonsymbolic, continuous fraction representations.

14. The Development of a Math Anxiety Scale for Chilean Kindergarten Children

M. Francisca del Río*[1], M. Inés Susperreguy[1], Christian Peake[1], Macarena Angulo[1,2]
[1] Faculty of Education, Universidad Diego Portales; Millennium Nucleus for the Study of the Development of Early Math Skills (MEMAT), Chile [2] Faculty of Education, Universidad Alberto Hurtado

Math anxiety has been identified as a critical factor negatively associated with mathematical achievement (Cipora et al., 2022; Primi et al., 2020). Research on math anxiety with children in early childhood education is still incipient, as it has been mainly studied in adults and older children. Additionally, most scales have been developed and validated with U.S. populations. In Chile, there is a significant math achievement gap favoring high socioeconomic status (SES) children, and math anxiety is already present in Grade 2 students, especially among those of low-SES (Guzmán et al., 2021). In the current research, we studied math anxiety with children younger than in prior studies. We adapted to Spanish the math anxiety scale developed by Lu and colleagues (2021) for kindergarten children in the U.S. This scale was administered to 125 Chilean kindergarten children from middle/low-SES schools in Santiago, Chile (M age=73.46 months). Results showed a good reliability of the scale (Cronbach alpha= .73), with a single factor explaining approximately 57% of the variance of the responses. Math anxiety was negatively correlated with math achievement scores ($r=-.213$, $p=.05$). There were no differences between boys and girls in their math anxiety scores nor the relation between math anxiety and math achievement. The development of this instrument allowed us to better

understand math anxiety and its relation to math performance in Spanish-speaking countries from an early age.

15. The role of maths anxiety and confidence in understanding performance on both the long and verbal versions of the Cognitive Reflection Test

Michael Waldron*, Thomas Hunt, Edward Stupple, Paul Staples
University of Derby

Maths anxiety is an aversive reaction that some individuals have towards mathematics. Whilst typically studied in an educational context, maths anxiety can also impact individuals' choices and decisions in a much wider context. One key aspect of rational decision-making is analytical thinking. Maths anxiety has previously been shown to be related to poorer performance on the cognitive reflection task (CRT), a measure of analytical thinking. While many questions about this relationship remain, the current research focused on whether this relationship was specific to mathematical measures of analytical thinking, and what the role of confidence may have been. This was investigated in a sample of 110 participants (83 females). Participants were presented with multiple psychometric tests including measures of maths anxiety, maths self-efficacy, subjective numeracy, and state and trait anxiety. They were then presented with both a mathematical and a non-mathematical version of the CRT, alongside a test of numeracy. Hierarchical regression analyses demonstrated that maths anxiety was a significant predictor of performance on both a mathematical and non-mathematical CRT. It was also demonstrated that this relationship was still significant after considering the role of both confidence and numeracy in addition to the other variables, although confidence was highlighted as a partial mediator. This is consistent with previous research findings but expands upon these by considering the role of confidence. Higher Maths anxiety was thus found to be related to lower levels of analytical thinking. It is suggested future research focuses on exploring maths anxiety and confidence in more applied domains.

16. Children's number line performance: The impact of directionality and modality

Ciara Roche*, Sophie Leonard, Mariuche Gomides, Flávia Santos
School of Psychology, University College Dublin

Number-line estimation tasks allow researchers to capture and understand individuals' abilities to represent and estimate numerical quantities spatially. Variability is observed in children's number line estimation performance, which usually is horizontally left-to-right oriented in Western cultures. Several mechanisms may impact number-space mappings and their relationship with wider numerical performance. As for exploring visuospatial mechanisms, Leonard & Santos (MCLS 2023) implemented a digital multi-directional number line estimation paradigm. We adapted this paradigm for children to investigate the configuration of number space mappings under several conditions. A sample of 185 primary school children in Dublin aged 8-10 years old, used tablets to complete an embodied number line estimation task encompassing directionality (vertical top-to-bottom; vertical bottom-to-top; horizontal left-to-right or horizontal right-to-left) and modality (visual or auditory calculation) as variables. Contrary to previous findings of a fixed internal number line moving from left to right, our results suggest that children's number-space mappings may be more robust along a vertical axis moving upwards ($F = 14.05$, $p < .001$). In addition, children's multi-directional number line estimation differed depending on input modality. The findings provide insight into the variability in children's number line estimation and suggest that number-space mappings may

occur across multiple axes depending on embodied, educational or environmental factors. Supports: UCD Ad Astra Fellowship; Irish Research Council.

17. Conditionality of adaptiveness: Investigating the relationship between numeracy and adaptive behavior

Supratik Mondal*
SWPS University of Social Sciences and Humanities

Recent studies have illustrated that individuals with higher numeracy are more likely to make adaptive choices than individuals with lower numeracy. Highly numerate individuals can consistently make normatively superior choices by maximizing expected value (EV) in meaningful choice problems (high-payoff condition). However, in trivial problems (low-payoff condition), they can also adaptively change their strategy to make good enough choices and not follow a normatively superior strategy. Upon inspection of choice problems used in earlier studies, it was revealed that payoff was not the only varying factor between the two payoff conditions. Therefore, it is unclear whether payoff conditions alone can provide sufficient context for adaptive modulation in decision strategy. In two pre-registered studies (N = 343), we tested numerate individuals' adaptiveness under high- and low-payoff conditions addressing the limitations of earlier studies. Results revealed that the presence of two payoff conditions together did not initiate adaptive strategy selection, regardless of participants' numeracy. Instead, numerate individuals, compared to less numerate individuals, consistently made more EV-consistent choices in both payoff conditions. We identified that the change in EV consistency across payoff conditions was influenced more by the absolute difference than the relative difference in the expected reward.

18. The Preschool Classroom Library: Is There a Place for Mathematics?

Michele Stites, Susan Sonnenschein*, Besjane Krasniqi
University of Maryland Baltimore County

Engagement in naturally occurring mathematical opportunities is a critical component of preschool mathematics development (Ginsberg et al., 2008). Although most preschool classrooms around the world contain libraries, preschool teachers often do not view the classroom library as a place for young children’s mathematics development (Stites et.al., 2021a; Stites et.al, 2021b) and prior research found few mathematics books in classroom libraries. This study investigates whether increased exposure to mathematics books in preschool classroom libraries increases children’s engagement with this genre of books? We will assess the number and types of books chosen, the number of minutes books were explored, and teacher involvement. Two classrooms received fully repopulated libraries consisting of 75 traditional storybooks and 75 mathematics themed books. Two classrooms, control sites, had no changes to the contents of the classroom library. An average of nine reliable observations per classroom during library time were conducted. Preliminary analyses indicated three particularly noteworthy findings. One, consistent with previous research, teachers did not prompt children to choose mathematics themed books. Most book exploration (65%) was done by individual children without teacher involvement. Two, children in the intervention classrooms chose mathematics books more frequently than those in the control classrooms. Three, the average number of minutes children spent exploring mathematics books was higher in the intervention classrooms than in control classrooms (M=4.42 minutes). We may be

missing a critical opportunity to expose children to acquiring mathematics skills by increasing their exposure to mathematics books and their engagement with such text.

19. Presemantic and semantic processing of digits in adults with developmental dyscalculia

Samuel Lepoittevin*[1], Michael Andres[1], Alice De Visscher[2]
[1] Psychological Sciences Research Institute, Université Catholique de Louvain, Belgium [2] Research Center in the Psychology of Cognition, Language, and Emotion (PsyCLE), Université Aix-Marseille

A core difficulty in developmental dyscalculia is the efficient processing of Arabic digits. This difficulty has been related to a semantic deficit affecting either the magnitude representation or its access from numerical symbols. But recent data have raised the hypothesis that the processing of Arabic digits is slowed down due to impaired digit visual recognition (i.e., recognizing a symbol as one of the digits, no matter its identity or numerical meaning). The present study aims to test whether the difficulty to process Arabic digits remains prevalent in adults with developmental dyscalculia and whether it is effectively associated with a digit visual recognition deficit. We compared adults with dyscalculia to age-matched controls in a magnitude comparison task that required to identify the largest of two digits, and in a lexical decision task that required to decide whether a visual stimulus is a digit or not. The results showed that participants with dyscalculia took more time than controls to perform the comparison task, whereas they were as fast and as accurate as controls in the digit lexical decision task. Overall, this finding indicates that developmental dyscalculia continues to affect the ability to process numerical magnitude in adulthood, and this cannot be explained by a visual recognition deficit for Arabic digits.

