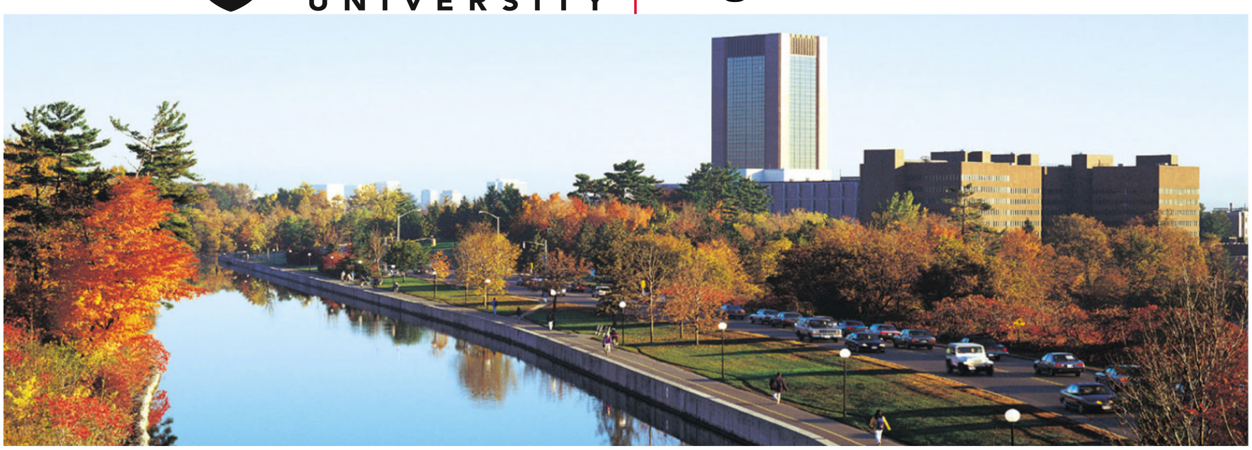
MATHEMATICAL COGNITION AND LEARNING SOCIETY

Program
2019 Mathematical Cognition and Learning Society Conference

June 16-18, 2019
Carleton University, Ottawa ON, Canada

Local Organizers:
Jo-Anne LeFevre, Rebecca Merkley, Erin Maloney, Chang Xu, Emilie Roy

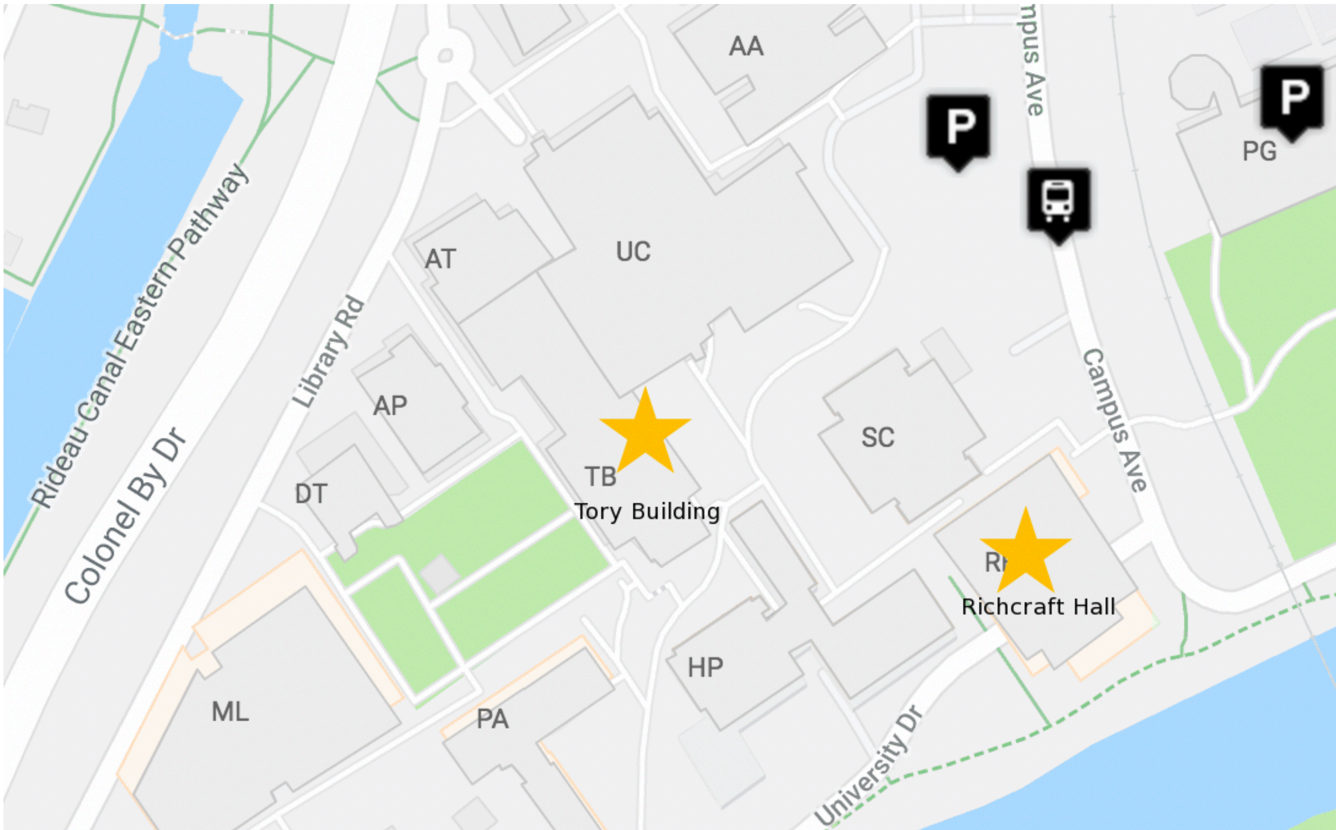
Carleton UNIVERSITY | INSTITUTE OF Cognitive Science