20. Spatial working memory capacity moderates the association between fine motor skills and mathematics in preschoolers

Ursula Fischer*[1], Stephanie Roesch[2], Julia Bahnmueller[3], Roberta Barrocas[4], Nadine Bollmann[5], Korbinian Moeller[3]
[1] University of Applied Sciences in Special Needs Education, Zurich [2] University of Tuebingen, Germany [3] Loughborough University [4] Leibniz Institut fuer Wissensmedien, Tuebingen [5] Thurgau University of Teacher Education, Kreuzlingen

Introduction Recent research suggested that fine motor skills and finger gnosia are both preconditions for successful finger counting in early childhood and predict children's mathematical development. However, other domain general skills such as working memory also showed associations with children's finger counting skills comparable to if not stronger than fine motor skills and/or finger gnosia. Methods To better understand the potential role of working memory in the association between fine motor skills/finger gnosia and finger counting, we combined datasets from two separate studies (N = 271, 127 girls, age M = 59.5 months, SD = 9.78). In both studies, which used mostly identical tasks, children were tested on fine motor skills, finger gnosia, spatial working memory, and finger counting skills. Results After controlling for age, children's fine motor skills and spatial working memory capacity were both associated significantly with their finger counting skills, whereas finger gnosia was not. Subsequent moderation analyses indicated that working memory consistently moderated the relationship between fine motor skills and finger counting skills. In each moderation analysis, the association was strongest for children with low working memory capacity and was not significant for children with high working memory capacity. Conclusions These results

suggest that children with low working memory capacity rely more on their fine motor skills to count on their fingers compared to children with high working memory capacity, who might not need to. Accordingly, future research and intervention on finger counting skills should consider both spatial working memory and fine motor skills.

21. How equal are equivalent fractions?

Georgios Thoma*, Korbinian Moeller, Julia Bahnmueller
Centre for Mathematical Cognition, Loughborough University

Fraction magnitude understanding was found to be an important predictor of later math achievement. Several studies were conducted aiming at disentangling the underlying mechanisms of fraction magnitude processing in general. Overall, results suggest that the holistic magnitude of fractions is not always activated and used automatically. Rather, the use of holistic and componential processes seems to depend on the type of fraction, amongst other factors. Following this line of research, the current study set out to further expand our knowledge about the underlying mechanisms of fraction magnitude processing by specifically zooming in on a so far under-researched fraction type: equivalent fractions. In this study, participants were presented with a same-different-task evaluating their performance in categorizing fractions pairs as numerically the same (i.e., when these are identical, e.g., 1/2_1/2 or equivalent, e.g., 1/2_2/4) or numerically different (e.g., 1/2_1/3). Equivalent fraction pairs were further manipulated with respect to the divisor required to reduce them to the respective base fraction (e.g., divisor 2: 1/2_2/4, divisor 3: 1/2_3/6, divisor 4: 1/2_4/8). Fraction pairs were presented simultaneously and matched for problem size and numerical distance. Replicating findings by Gabriel, Szucs, and Content (2013; Frontiers in Psychology), results showed that performance was worse for equivalent compared to both identical and different fraction pair conditions. Moreover, an effect of divisor was found for equivalent fraction pairs. Overall results suggest that rather than being processed holistically, procedural strategies including the manipulation of fraction components are used to process equivalent fractions – in some cases more so than others.

22. The direction of SNAs is modulated by task demands rather than stimuli rotation and visual perspective taking

Valter Prpic*[1,2], Darek Costa[3], Patrick Cullen[4], Andrew Stretton[2], Serena Mingolo[3], Mauro Murgia[3]
[1] Department of Philosophy and Communication, University of Bologna, Bologna [2] Institute for Psychological Sciences, De Montfort University, Leicester [3] Department of Life Sciences, University of Trieste [4] School of Science, University of Law

Introduction. Spatial-Numerical Association (SNA) is a tendency to associate small numbers with the left space and large numbers with the right space. The most common demonstration of this phenomenon consists in a response advantage with congruent lateralised response keys (SNARC, Dehaene et al., 1993). A similar association also exists between numbers and the vertical/sagittal space, with small numbers being responded faster with a bottom/close key and large numbers with a top/far key (Aleotti et al., 2020, 2022). Since SNAs are linked with egocentric spatial coordinates, we assessed whether number rotation or visual perspective taking (VPT) can influence the SNARC effect. Methods. Numbers were presented rotated by 90/180/270 degrees, either alone (control condition) or within an image depicting an agent mimicking participants' task position (VPT condition). In the latest case, participants were

required to respond as if they were the agent. For each condition, participants performed a parity judgement or a magnitude classification task. Results. Neither number rotation nor VPT seem to play a role in moderating the direction of SNARC. Conversely, the direction of the vertical/sagittal effect seems determined by task demands, with parity judgement and magnitude classification tasks eliciting SNAs with opposite directions. Conclusions. The direction of these patterns suggest that different mechanisms are involved in vertical/sagittal SNAs, with magnitude classification being compatible with grounded cognition (more is up) and parity judgement with reading direction (first items up).

23. Supporting the development of numerical cognition in preschool children: tablet-based vs. paper-pencil training

Hoyeon Lee*[1], Sandrine Mejias[2], Margault Sacré[1], Christine Schiltz[1]
[1] University of Luxembourg [2] University of Lille

The importance of early mathematical skills has been widely demonstrated by their impact on academic achievement (Duncan et al., 2007), and career success (Romano et al., 2010). Many tablet applications have been developed to support children's cognitive development, but their adoption for early math education remains controversial. The present comparative study examines different mathematics trainings for preschoolers to identify those that best support the development of mathematical skills. One hundred sixty-one French preschoolers (aged 4 and 5 years) were randomly assigned to one of three training groups: one used a tablet for visuospatial training (n=53), one used a tablet for pre-mathematic training (n=52), and the last one used a paper-pencil format for pre-mathematic training (n=56). The training lasted 8 weeks (2 sessions of 20 minutes a week). All participants underwent pre- and post-training assessment of their basic cognitive and numerical processing ability (visuospatial skills, short-term memory, motor rapidity, counting, symbolic/non-symbolic magnitude estimation, symbol-to-numerosity mapping, ordinality, and simple arithmetic). The repeated measures ANOVA showed that visuospatial skills were selectively enhanced by tablet-based visuospatial training ($F(2,155)=3.468$, $p=.034$), whereas single-digit number comparison acuity was selectively promoted by pre-mathematical training regardless of its format ($F(2,155)=3.76$, $p=.026$, post-hoc ptukey<.001 for the tablet-based pre-math training group, and ptukey=.033 for the paper-pencil pre-math training group) only for 4-year-old children but not for 5-year-old children. The results suggest that specific training is needed to develop different domains of preschooler's numerical cognition, and that it is premature to confirm a specific benefit of tablet use for this age group.

24. Evaluating Brazilian children's early numerical concepts development using MARKO-Screening

Fernanda Freitas*[1], Moritz Herzog[2], Antje Ehlert[3], Annemarie Fritz[4], Vitor Haase[5]
[1] Graduate Program of Psychology: Cognition and Behavior, Universidade Federal de Minas Gerais, Belo Horizonte [2] Institute for Educational Research, University of Wuppertal [3] University of Potsdam [4] Akademie Wort+Zahl, Germany [5] Universidade Federal de Minas Gerais, Belo Horizonte

A substantial percentage of Brazilian children are struggling to reach the minimum level of proficiency in mathematics. Based on the empirically validated Model of Numerical Concept Development, the MARKO series was designed to identify and support children with mathematical learning difficulties (Fritz et al., 2013). The study aims to evaluate the feasibility

of the model and MARKO instruments for describing Brazilian's children basic math performance. MARKO-Screening was translated and adapted to Brazilian-Portuguese following the International Test Commission guidelines. Brazilian children from preschool, first and second grade (N=135; mean age=80.83 months; SD=9.98 months) were evaluated using MARKO-Screening. A Rasch analysis was employed to estimate the difficulty of the items. In general, item's difficulty arranged as expected by the Model of Numerical Concept Development's levels. Results showed that Brazilian children develop one level of the model per year, following the same pattern of German children. However, Brazilian children reached less than 50% of correct answers in the items related to cardinality, indicating difficulties to acquire this crucial basic math concept. The present findings suggest that Model of Numerical Concept Development and MARKO series may be useful for supporting Brazilian children's mathematical learning. Fritz, A., Ehlert, A., & Balzer, L. (2013). Development of mathematical concepts as basis for an elaborated mathematical understanding. South African Journal of Childhood Education, 3(1), 38-67.

25. The role of cultural support on commutativity at varying levels of abstraction

Isabelle Boni*, Steven Piantadosi
UC Berkeley

The extent to which people can infer new mathematical concepts in the absence of cultural support— such as formal schooling and market experience— is not clear. We test such learning with a simple math concept: additive commutativity. Experimental work with children in industrialized cultures suggests that cultural support is necessary, since children take time to learn commutativity and ultimately show signs of knowing it after entering school. Our prior research also shows that unschooled Tsimane' adults do not succeed on symbolic and word problem commutativity tasks. However, these tasks may be too abstract, and participants might not have had enough training to understand them. To address this, we implement a concrete commutativity task with more training and tangible tokens, including sums with specified (e.g. 2+1 vs. 1+2) and unspecified (e.g. 2+Dax vs. Dax+2) quantities. We find significantly better performance on concrete tasks, even in Tsimane' participants with limited levels of formal schooling and other cultural supports. The best performance emerges in trials with unspecified quantities. This suggests that cultural support is not necessary to understand the commutative principle, but is necessary to apply it to more abstract problems.

26. From Here to There and Beyond: Understanding Optional Challenge Seeking in an Educational Math Game

Allison Liu, Kirk Vanacore, Alena Egorova, Cindy Trac*, Erin Ottmar
Worcester Polytechnic Institute

Mathematics students often fear failure and consequently avoid challenging tasks that could benefit their learning (Kapur, 2008). Students are more likely to engage with failure in game contexts (Gee, 2003), but including game elements in learning materials can also hinder challenge-seeking behaviors (Chase et al., 2020). Research can elucidate how specific gamification systems encourage challenge-seeking and interact with other contextual variables to influence mathematics learning. We explore these questions using From Here to There (FH2T), an educational math game. FH2T comprises 14 game worlds: each contains 14 problems that must be completed to progress to the next world, plus four optional challenge problems. We investigate which in-game behaviors and learner characteristics predict whether

a student starts and/or completes FH2T's optional problems, and how playing optional problems relates to students' algebraic understanding and math anxiety post-intervention. As part of a larger efficacy study, 1,430 7th grade students played nine 30-minute sessions of FH2T and completed a pretest and posttest assessing algebraic understanding and math anxiety. Multilevel regressions will predict: 1) the number of optional problems students start and complete, using in-game metrics (tied to different gamification systems of rewards, error feedback, and exploration of alternative solutions), student demographics, and prior algebraic understanding and math anxiety; and 2) students' post-intervention algebraic understanding and math anxiety, using students' progress and performance on the optional problems. Our findings can help determine the gamification systems that may best support productive challenge-seeking behaviors for math learning, informing the design of future educational math games.

27. The effects of a symbolic number training intervention on children's developing numeracy skills

Fiona Jelley*
Department of Education, University of Oxford

Introduction: There is much debate about the key factors involved in formal mathematics learning. Symbolic number skills (e.g., number representation and counting) are strongly linked to arithmetic; however, there is limited research that tests causal relationships. The aim of this study was to investigate the potential causal link between children's symbolic number knowledge and their arithmetic skill. Methods: A randomised controlled trial was conducted to test the effects on children's arithmetic of an app-based game designed to 'train' symbolic number knowledge and counting. A sample of 91 4-5-year-old children were randomly assigned to either the intervention group, who had access to the game, or the active control, who played an identically structured game using letters. Children completed numeracy and literacy measures at pre- and post-test. Results: The number training was effective in improving children's ability to judge number order: the numbers group significantly outperformed the letters group, controlling for pre-test (d=0.55 [0.01, 1.09]). The letters training had a corresponding positive impact on letter ordering (d=0.56 [-0.10, 1.22]). There were no further statistically significant effects, although some trends in expected directions were observed. Conclusions: Despite no evidence of 'far transfer', it is useful to have demonstrated improvement of the specific skills the games intended to enhance. One key limitation to be discussed was the low intensity of the intervention. The findings from this study will contribute both theoretical and practical insights relevant to our understanding of number knowledge and children's arithmetic development, and have implications for mathematics intervention and further research.

28. The influence of phonological processing on children at risk of mathematical learning disability: An intervention study

Xiujie Yang*, Kiachun Liu
Faculty of Psychology, Beijing Normal University

Children who fall behind their peers in math before formal education have a higher risk of developing dyscalculia. It is suggested that phonological processing skills, including phonological awareness, rapid automatized naming, and phonological memory, can predict children's mathematical development (De Smedt et al., 2010; Yang et al., 2021; 2020).

However, literature on children's math improvement by training them with phonological processing skills is still scarce. This study aims to address these gaps by conducting a phonological processing intervention in young children at risk of mathematics difficulties. 118 kindergarteners at risk of MLD were followed three times with a 6-month interval. They were randomly divided into the control group and the intervention group. The intervention group received 20 minutes of training on phonological skills per day for 20 days, while the control group received no additional training. We assessed children's phonological skills and mathematical abilities before and after the training, and a follow-up test was also carried out after four months to evaluate the persistent effects of the training. We used multivariate regression to analyze the predictive effects of phonological skills and MANOVA to examine the intervention effects on three phonological processing abilities and mathematics. We expected that: (1) phonological processing skills could significantly predict children's mathematical performance; (2) training effects on phonological processing skills could transfer to children's early mathematical skills, including counting, number knowledge, and arithmetic abilities.

29. Understanding and assessing young children's mathematical learning potential. (P)

Nathalie Parry*
University of Melbourne & KU Leuven

Early mathematical skills are foundational for later arithmetic proficiency, academic and professional success therefore, early identification and intervention for mathematics difficulties may mitigate factors placing children at risk of poor learning and life outcomes. However, effective, educator friendly tools to assess young children's mathematics skills are limited. Dynamic assessment, which combines assessment and effective instruction through mediated learning, presents an opportunity to measure learning potential by assessing students' responses to quality instruction in a shorter period of time than typical Response to Intervention processes. Targeted dynamic assessment sequences can also provide insights into students' cognitive processing while engaging in mathematical tasks. The purpose of the proposed longitudinal study is to understand the variability in learning potential of 60 preschool learners (aged 4-5). Specifically, dynamic assessments will be used to explore young children's learning potential on tasks related to early mathematical competencies and general cognitive processing. Early mathematical competencies, including mathematics specific language, will be measured at three time points as children transition from preschool to the end of their first year of formal schooling. This research is significant because dynamic assessment offers an individualised method for assessing young children's mathematics learning potential and designing interventions for those who may be at increased risk of failure in early school-based mathematics.

30. Neural similarity between children and their mothers for reading and arithmetic. (P)

Lien Peters, Aymee Alvarez*, Daniel Ansari
Brain & Mind Institute, Western University

Reading and arithmetic are critical scholastic skills that children acquire early in primary school. Research has shown that parental reading skills influence children's reading ability, yet such parental influences remain uninvestigated in the context of arithmetic abilities and next to nothing is known about common and distinct parental influences on both reading and arithmetic development. The current poster will present an analysis plan to identify similarities at the

neural level between children and their mothers, for both reading and arithmetic. This analysis is part of a larger project, in which children's biological mothers went through the exact same cognitive and neuroimaging testing battery as their children, allowing us to investigate whether parental factors contribute to reading and arithmetic ability over and above child factors. Our analysis plan describes the use of multivariate methods on fMRI data to test whether the neural similarity between children and their mothers is higher than the neural similarity between children and random adults. We will test this hypothesis along multiple areas of the brain using a searchlight approach, since we do not have specific predictions about anatomical regions in which we should expect higher similarity between relatives. We will conduct this analysis for reading and arithmetic, separately. Our results will contribute to understanding and identifying familial influences in the functional organization of brain regions that are recruited for reading and arithmetic.

31. Individual differences in mathematical expertise: The effects of cognition, personality and domain-specific creativity. (P)

Rebecca Myers*, Valentin Gulyás, Dénes Szücs
Centre for Neuroscience in Education, Department of Psychology, University of Cambridge

Research on individual differences in maths cognition typically focuses on children and adolescents and/or comparing typical learners with those with mathematics difficulties. However, less is known about the factors underpinning exceptional mathematical potential and achievement, particularly in post-compulsory education. Whilst a few promising studies have provided valuable insights, there remains a lack of clarity and consensus on the complex relationship between mathematical expertise (ME) and certain cognitive and non-cognitive correlates, particularly depending on how factors are defined and assessed. This study aims to clarify this. Participants include university students of different levels/types of ME. This currently consists of 3 discipline-based subgroups (mathematics, engineering and psychology) in line with previous research, with minimum 30 participants sought per subgroup. ME may be further distinguished based on highest level of maths attained and extra-curricular maths achievement. The current in-person study includes cognitive measures of fluid intelligence, visuospatial working memory precision, numerical processing and maths creativity (problem-solving and problem-posing divergent thinking tasks). Furthermore, personality is considered at the trait and sub-trait level. Data collection is ongoing until May 2023. Correlational analysis to highlight consistent relationships between factors alongside between-group comparisons (e.g., ANOVAs) will be carried out using R. Based on the literature, it is hypothesised that high ME will be linked to fluid intelligence and higher scores on certain facets of maths creativity and visuospatial working memory precision, with task-dependent distinctions. Personality differences may occur at the sub-trait, as opposed to trait level. The relationship between ME and other factors appears less clear.

32. Understanding the relationship between procedural complexity in mathematics and spaced retrieval practice. (P)

Ewan Murray*[1], Aidan Horner[1], Silke M. Göbel[1,2]
[1] University of York [2] University of Oslo

Learning mathematics is highly cumulative and forgetting impedes future learning. Spacing out repeated practice has been found to better improve retention than practice in a single (massed) session (Cepeda et. al., 2006, Hattie, 2008) and actively testing students increases

retention more than restudying (Rowland, 2014, Adesope et. al., 2017). It has been proposed that spaced learning is less effective for more complex material (van Gog & Sweller, 2015; but see Karpicke & Aue, 2015 for a different view), however, we do not know whether the effectiveness of retrieval practice is modulated by material complexity. We will assess the effectiveness of spaced retrieval practice as a function of procedural complexity for mathematical material. We will test at least seventy undergraduate students without an A level in mathematics in a two (spaced or massed) by two (lower or higher complexity) between participants' experimental design. The dependent variable will be the retention of the mathematical material on a post-test. Procedural complexity will be operationalised by the number of steps required to perform the procedure. We predict a benefit in retention for spaced relative to massed retrieval, and critically that this spacing effect will be greater in the lower relative to higher complexity condition.