Program Overview

	16 June	17 June	18 June
8:00am 8:30am	Registration Coffee & Tea	Registration Coffee & Tea	MCLS Business Meeting – RB2200/RB Atrium Coffee & Tea
9:00am	**Pre - Conference workshops** Bayesian analysis – RB2200 Writing – TB446 Open Science – TB447	Symposia Session 3 9:00 - 10:05am S7 (TB446), S8 (TB447) S9 (RB2200),	Symposia Session 7 9:00 - 10:05am S19 (RB2200), S20 (TB446), S21 (TB447)
10:25am		Symposia Session 4 10:25 - 11:30am S10 (TB446), S11 (RB2200), S12 (TB447)	Symposia Session 8 10:25 - 11:30am S22 (TB446), S23 (RB2200), S24 (TB447)
11:50am	**Lunch** Opening Remarks RB Atrium	**Lunch** Poster Session 2 11:50 - 1:30pm (P2)	**Lunch** Poster Session 4 11:50 - 1:30pm (P4)
1:00pm	Symposia Session 1 1:00 - 2:05pm S1 (TB446), S2 (RB2200) S3 (TB447)		
1:40pm		Symposia Session 5 1:40-2:45pm S13 (RB2200), S14 (TB446) S15 (TB447	Symposia Session 9 1:40 - 2:45 pm S25 (RB2200), S26 (TB447), S27 (TB447)
2:30pm	Symposia Session 2 2:25 - 3:30pm S4(RB2200), S5 (TB446), S6(TB447)		
3:10pm		Symposia Session 6 3:10- 4:15pm S16 (RB2200), S17 (TB446) S18 (TB447)	Symposia Session 10: 3:10- 4:15pm S28 (TB447), S29 (TB446) S30 (RB2200)
4:00pm	Poster Session (P1) Cash Bar and Appetizers Lightning Talks (L1) - RB 2200 C1 - C3 [4:00 – 4:15 pm] L1 – L6 [4:30 – 5:00 pm] L7 – L12 [5:15 – 5:45 pm]		
4:15pm		Poster session (P3) Cash Bar and Appetizers Lightning talks (L2) RB 2200 C4 - C6 [4:30 – 4:45 pm], L13 - L18 [5:00 – 5:30 pm] L19 - L24 [5:45 – 6:15 pm]	Closing Remarks RB Atrium
6:00pm			

RB – Richcraft Building (second floor); TB – Tory Building (fourth floor); All Poster Sessions in Richcraft Atrium



Day 1: Sunday June 16

9:00 am – 12:00 pm: Pre-conference workshops

12:00 pm – 1:00 pm: Lunch (RB Foyer) and Welcome (12:30 in RB 2200)

1:00 - 2:05 Symposia session 1

S1	**Home numeracy activities and mathematical achievement** 1: Venera Gashaj, University Pompeu Fabra, Barcelona 2: Sum Kwing Cheung, The Education University of Hong Kong 3: David Munez, National Institute of Education, Singapore 4: Kerry Lee, The Education University of Hong Kong	**TB446**
S2	**Numerical skills and cognition in kindergarten: Predictors of individual differences in math ability and growth in math skills in early elementary school.** 1: Nathan Lau, Western University, Canada 2: Andrew Ribner, University of Pittsburgh, USA 3: Rebecca Bull, Macquarie University, Australia 4: Daniel Ansari, Western University, Canada	**RB2200**
S3	**Understanding Mathematical Notations and Representations** 1: Dirk Schlimm, McGill 2: Ulises Xolocotzin Eligio, Cinvestav 3: Juan Pablo Mejía Ramos, Rutgers University, USA 4: David Landy, Indiana University	**TB447**

2:25 - 3:30 Symposia session 2

S4	**A tricky mathematical problem: Developing rigorous and valid measurements of the preschool home numeracy environment** 1: Victoria Simms, Ulster University, UK 2: Camilla Gilmore, Loughborough University, UK 3: David Purpura, Purdue University, USA 4: Sanne Rathé, KU Leuven, Belgium	**RB2200**
S5	**Numerical Cognition: Domain-General and Domain-Specific Processes** 1: Elien Bellon, KU Leuven 2: Ian Lyons, Georgetown University 3: Jamie Campbell, University of Saskatchewan 4: Angélique Roquet, Aix-Marseille Universite	**TB446**
S6	**Number line estimation: Understanding strategy use, digit placement, and gamification for typical and atypical number lines.** 1: Korbinian Moeller, Leibniz-Institut für Wissensmedien, Tuebingen, Germany 2: Hilary Barth, Wesleyan University, CT, USA 3: Koen Luwel, KU Leuven, Belgium 4: Sabrina Di Lonardo, Carleton University	**TB447**

4:00 pm-6:00pm: Poster Session (P1; RB Foyer) and Lightning Talks (L1: RB 2200)

4:**00pm Lightning Talks Session 1**

4:00 pm Collaboration Pitches	C1. **Opportunities to Learn via Big Data in a Numeracy Intelligent Tutor** - Rene Grimes, University of Texas, Austin C2. **Mathemarmite: a video game to train children count** - Pedro Cardoso-Leite, University of Luxembourg C3. **Study of the causal role of the intraparietal sulcus in tasks that involve complex processing of magnitudes: space, number and time** - Sara Garcia Sanz, Universidad de la Sabana, Colombia
4:30pm Data Blitzes	L1. **Math and the brain: Lessons from functional neuroimaging** - Marie Arsalidou, National Research University, Moscow L2. **Pupillometric Indices of Arithmetic Approximation in College-Aged Adults** - Amanda L. McGowan, Michigan State University L3. **Effects of different transcranial electrical stimulation protocols on arithmetic learning** - Jochen Mosbacher, University of Graz L4. **Development of a Negative Priming effect in a non-symbolic numerical comparison task** - Arnaud Viarouge, University Paris Descartes L5. **Investigating the modality specific cognitive abilities predictive of arithmetic ability** - Rosemary Penford, University of Cambridge L6. **Rules of Order: Evidence for a fundamental bias when processing the ordinality of numbers** - Selvia Gattas, Georgetown University
5:15pm Data Blitzes	L7. **Spontaneous Gestures When Explaining Fraction Comparison Problems** - Michelle Hurst, University of Chicago L8. **Predictors of Fraction Word Problem Solving** - Haobai Zhang, University of

	Delaware L9. **Spatial Representations of Symbolic Fractions and Non-Symbolic Ratios: SNARC Effects and Number Line Estimation** - Rui Meng, University of Wisconsin L10. **Changes in Students' Fraction Arithmetic Errors from Fourth through Sixth Grades in Response to Classroom Fraction Instruction** - Kelly-Ann Gesuelli, University of Delaware L11. **Specific early numeracy skills mediate the relation between executive function skills and mathematical skills** - Jenny Yun-Chen Chan, University of Minnesota L12. **Giving students control: Improving the math outcomes of at-risk elementary students** - Macey Cartwright, University of Cincinnati