33. The role of estimation strategies in human numerosity estimation. (P)

Trygve Solstad*[1], Eivind Kaspersen[1], Jeremy Hodgen[1,2], Elisabeth Inge Romijn[1]
[1] NTNU-Norwegian University of Science and Technology [2] UCL-University College London

The behavioural signatures of human numerosity estimation—such as the exact vs approximate estimation ranges, underestimation bias and normally distributed estimates—have been theorised to arise from implicit perceptual mechanisms (Cheyette & Piantadosi, 2020). At the same time, people report to rely on a range of explicit strategies when estimating the numerosity of dot-pattern images (Gandini, 2008; Yeo & Price 2021). For instance, in our pilot studies, some participants reported comparing the density of dots in the current trial to that of previous trials, while others reported counting the number of dots from memory. In our planned project we will investigate the relationship between estimation strategies and behavioural signatures of human numerosity estimation. To do this, we will use a multiple-choice survey to collect trial-by-trial strategy reports in a standard numerosity estimation paradigm. Participants will be shown displays of random dots for less than one second and prompted to estimate the numerosity as quickly and accurately as possible. We will then analyse the effect of strategy use on behavioural measures. Finally, any new hypotheses generated from this analysis will be experimentally tested by stimulating participants to use particular strategies and observing any behavioural effects.

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34. Does math anxiety influence how people process discounts? (P)

Fernando Ojedo*, Pedro Macizo
Mind, Brain and Behaviour Research Center (CIMCYC), University of Granada

Previous literature suggests that there is a negative relationship between mathematics anxiety and mathematic performance (Dowker, Sarkar & Looi, 2016). This can be observed not only in an academic context but also in many daily life activities, for example, in those tasks related to money processing (Suri, Monroe, & Koc, 2013). In the present research, we aim to observe how mathematics anxiety can lead to worse discount computation, not only through worse

arithmetic performance but also through the use of less efficient strategies. In two experiments we compared the price discounting computation performance between high and low math anxious individuals using different tasks. In Experiment 1, we asked participants to calculate the final prices after the discount while we manipulated the difficulty and the type of discount (absolute vs. percentage). In Experiment 2, we designed another task where participants had to indicate a discount that offered the largest benefit. We expect to observe how math anxiety modulates the performance of the participants in both experiments.

35. The role of home and preschool environment on maths development in the early years: Do differences in quality matter? (P)

Amy Godfrey*[1], Sylvia Gattas[1], Zachary Hawes[2], Steven Howard[3], Rebecca Merkley[4], Rosie O'Connor[1], Jelena Sučević[1], Gaia Scerif[1]
[1] Department of Experimental Psychology, University of Oxford [2] Department of Applied Psychology and Human Development, University of Toronto [3] School of Education, University of Wollongong [4] Department of Cognitive Science, Carleton University

Early maths skills are an important predictor of later maths and academic achievement. Providing a suitable environment for maths learning is central to the development of these skills. Home environment research has shown children in higher quality home environments are more likely to overachieve in maths compared to those in lower quality environments. However, with many children also attending preschool, it is important not to overlook the influence that preschool learning environments have on these maths skills. This research aims to understand the relative impact of both home and preschool environment on early years maths development. A secondary analysis of data collected as part of the Orchestrating Numeracy and the Executive project will be conducted. Mathematics achievement scores from 193 preschool children tested at two time points, alongside a home environment questionnaire (N = 90) and the SSTEW observation with a novel mathematics subscale from the 15 participating settings will be drawn on in this study. We hypothesise that maths outcomes will be associated with home and preschool environment quality, and each will contribute differently to overall maths achievement. We will report on changes in maths ability over time, alongside effects of home and preschool environment, identifying whether differences exist when preschool and home environments vary in quality. These results will provide novel insight into the contribution that different environments may have on children's early maths development.

36. Exploring the impact of an intervention on the relationship between the early maths abilities and executive functions: a network analysis approach. (P)

Jelena Sučević*[1], Sylvia Gattas[1], Amy Godfrey[1], Zachary Hawes[2], Steven Howard[3], Rebecca Merkley[4], Rosemary O'Connor[1], Gaia Scerif[1], The ONE Team
[1] Department of Experimental Psychology, University of Oxford [2] Department of Applied Psychology and Human Development, University of Toronto [3] School of Education, University of Wollongong [4] Department of Cognitive Science, Carleton University

Executive functions (EF) and maths skills are already related in the early years, with existing research suggesting that EF are predictive of later maths achievement. Moreover, integration of maths skills and EF is thought to play an important role in mathematical learning (Scerif et al., under review). The ONE (Orchestrating Numeracy and the Executive) programme is a randomised controlled trial designed to support development of early mathematics skills by incorporating executive challenge into early maths learning. A total of 193 4-years-old children

took part in the programme, half in the intervention and half in the business-as-usual condition, and their EF and maths skills were tested on EF and maths tasks before and after the intervention. The aim of the present investigation is to test the feasibility of a network analysis approach to better understand how the intervention might influence the relationship between EF and maths skills. A similar network approach has been recently used to test changes in EF structure following cognitive training in 9-10 and 15-17-years-olds, and revealed that both age and cognitive training lead to changes in EF network structure (Menu et al., 2022, Scientific Reports). Our goal is to test whether a network analysis approach can be used to test the structure and the relationship of EF and early maths in young children. Moreover, we want to test whether the intervention will lead to changes in the EF-maths network structure. We believe this approach has potential to provide additional valuable insights into the nature of intervention effects.

37. There is "order" and "order": Behaviour, electroencephalography, and age-related markers of learning novel symbols via sequential or non-sequential order information. (P)

Bethan Grimes*, Alex Fraser, Sylvia Gattas, Julia Dabrowska, Devanshi Trivedi, Gaia Scerif Scerif
Experimental Psychology, University of Oxford

Artificial symbol learning paradigms have been used to investigate novel symbol learning under different conditions (e.g., mapping individual symbols to non-symbolic magnitude, vs. learning about new symbol order), both of which elicit behavioural and event-related potential (ERP) responses that resemble those associated with real numerical symbols. It is unclear how children utilise ordinal information to learn novel symbols. Children aged 5-7 can accurately identify number lists in the correct order if they are presented in sequence (‘2-3-4’) compared to lists that were out of sequence (‘2-4-6’), but little is known about the role of sequential information in learning. We aim to replicate adult behavioural and ERP findings of artificial symbol learning, as well as to investigate the role of sequences in artificial learning of ordinal information. One group will be presented symbols in sequence and the other group will receive the symbols out of sequence, but still in correct order. It is hypothesised that sequential learning will result in comparable behavioural and ERP outcomes to what is observed with real numbers. However, non-sequential learning will not. The paradigm will be adapted to collect data with children aged between 4 and 8, to develop our understanding of the role of sequences and order in number learning.

Symposia 2.00 pm – 3.15 pm

Learning environments contributing to early numeracy and literacy skills

Chair: Jenni Salminen
Department of Teacher Education, University of Jyväskylä

Home learning environment has been acknowledged as one of the most central contexts for the development of numeracy and literacy skills in early childhood. Particularly, the myriad of shared activities and interaction with their significant caregivers (e.g., parents), have been shown to play an important role in contributing to skill development. At the same time, a substantial number of under school aged children participate in institutional early childhood education and care (ECEC) on a daily basis. Young children are exposed to early learning programs, including numeracy and literacy contents, and they engage into shared activities and interaction with their ECEC caregivers. Consequently, the two learning environments are likely to contribute to the development of children's numeracy and literacy skills, but the research dialogue between the two continues to be rather limited. The central aims of the current symposium are 1) to add understanding of the underlying processes and mechanisms through which characteristics of caregiver-child interaction within these two learning environments can impact children's skill development (papers 1 and 4) and 2) to examine how the caregivers can be supported in facilitating children's skills via activity-based intervention in the home environment (paper 2) and professional development in the ECEC environment (paper 3). The presentations in the symposium will thus facilitate cross-context discussion between the two learning environments, and further aid in recognizing the beneficial preconditions for early learning.

Presentation 1: Fathers' but not mothers' use of spatial language predicts children's interest in spatial activities and growth trajectories of spatial skills

Xinzhuo Zou*, Xiao Zhang, Hao Li, Cuina Liu
Faculty of Education, The Education University of Hong Kong

Parents' use of spatial language with their children has been found to correlate with children's spatial skills. However, previous studies have mainly focused on mothers' spatial language use and ignored fathers' roles. This study aimed to examine the extent to which fathers' and mothers' use of spatial language with their children was associated with children's interest in spatial activities and growth trajectories of spatial skills during the three years of preschool. Two hundred and ten Chinese preschool children (mean age = 46.58 months and SD = 3.88 months at the first wave of assessment) and their fathers and mothers from Hong Kong participated in this study. Mothers and fathers independently reported their own frequencies in using spatial language with their children and their own expectations of children's spatial skills in the first year of preschool, and in the second and third years, mothers reported children's interest in spatial activities. Children were tested individually on their spatial skills for five times across the three years. Latent variable analysis revealed that fathers' but not mothers' use of spatial language significantly predicted their children's later interest in spatial activities and growth trajectories of spatial skills. Father-reported spatial language was predicted by mothers' earlier expectations of children's spatial skills. The findings underscore the importance of paternal spatial language input in enhancing children's spatial interest and skill development.

They also underscore the potential role of mothers' expectations toward their children's spatial development in fathers' engagement in spatial talk.

Presentation 2: Guiding caregivers to support their children's early learning trajectories using TOYBOX numeracy, literacy and wellness strategies

Erin A. Maloney*[1], Sheri-Lynn Skwarchuk[2], Heather Douglas[3], Stephanie Bugden[2], Alyssa Wright[2], Gracynn Eades[3], Kierra Lodwick[2], Madison Young[2], Mikaila Collins[2], Sarah Melo[4]
[1] University of Ottawa [2] The University of Winnipeg [3] Carleton University [4] Louis Riel School Division

TOYBOX provides free, evidence-based numeracy, literacy, and wellness strategies for caregivers and their two-to-eight-year-old children (see TOYBOXManitoba.ca). The project was developed by parents and educators for caregivers (a) because there is limited content and pedagogical knowledge available for general audiences in Canada; (b) to address the concern that children who start school with skill and knowledge deficits have difficulty catching up; and (c) to take advantage of the learning opportunities that occur before school entry. TOYBOX was developed for Manitoba families because this province has the second highest child poverty rate in Canada. Overall, 1 in 4 children are developmentally vulnerable, with an even higher proportion of 1 in 2 for Indigenous children. Each TOYBOX strategy has three levels, accompanying illustrations, video tips, explanations about activity importance, academic references, curriculum links, and where possible, Indigenous applications. The first 108 strategies were made available during the pandemic through email, or via coloring books distributed to families in communities with limited internet. Eight out of ten caregivers that piloted the strategies (N=107) felt that the strategies helped their children learn numbers and letters; and they learned how to engage their children in learning opportunities, validating home learning research recommendations. Anecdotal data from a second controlled study (N=101 families) showed promising gains when children's number and letter skills were assessed pre- and post- intervention, and families were randomly assigned to one strategy type (numeracy vs literacy). These data will be unveiled during the presentation, along with a description of the TOYBOX project.

Presentation 3: Enhancing teachers' pedagogical awareness of teaching early mathematical skills to children

Piia Parviainen*[1], Kenneth Eklund[2], Merja Koivula[1], Tarja Liinamaa[1], Niina Rutanen [1]
[1] Department of Education, University of Jyväskylä [2] Faculty of Education and Psychology, University of Jyväskylä

Teachers' underlying pedagogical orientation and practices are critical in supporting children's mathematical skills development and learning in the context of early childhood education (Salomonsen, 2020). Therefore, pedagogical awareness, including awareness of 1) developmentally appropriate mathematical content, 2) appropriate mathematical teaching and learning, and 3) evaluation and reflection, is seen important in implementing early childhood mathematics education (Gasteiger & Benz, 2018). It is not, however, evident how teachers change their awareness when participating in a tailored mathematics professional development (PD) programme, designed around principles of transformative learning (Mezirow, 1991) and self-identified learning aims, besides, including implementation of mathematics education in child groups. This case study aimed to explore changes in teachers' (N=7) pedagogical

awareness of teaching early mathematical skills to 3- to 7-year-old children when participating in such programme. Standard ethical principles were followed throughout the study. Thematic analysis of semi-structured individual interviews revealed that observation, reflection, and active involvement in relation to theoretical orientation enhanced pedagogical awareness. Teachers broadened understanding of mathematical content that could be taught to different aged children, perceived essence of child-initiated mathematical learning, and discovered ways to teach mathematical skills in different daily situations and play. References:Gasteiger, H., & Benz, C. (2018). Enhancing and analyzing kindergarten teachers' professional knowledge for early mathematics education. Journal of Mathematic Behavior, 51, 109–117. https://doi.org/10.1016/j.jmathb.2018.01.002Mezirow, J. (1991). Transformative dimensions of adult learning. Jossey-Bass.Salomonsen, T. (2020). What does the research tell us about how children best learn mathematics? Early Child Development and Care, 190(13), 2150–2158. https://doi.org/10.1080/03004430.2018.1562447

Presentation 4: Role of early teacher-child interactions in numeracy skill development

Jenni Salminen*[1], Eija Pakarinen[1], Tuire Koponen[2], Marja-Kristiina Lerkkanen[1]
[1] Department of Teacher Education, University of Jyväskylä [2] Department of Education, University of Jyväskylä

Teacher-child interaction quality, as part of early learning environment in formal early childhood education, has been shown to benefit the development of variety of children's skills prior to school age, but only limited evidence exists for the development of early numeracy skills. This study investigates the role of early teacher-child interaction quality in toddler classrooms and the development of numeracy skills, when controlling for child's age, gender, and parental education. The 145 participating Finnish children (79 boys, 66 girls) were assessed individually in their early numeracy skills (object counting, number production, number sequences, math concepts) four times between ages 2.5 and 5.9. Observed quality of teacher-child interaction (i.e., emotional and behavioral support; engaged support for learning) in toddler classrooms (N = 42) was assessed with the CLASS-Toddler (La Paro et al., 2012). Parents (N = 126) reported on their education level. The analyses were conducted with longitudinal path models (Mplus, Complex option). Latent scores were used at age 2.5 and 5.5-5.9 to depict children's early numeracy skills. The results revealed that observed engaged support for learning in toddler classrooms (β= .219, p = .015), age (β= .365, p = .000), and parental vocational education (β= .177, p = .015) were related to children's numeracy skills at the age of 2.5. Math skills at age of 5.5-5.9 were predicted by earlier numeracy skills (β= .534, p = .000) but not by quality teacher-child interactions in toddler classrooms. The results highlight the importance of teachers' support for children's numeracy skills in toddlerhood.

Post-stroke numerical deficit (Acalculia): Prevalence, impact, assessment and interventions

Chair: Yael Benn
Department of Psychology, Manchester Metropolitan University, Manchester, UK

Acalculia is an acquired disorder following stroke or brain-injury. Symptoms can include difficulty processing numerical information (e.g., 'phone numbers), performing calculations or understanding quantities (money, time). Until recently, acalculia was not routinely screened

for as part of the standard care process, resulting in poor understanding of the prevalence, nature and impact of acalculia. This in turn has led to a lack of evidence-based, easily implementable interventions, with only a handful reported in the literature to date. Recent cognitive screening approaches (Oxford Cognitive Screen; OCS) now include numerical items, allowing us to gain insights into prevalence and range of symptoms. With numbers being increasingly important in modern life, stroke survivors have identified an urgent need to focus research on post-stroke acalculia to improve diagnosis and treatment. This symposium will present recent advances in bridging the gap between academic research on numerical cognition, and translation to clinical practice. The presentations in order will: 1. Report qualitative data exploring the impact of acalculia on patients' life. 2. Report analysis of the OCS database revealing the prevalence and nature of acalculic symptoms in English-speaking patients (n=~800). 3. Discuss the Ecological Assessment Battery for Numbers (EABN) and an intervention for transcoding deficit. 4. Describe brain-stimulation intervention (tDCS) for improving numerical cognition. Conclusions: Combined, we highlight the urgent need to increase awareness of acalculia amongst patients and professionals involved in post brain-injury care. There is a substantial and presently unmet clinical need to support professionals and patients by developing suitable evidence-based interventions for acalculia.

Presentation 1: The lived experiences of Acalculia

Yael Benn*[1], Mark Jayes[1], Martin Casassusa[2], Marney Williams[3], Colin Jenkinson[3], Ellen McGowan[4], Paul Conroy[5]

[1] Department of Psychology, Manchester Metropolitan University [2] Universidad Autónoma de Chile, Providencia, Región Metropolitana [3] PCPI (Patient, Carer & Public Involvement) [4] Pennine Care NHS Foundation Trust, Greater Manchester and Derbyshire [5] School of Health Sciences, University of Manchester

Aims: To understand the impact of acalculia on adults with acquired brain-injury, and to explore professional support available for patients. Methods: We explored the impact of acalculia on the lives of 16 brain-injury survivors (7 males) with acalculia and 7 carers (4 males), using semi-structured interviews. Participants ranged in age (mean = 58 years, SD=12.95), time post brain-injury (mean =7.39 years; SD=6.52), country of residence, and numeracy level prior to brain-injury. Data were analysed using thematic analysis. Results: Three main themes were identified: Awareness and Diagnosis, Emotional and Physical Impact, and Coping Strategies and Independence. Participants emphasised that concerns about language and mobility took precedence in the period immediately post brain-injury, and they only became aware of their difficulties with numbers later in their recovery. Both participants and carers repeatedly referred to the lack of awareness of, and support for, acalculia by all professionals (in contrasted with support given for equally prevalent conditions such as language difficulties). Many reported emotional and practical impact that acalculia has had on their lives and independence. Conclusions: Our results highlight the urgent need to increase awareness of acalculia amongst patients and professionals involved in post brain-injury care. There is a substantial and presently unmet clinical need to support professionals and patients by developing and integrating suitable assessments and interventions for acalculia.