4:**00pm Poster Session 1**

1	The Role Of Continuous Visual Cues In Numerosity Perception: A Computational Investigation		Alberto Testolin
2	Parental Beliefs About Math Importance Buffer Against The Effect Of Parental Math Anxiety In Preschool-Aged Children		Alex Silver
3	The Utility Of Audio Recordings For Examining Kindergarten Math Instruction	(P)	Alexa Ellis
4	Modeling Median Estimates Overstates Regularity In Children's Number Line Estimation		Alexandria A. Viegut
5	Teaching Geometric Similarity With Dynamic Digital Technology: A Multiple-Case Study Of Classroom Practices Of English Secondary Mathematics Teachers	(P)	Ali Simsek
6	The Importance Of Representational Shift: An Investigation Of The Cognitive Mechanisms And Individual Differences Underlying Math Performance		Allison Liu
7	Anxiety And Children's Mathematical Learning: Testing An Expressive Writing Intervention		Almaz Mesghina
8	The Neural Correlates Of Mathematical Learning In 8- To 10-Year-Old Children	(P)	Alyssa Kersey
9	Navigating The Relations Between Spatial Processes And Performance On Numerical And Mathematical Tasks		Andie Storozuk
10	Investigating The Influence Of Graphical And Textual Framing On Problem Solving Accuracy And Strategy Use		Anna Bartel
11	Is Computationally-Complex Behavior Embedded In The ANS?		Anna J Wilson
12	Patterns In Parents' Broad Early Math Support		Ashli-Ann Douglas
13	Task-Evoked Connectivity Of The Putative Number Form Area In Typically Developing Kindergartners		Benjamin Conrad

14	The ERP Effects Of Shared Components In Fraction Comparisons	(P)	Brian Rivera
15	Underpinnings Of Early Addition: Investigating Number Partners Understanding	(P)	Brianna Devlin
16	Is Writing Handedness Involved In The Neural Representation Of Symbolic Number?		Celia Goffin
17	Endpoint Reversal And Digit Dependence In Numerical Estimation		Chenmu Xing
18	Small Vs. Large: An Examination Of Gevers Et Al. (2006) Using Word Primes	(P)	Craig Leth-Steensen
19	Working Memory: Reliability Analysis Of Measures Within Mathematics In Grade School Age Children In The United States	(P)	Dana Miller-Cotto
20	Effects Of Attitudes, Mindset, And Anxiety On Children's Numeracy Attainment		Dawn Short
21	A Deep Learning Method To Compare Problem Similarity In Education.		Dominic Mussack
22	Children's With Different Profiles Of Direction Of Effect Understanding Demonstrated Different Levels Of Mathematics Achievement		Eason Sai-Kit Yip
23	To The Math Anxious, What Is Considered Math?	(P)	Eli Zaleznik
24	Acquisition Of French Un		Elisabeth Marchand
25	How Preschool Teachers Use Math Talk Across Different Instructional Times And Activities	(P)	Emily Braham
26	"When Will I Need This In The Real World?": Realistic Problem Solving In Sixth Graders		Emily J. Rowe
27	The Emergence Of Gender Gaps In Math Learning During A Single High-Quality Instructional Opportunity		Emily Lyons
28	The Innateness Of Number: A Case Study Using Children's Counting Books		Emily Sanford
29	Comparing Response Modes In Number Line Estimation: Does It Matter When You Respond With A Mouse Or With Your Eyes?		Kelsey J. Mackay
30	Physical Fitness Correlates With Kindergarteners' Mathematics Other Than Language		Li Wang
31	Does It Add Up? Comparing Arithmetic Processing In Bilinguals And Monolinguals	(P)	Mona Anchan
32	Non-Symbolic Comparison Of Stimulus Magnitudes In An Artificial Algebra Without Feedback		Nicola Morton
33	Why We Love Or Hate Math: How Experiences Shape Attitudes About Math		Rachel Jansen

Day 2: Monday June 17

9:00 - 10:05 Symposia session 3

S7	**Improving mathematics using cognitive training: From basic mechanisms to translation** 1: Korbinian Moeller, University of Tubingen, Germany 2: Roi Cohen Kadosh, University of Oxford, England 3: Geetha B. Ramani, University of Maryland, College Park, USA 4: Torkel Klingberg, Karolinska Institutet, Sweden	**TB446**
S8	**Language, culture, and numerical thinking in non-industrialized cultures** 1: Isabelle Boni, UC Berkeley 2: Rose M. Schneider, UC San Diego 3: Benjamin Pitt, UC Berkeley 4: Tania Cruz, UC Berkeley	**TB447**
S9	**Whole Number Bias: Developmental, Contextual, Linguistic and Neural Perspectives** 1: David W. Braithwaite, Florida State University 2: Jake McMullen, University of Turku, Finland 3: Kexin Ren, Temple University, USA) 4: Miriam Rosenberg-Lee, Rutgers University, USA	**RB2200**