Presentation 2: Acalculia: prevalence, nature, and brain-pathology

Madeeha Kahn Israeel*[1], Georgiana Apreutesei[1], Sam Webb[2], Yael Benn[1], Nele Demeyere[2]
[1] Manchester Metropolitan University [2] University of Oxford

Aims: To explore the prevalence of Acalculia, the nature of common acalculic errors, and examine the link between error-type and brain-lesion. Methods: The Oxford Cognitive Screen (https://www.ocs-test.org) includes seven number questions: three requiring the patients to write spoken numbers (e.g. 400, 708 and 15,200) and four calculations (e.g. 6+3, 7+9, 8-5 and 36-17). Patients' responses are recorded, and brain-scans are available for some patients. We have analysed data from N= ~800 (~450 with brain-scans) patients, recording the type of errors (e.g., lexical errors: 708 -> 700 8). We then matched common error-types with specific brain-pathology of patients (lesion-overlap analysis). Results: mid-analysis data of n=454 suggests that acalculic symptoms are common with 269/454 (59.25%) of patients making at least one error on the number questions. Common transcoding errors include lexical errors, and zero errors, both of which can result in devastating impact in real life (e.g., transferring 1000 instead of 100 pounds). Common calculation errors included errors with carry-over operations and small-to-medium estimation errors (e.g., 6+3= 8). Analysis of brain scans is still ongoing, but will be reported in June. Conclusions: Acalculia appears to have high prevalence. The availability of databases such as the OCS is limited, but the information that can be extracted from these is valuable for understanding the prevalence and nature of conditions, in order to prioritise the development of interventions for highly prevalent difficulties, and to begin examining the trajectory of recovery based on brain pathology and cognitive deficits.

Presentation 3: Assessment and behavioural intervention for acalculia

Maureen Lemanissier[1], Camille Riboulot[1], Charlotte Dehollain[2], Agnès Weill-Chounlamountry[2], Marie Villain*[3]
[1] Speech Therapy Department, Sorbonne Université [2] Pitié-Salpêtrière University Hospital [3] Sorbonne Université, Paris Brain Institute

Aims: To develop a measure for evaluating number-processing deficit in everyday life, and to assess the efficiency of acalculia intervention. Methods: The EABN (Robert et al., 2020; Villain et al., 2015) includes 8 timed-tasks modelling common daily situations involving number processing: shopping, cooking, etc. We used the EABN to assess acalculic symptoms among n=105 patients with neurological deficits (stroke, Traumatic Brain Injury, Mild Cognitive Impairment, Alzheimer), and to evaluate the effectiveness of an intervention targeting numerical transcoding in two patients with chronic acalculia. The protocol consisted of 3 phases: baseline phase involving general cognitive intervention (5-7 sessions); targeted numerical-specific intervention (10 sessions) and follow-up (3 sessions). The intervention was stepped, structured, and aided with visual and material aids (e.g. colours, tables, cubes). Results: Transcoding deficits symptoms were present among 68/105 patients (64.76%). When considering only stroke patients, left hemisphere lesions were associated with greater deficit. The intervention resulted in significant improvement in transcoding skills in both patients during the targeted intervention phase. Conclusions: We highlight the consequences of acalculia on activities of daily living, and illustrate that targeted intervention can be effective in improving transcoding skills. Further validation of intervention in this understudied area is essential.
References: Robert, H., Villain, M., Prevost-Tarabon, C., Cocquelet-Bunting, M., Glize, B., Pradat-Diehl, P., & Bayen, E. (2020). Annals of physical and rehabilitation medicine, S1877-

0657.Villain, M., Tarabon-Prevost, C., Bayen, E., Robert, H., Bernard, B., Hurteaux, E., & Pradat-Diehl, P. (2015). Annals of physical and rehabilitation medicine, 58(5), 283-288.

Presentation 4: Brain stimulation intervention (tDCS) for improving numerical skills

Maryam Hussain*, Nick Davis, Yael Benn
Department of Psychology Manchester Metropolitan University

Background: Previous studies have demonstrated that numerical skills can improve with the application of transcranial Direct Current Stimulation (tDCS), however studies typically involve reapplying tDCS over several days, which restricts the transferability of the method to patients with mobility issues. In addition, the accumulation of effects from numerous sessions can be dangerous.Aims: To investigate whether a single session of tDCS, followed by four home-practice sessions without tDCS, can result in enhancement of numerical skills.Methods: Nineteen university students learnt the magnitude association of nine arbitrary symbols, previously used by Cohen Kadosh et al. (2010). Numerical proficiency was assessed using a number-to-space task (placing a novel symbol onto a horizontal line with the "1" and "9" symbols placed at the left right ends respectively), and numerical Stroop (choose the symbol that is physically larger in size (e.g. 2 3)). tDCS (anodal to right parietal lobe and cathodal to left parietal lobe), was applied during the first training session to N=10, while N=9 participants received sham stimulation. Results: Single tDCS session significantly improved participants' response times and accuracy on the number-to-space mapping tasks, but not on the numerical Stroop task, implying that while learning improved, this learning did not become ‘automatic’ over the 5 sessions. Conclusions: Single session tDCS should be further considered as an avenue for interventions, perhaps with more intense or longer practice post-tDCS to achieve automaticity of processing. Reference: Cohen Kadosh, R., et al., (2010), Current Biology, 20(22); 2016-2020.

Word problems? No problem! School-based interventions for students with word-problem difficulty

Chair: Katherine Berry
The University of Texas at Austin

To show mathematics competency, students need to understand how to set up and solve word problems. Because many mathematics items in textbooks and on assessments are embedded within word-problem scenarios, word-problem proficiency proves necessary to demonstrate successful mathematics performance. Of concern, students with mathematics difficulty (MD) demonstrate lower word-problem performance and make significantly more errors when solving word problems than peers without MD (Kingsdorf & Krawec, 2014). A valuable approach for improving the word-problem skill of students with MD is through schema-based interventions. In word-problem interventions using schemas, students first identify a word problem as belonging to a problem type and then use a specific solution strategy associated with that schema to solve the problem. Developing schemas for categorizing word problems proves beneficial by helping students understand novel problems as belonging to familiar categories (e.g., Cooper & Sweller, 1987; National Research Council, 2001; Ng & Lee, 2009), and has been found to be more effective than other techniques for teaching word-problem

solving to students with MD (Zhang & Zin, 2012). In this symposium, we introduce researchers and educators to three efficacious schema-based word-problem interventions for implementation in schools: (1) Grade 3 Pirate Math Equation Quest Intervention; (2) Grade 3 Pirate Math Equation Quest Vocabulary Intervention; and (3) Grade 4 Multi-Step Word-Problem Intervention. Our objectives are to: (1) highlight the research on the teaching of schemas for single- and multi-step word-problem solving; and (2) review the components of effective word-problem instruction, particularly for students with MD.

Presentation 1: Grade 3 Pirate Math Equation Quest Intervention

Katherine Berry*, Jessica Mao
The University of Texas at Austin

The purpose of the Grade 3 Pirate Math Equation Quest Intervention was to determine the efficacy of a schema-based word problem intervention for third graders with mathematics difficulty (MD), and to explore the potential advantage of embedding pre-algebraic reasoning instruction within the intervention. We implemented a randomized control trial and randomly assigned 304 students to one of three conditions: Pirate Math Equation Quest (PMEQ) intervention (n = 105); Pirate Math without Equation Quest (PM-alone) intervention (n = 84); or the business-as-usual (BaU) comparison (n = 115). Our main research question was: Do the paths by which word-problem intervention improves word-problem performance differ for word-problem intervention with versus without embedded pre-algebraic reasoning instruction? For students assigned to treatment conditions, interventionists conducted sessions 3 times per week, for 16 weeks, 30 min a session (i.e., 48 sessions). PMEQ and PM-alone students participated in five activities during each session: (1) mathematics fact flash cards, (2) pre-algebraic reasoning and equal-sign practice (PMEQ) or mathematics review activity (PM-alone); (3) interventionist-led lesson featuring schema instruction; (4) schema sorting practice, and (5) cumulative review. PMEQ and PM-alone students demonstrated superior word-problem performance over the comparison group (BAU), with effect sizes of 2.66 and 2.44, respectively. The current study suggests an advantage for PMEQ and provides justification for the use of the equation-solving component within schema-based word-problem intervention. This research confirms the importance of teaching students to set up and solve word problems by using schemas and relying on mathematical equations to represent a word problem's structure.

Presentation 2: Pirate Math Equation Quest Vocabulary Intervention

Elizabeth Stevens, Audrey Leroux*
Georgia State University

Students' mathematics vocabulary knowledge positively relates to their mathematics performance (Powell et al., 2017). Students have general word knowledge (e.g., more, less) but require word-problem (WP)-specific word knowledge to successfully solve WPs (e.g., more than, less than; Kintsch & Greeno, 1985). We aimed to determine if WP-vocabulary instruction combined with schema instruction provided an advantage to WP solving for third-grade students with MD above and beyond schema instruction alone. In this study, we used the paper-and-pencil based Grade 3 Pirate Math Equation Quest but transformed the intervention to be delivered online over fewer sessions. We randomly assigned 75 third graders with MD to one

of three conditions: WP intervention with explicit vocabulary instruction (WP+V), WP intervention without vocabulary instruction (WP-only), or business-as-usual intervention (BAU). Students in the treatment conditions received 22, 50-min lessons provided virtually in small groups. Students in the WP+V condition received 12 min of explicit instruction on vocabulary commonly found within Grade 3 word problems. On a WP vocabulary measure, students in WP+V significantly outperformed students in WP-only (ES = 0.43) and BAU (ES = 0.83). On a WP measure, students in the WP+V outperformed students in WP-only (ES = 0.08) and BAU (ES = 0.43) with small to moderate effect sizes, although these were not significant. These findings provide preliminary support for the benefits of incorporating explicit vocabulary instruction in WP schema intervention to improve students' mathematics-vocabulary outcomes.

Presentation 3: Grade 4 Multi-Step Word-Problem Intervention

Tessa Arsenault*, Alison Hardy, Syeda Sharjina Akther, Sarah Powell
The University of Texas at Austin

Schema instruction enhances the word-problem solving skills of students with MD (Powell et al., 2020). However, most schema instruction research focuses on single-step word problems with additive problem types (Peltier & Vannest, 2017). Of the research on multi-step and multiplicative problems, authors report mixed results (Alghamdi et al., 2020). Given the focus on multi-step word problems on national standards in the elementary grades, there is a need to expand the research base on schema instruction. We implemented a randomized control trial to explore whether an algebraic reasoning component enhances the word-problem performance for multi-step word problems at Grade 4. We randomly assigned 132 students to three conditions: word-problem intervention with pre-algebraic-reasoning instruction (WP+PAR; n = 47), word-problem intervention without pre-algebraic reasoning instruction (WP-alone; n = 43), or business-as-usual (BAU; n = 42). For students assigned to the treatment conditions, interventionists conducted sessions 3 times per week, for 12 weeks, 35 min a session (i.e., 39 lessons). WP+PAR students learned to set up and solve multi-step word problems using a single equation with multiple operator symbols (e.g., (5 + 6) – 2 = 9) while WP-alone students solved multi-step word problems in two steps (e.g., 5 + 6 = 11; 11 – 2 = 9).From pretest to post-test, the average gain was 8.56 points for WP+PAR, 7.97 points for WP-alone, and 2.17 points for BAU. These findings extend our previous research by confirming the added value of an embedded pre-algebraic-reasoning component for solving multi-step word problems.

Discussant

Jonte Myers
Georgia State University

Cognitive, affective, and developmental factors in the spatial and ordinal understanding of numbers

Chair: Jenny Yun-Chen Chan
The Education University of Hong Kong

Spatial and ordinal understanding of numbers are important predictors of mathematics achievement. Using paradigms, such as number line, ordinal judgment, and numerical ordering, this symposium explores the affective influences (Paper 1), cognitive processes (Paper 2), developmental progressions (Paper 3), and spatial learning (Paper 4) of numbers. First, using the multi-directional number line estimation task, Leonard and Santos found that math, but not spatial, anxiety predicted number line estimation performance among UK undergraduate students, suggesting the roles and specificity of affective factors in spatial-numerical associations. Second, using the judgment and ordering tasks, Xu and colleagues found similar cognitive processes among Canadian third-graders, and their ordinal knowledge uniquely predicted arithmetic performance. The findings provide insights into the measures of ordinal knowledge and its role in mathematical development. Third, Chan and Mazzocco investigated US kindergartners' ordinal knowledge in space using children's number line estimates in relation to each other and the benchmarks. They found that ordinal knowledge predicted mathematics performance and this relation may be mediated through interval knowledge. Finally, Slipenkyj and colleagues trained adults on symbolic ordering through an associative paradigm vs. a spatial-positional paradigm. Both paradigms supported learning of endpoints; the spatial-positional paradigm also supported learning of the midpoint, but specifically in the spatial-positional task, suggesting an important role for learning and computational settings. Through these presentations (15 minutes each) and open discussion (15 minutes), we hope to stimulate collaborations across disciplines and continents to jointly advance our knowledge that promotes learning of spatial and ordinal numbers.

Presentation 1: Number Line Estimation is Associated with Maths Anxiety but not Spatial Anxiety: Evidence from a Multi-directional Number Line Paradigm

Sophie Leonard*, Flávia Santos
University College Dublin

The visuospatial number line is considered a window to understanding the long-standing link between space and numbers in the brain. However, domain-specific anxieties, namely maths and spatial anxiety may have long-term consequences on number-space mapping and winder mathematics achievement. This study examines the impact of maths anxiety and spatial anxiety on both number line estimation and purely arithmetic elements of mathematical performance. We designed a multi-directional number line paradigm comprising number line directionality (vertical top-to-bottom; vertical bottom-to-top; horizontal left-to-right or horizontal right-to-left) and modality (visual or auditory calculation) as variables. Performance was assessed using reaction time and accuracy data and analysed with self-reported levels of maths anxiety and spatial anxiety. The paradigm was administered online to 193 undergraduate students in the United Kingdom who received their primary mathematics education through English. Multivariate regression models indicated that while both arithmetic ($R^2 = .087$, $p < 0.001$) and number line aspects ($R^2 = .024$, $p < 0.05$) of performance were predicted by maths anxiety, no significant relationship was found for spatial anxiety across either domain. Furthermore, while

no gender differences were found in any aspect of task performance, significant differences were found in both anxieties relating to task performance. Results suggest divergences in the emotional factors impacting number line estimation, and the multi-directional number line task provides insight into the spatial underpinnings of the internal number line. The study received funding from the UCD Ad Astra Scholarship.

Presentation 2: A Direct Comparison of Two Measures of Ordinal Knowledge

Chang Xu*[1], Jo-Anne LeFevre[2], Sabrina Di Lonardo Burr[3], Erin A. Maloney[4], Judith Wylie[1], Victoria Simms[5], Sheri-Lynn Skwarchuk[6], Helena P. Osana[7]
[1] Queen's University Belfast [2] Carleton University [3] University of British Columbia
[4] University of Ottawa [5] Ulster University [6] University of Winnipeg [7] Concordia University

Children's knowledge of the ordinal relations among number symbols is related to their mathematical learning. Ordinal knowledge has been measured using judgment (i.e., decide whether a sequence of three digits is in order) and ordering tasks (i.e., order the three digits from the smallest to the largest). However, the question remains whether performance on these two ordinal tasks tap into similar cognitive processes. Canadian children (N = 87; Mage = 8.7 years, Grade 3) completed symbolic number tasks (i.e., number comparison, ordering, and judgment), measures of arithmetic fluency (i.e., addition and subtraction) and working memory (i.e., digit backward span). For both ordinal tasks, there was a reverse distance effect for ordered sequences such that children responded faster to adjacent than to non-adjacent sequences (e.g., 2 3 4 vs. 4 7 9) and a canonical distance effect for unordered sequences such that children responded faster to non-adjacent than to adjacent sequences (e.g., 4 2 3 vs. 4 9 7). Working memory and number comparison each predicted unique variance in the ordinal measures (ordering, judgment, and a latent ordinal factor based on the two measures). Furthermore, ordinal skills superseded the role of number comparison as the key predictor of arithmetic, controlling for children's gender and working memory skills. In summary, although both ordering and judgment tasks index ordinal knowledge, a latent factor that excludes task-specific error may be a better index than either task separately.

Presentation 3: Number Line Estimation Task Provides Insights into Children's Ordinal Understanding of Numbers

Jenny Yun-Chen Chan*[1], Michèle M. M. Mazzocco[2]
[1] The Education University of Hong Kong [2] University of Minnesota - Twin Cities

Children's performance on the number line estimation task, often measured by the percentage of absolute error (PAE), predicts their later mathematics achievement (Schneider et al., 2018). We propose that the task may also reveal (a) children's ordinal understanding of the target numbers in relation to each other and the benchmarks (e.g., endpoints, midpoints), and (b) the ordinal skills that are a necessary precursor to children's ability to understand the interval nature of a number line as measured by PAE. Using data from 104 US kindergartners, we measured whether children's estimates were correctly sequenced across trials and correctly positioned relative to a given benchmark within trials. Compared to children with average number of sequence errors, children with low sequence errors (i.e., correctly sequenced estimates across trials) scored higher on the Test of Early Mathematics Ability (TEMA). Similarly, compared to children with average number of benchmark errors, children with low benchmark errors scored higher on TEMA whereas children with high errors scored lower on TEMA. Although PAE fully mediated the relations between TEMA scores and either the

sequence or benchmark errors, our findings suggest that the number line estimation task may nevertheless reveal individual differences in children's ordinal understanding of numbers, and that such understanding may be a precursor to their interval understanding and later mathematics performance. Schneider, M., Merz, S., Stricker, J., De Smedt, B., Torbeyns, J., Verschaffel, L., & Luwel, K. (2018). Associations of number line estimation with mathematical competence: A meta-analysis. Child Development, 89(5), 1467–1484.

Presentation 4: Investigating the Impact of Learning and Computational Context on Ordered Artificial Symbol Sequences

Michael Slipenkyj*[1], Roma Siugzdaite[2], Jean-Philippe Van Dijck[2], Wim Fias[2], Ian Lyons[1]
[1] Georgetown University [2] Ghent University

In everyday life, there are numerous ways of learning ordinal information. However, it is unclear how learning and computational (i.e., task) context impact ordinal processing. In this study, two groups of participants were taught an artificial set of ordered symbols using feedback-driven learning. One group learned the symbols in an associative (i.e., pairwise comparison) paradigm, selecting which symbol in a pair belonged later in the ordered sequence. The other group learned the symbols in a spatial-positional paradigm (i.e., analogous to a number line verification task). In this task, a symbol was shown over a solid horizontal line, and participants responded whether that symbol was shown in the correct ordinal position. After extensive training (4 sessions on separate days), ordinal processing was evaluated using sequential versions of each group's task (i.e., the training task), followed by the other group's task (i.e., the transfer task). As expected, results demonstrated that both groups performed better on their own respective training task. Furthermore, we assessed the impact of symbol location in the sequence. In the associative task, both groups showed a general pattern of better performance for endpoint symbols. In the spatial-positional task, while the associative group again showed improved performance on the endpoint symbols, the spatial-positional group showed a tri-anchor pattern of better performance for the first, middle, and last symbol. This suggests that learning order spatially results in distinctive ordinal processing, but only in a spatial task. Broadly, these findings demonstrate that ordinal processing is influenced by computational and learning context.

Understanding the interplay of attention, executive function and mathematics by embracing complexity: From theory, to diversity, to intervention... and back to theory again

Chair: Gaia Scerif
Department of Experimental Psychology, University of Oxford

Attention and executive function (EF) are construed as key contributors to how we select information in our environment, commit this information to memory, to later retrieve and operate on it most effectively. Given these cognitive models, it is not surprising that individual differences in attention and EF correlate with indices of mathematics achievement, both concurrently and longitudinally. However, there remains a high degree of debate and uncertainty about the mechanisms underpinning these relationships. In this symposium, we

discuss the need to abandon models that treat domain-general skills in isolation, but rather embrace their complexity at multiple complementary levels. Eric Wilkey will begin our theoretical challenge to simple models of attention and EF, by presenting neuroimaging evidence that highlights the need to investigate the interplay between domain-general and domain-specific processes, rather than focusing on domain-generality. Emma Blakey will then cast a light on the importance of modelling complexity and diversity across children by investigating the interplay between socio-economic status, verbal abilities and EF as predictors of emerging mathematics. Rosie O'Connor will extend this focus on diversity in children, to diversity in the educators supporting them: she will discuss educators' variability in prior knowledge about EF and early years mathematics, and creative mixed methods solutions to capturing change in understanding of EFs in maths. Gaia Scerif will discuss causal models by reporting on the efficacy of an integrated EF and mathematics intervention involving preschool children and their educators. We aim to recruit an educator colleague to chair our session and challenge us.

Presentation 1: The domain-specificity of domain-generality: Attention, executive function, and academic skills

Eric Wilkey*
Vanderbilt University

Executive functioning (EF) is consistently implicated in the growth of academic skills such as literacy and numeracy. Deficits in EF often accompany learning disorders such as dyslexia and dyscalculia. Despite their well-established link, we lack a nuanced understanding of the specific neurobiological mechanisms that integrate the higher-order cognitive processes of EF with the control of lower-level cognition related to domain-specific skills. Current cognitive models often focus on the "domain-general" nature of EF, but much can be learned by embracing "task impurity" and empirically evaluating the interplay of domain-specific processing with higher-order cognitive constructs. I suggest that the focus on the domain-generality of EF has impeded exploration of its domain-specific roots.Using the example of number processing, I detail a series of neuroimaging studies exploring how domain-specific mechanisms interact with domain-general processing. These studies show that congruent and incongruent trials in a traditional non-symbolic number comparison task elicit different levels of activation in areas of the parietal lobe known to encode number. They also suggest that neural signatures associated with processing the congruency of visual cues, and not simply number in general, relate to mathematics achievement. These results have been published alongside a number of recent studies that explore the neural signatures of selective attention to number and EF research that has investigated individual differences in context-specific EF. These data provide promising insights about how we might further our understanding of the influence of domain-general processing on domain-specific academic skill development.

Presentation 2: Why do Inequalities in Early Maths Skills Arise?

Emma Blakey*[1], Ella James-Brabham[2]
[1] University of Sheffield [2] Loughborough University

By school entry, socioeconomic attainment gaps are apparent in maths ability and these gaps widen over development. However, little is known about the mechanisms that drive early disparities. We aimed to take a comprehensive look at what factors correlate with

socioeconomic attainment gaps, by examining executive functions, verbal ability and home maths activities, factors which are often studied in isolation. Across two studies (N=196, N=145), with children from socially diverse backgrounds and with different measures, we find that socioeconomic disparities in maths are apparent at age 3. These disparities are mediated by executive functions - with strong links to inhibitory control – and verbal ability. Despite substantial variation in home maths activities, they did not correlate with socioeconomic status or children's maths skills. We propose a model where socioeconomic status may influence the development of verbal skills which in turn impacts executive functions, and this shapes children's ability to learn and do maths. We discuss the importance of longitudinal research and randomised control trials with these factors to confirm whether these are causal determinants of attainment gaps. This work will be essential in understanding how we can narrow attainment gaps and support all children to thrive in maths.

Presentation 3: Knowledge of Mathematics and Executive Functions in Preschool Educators: Intervening and Measuring Change

Rosemary O'Connor*[1], Sylvia Gattas[1], Amy Godfrey[1], Zachary Hawes[2], Steven Howard[3], Rebecca Merkley[4], Gaia Scerif[1]
[1] Department of Experimental Psychology, University of Oxford [2] Department of Applied Psychology and Human Development, University of Toronto [3] School of Education, University of Wollongong [4] Department of Cognitive Science, Carleton University

Although evidence points to executive functions (EFs) playing a central role in the development of mathematical skills, the concept of EF is often unfamiliar to early childhood educators. It is also common for preschool practitioners to report a lack of confidence in their own mathematics. This may, in turn, impact their likelihood to engage in early years mathematics activities over and above other educational targets. Providing practitioners with the knowledge and skillset to support children's EF skills in the context of early years mathematics may be an effective way to improve the quality of mathematical education at preschool. This talk will focus on the knowledge development element of a feasibility trial of the ONE programme: an early years intervention that aims to support educators to embed executive challenge in mathematical education through professional development sessions and a set of activities for educators to carry out with the children. N=51 practitioners at 15 settings provided quantitative data on their prior knowledge and confidence, as well as preschool practices. An average of 4.14 practitioners across 8 settings took part in The ONE programme, contributing data on knowledge change at the setting level. Given the variation in staff experience and the lack of prior knowledge of EFs, test-like methods of capturing knowledge were not appropriate. Instead, a novel, mixed-methods approach to measuring knowledge and knowledge change will be described. Findings indicate both qualitative and quantitative intervention-related changes in practitioner knowledge. Implications will be discussed for future educational intervention design.

Presentation 4: From practice back to theory: Making the executive 'function' via integration with early years mathematics

Gaia Scerif*[1], Sylvia Gattas[1], Zachary Hawes[2], Steven Howard[3], Rebecca Merkley[4], Rosemary O'Connor[1], Jelena Sugevic[1]
[1] Department of Experimental Psychology, University of Oxford [2] Department of Applied Psychology and Human Development, University of Toronto [3] School of Education, University of Wollongong [4] Department of Cognitive Science, Carleton University

A vast body of work highlights executive functions (EFs) as robust correlates of mathematics achievement over the primary and preschool years. Yet, despite such correlational evidence, there is limited evidence that EF interventions yield improvements in early years mathematics. As intervention studies are a powerful tool to move beyond correlation to causality, failures of transfer from executive functions interventions are highly problematic for theory. We hypothesised that an intervention that considers EF in its interplay with mathematical content and the environment are more likely to be effective in supporting mathematics development than intervention that treat EF in isolation, or "business-as-usual" (BAU) environments that do not routinely consider the integration of EF with mathematics. 193 children took part (mean age = 47.2 months). Each child completed multiple mathematics and EF assessments before and after The ONE programme. Environmental indices were also obtained: child eligibility for early years pupil premium status (EYPP) was used as a proxy low socio-economic status (SES). The intervention group achieved higher scores than the BAU group on a combined numeracy measure, and the EF index. Modelling EYPP eligibility revealed interaction effects of intervention and EYPP: EYPP-eligible children in the intervention group scored higher than those in the BAU group on three numerical measures and on two EF measures. Our findings emphasise the need to consider the dynamic interplay of EFs with co-developing cognitive functions such as early mathematics skills, and the environment in which they develop, when building causal models about the role of EF in mathematics.