10:25 - 11:30   Symposia session 4

S10	**Are inhibitory skills important for mathematical performance?** 1: Caron Clark, University of Nebraska 2: Kerry Lee, The Education University of Hong Kong 3: Sum Kwing Cheung, The Education University of Hong Kong 4: Bert de Smedt, University of Leuven, Belgium	**TB446**
S11	**Current Directions in Symbolic Number Processing** 1: Hans-Christoph Nuerk, University of Tuebingen, Germany 2: Erin Maloney, University of Ottawa 3: Krzysztof Cipora University of Tuebingen, Tuebingen 4: Tom Faulkenberry, Tarleton State University, Texas	**RB2200**
S12	**Language: A tool for learning arithmetic** 1: David J. Purpura, Purdue University 2: Kiran Vanbinst, University of Leuven 3: Chang Xu, Carleton University 4: Jason C. Chow, Virginia Commonwealth University,	**TB447**

11:50 am - 1:30 pm: Lunch + Poster session (P2) in RB Foyer

34	Executive Function And Math Achievement: A Meta-Analysis On Early Sex Differences	(P)	Dominic Kelly
35	Development Of Decomposed Parallel Processing In Dual Language Immersion Second Graders	(P)	Emily Speed

36	Testing The Motor Simulation Theory In Processing Canonical And Non-Canonical Finger Numeral Configurations		Firat Soylu
37	Calcularis® Efficacy In Children With Developmental Dyscalculia Barely Familiar With Computers		Flavia Santos
38	The Role Of The Need For Cognition In Math Anxious Students' Mathematic Achievement		Fraulein Retanal
39	Math Vocabulary And Fraction Mapping Skills		Hafsa Hasan
40	Quantity And Quality Of Gestures Are Related To Performance On An Embodied Geometric Estimation Task		Hannah Smith
41	Cross-Cultural Differences In Children’s Mathematical Development: Investigating The Home Numeracy Environment	(P)	Heather Lyle
42	Modality Preferred Network In Visual And Auditory Magnitude Processing Predict Arithmetic Performance	(P)	Hui Zhao
43	Cross-Linguistic Effects On Adults’ Number Line Estimation Skills		Iro Xenidou-Dervou
44	The Ratio Processing System Supports Non-Symbolic Ratio Arithmetic		Isabella Starling Alves
45	Fractions, Decimals, Percentages: Rational Numbers In Cognitive Arithmetic		Jacob Bornheimer
46	Monotonic Responses To Numerosity In Early Visual Cortex Are Eccentricity Dependent		Jacob Paul
47	Fraction Card Games For Connecting Area Models And Symbols	(P)	Jacob R. Butts
48	Maternal Gender Biases In Early Exposure To Mathematics		Jamie Patronick
49	Algebraic Vs. Arithmetic Conceptions Of ‘X’ When Solving Missing-Operand Problems		Jeffrey Bye
50	Experience With A Dynamic Algebra Notation System Predicts High-School Students’ Algebra Performance		Jenny Yun-Chen Chan
51	Word Problems: How Performance Varies With ADHD Traits And Math Anxiety		Jesse Nietmann
52	Rote Versus Rule: Revisiting The Role Of Language In Mathematical Thinking		Jike Qin
53	An Investigation Into Children’s Mathematics Attitudes And Their Arithmetic Fluency: How Do Teachers And Parents Play A Role In Their Development?		Jill Price
54	Cross-Language Differences In Remembering And Identifying Fractions		Jimin Park
55	The Effects Of Technology On Problems-Solving Skills For Low-Achieving Students		Jiyeon Park

56	Effects Of Transcranial Electrical Stimulation On Arithmetic Learning And Neural Plasticity	(P)	Jochen A. Mosbacher
57	Confidence Counts: Relationships Between Math Dispositions And Fractions Knowledge.		John Binzak
58	Effects Of Combined Attention And Math Interventions In At-Risk Pre-Kindergarten Children Are Moderated By Working Memory		Marcia Barnes
59	Gain Scenarios Promote Attention To Number, Instead Of Proportion, During Proportional Reasoning Tasks		Karina Hamamouche
60	Understanding Of Arithmetic Concepts: Does Problem Format Matter?		Katherine M Robinson
61	Exploring Differential Relations Between Spatial Abilities And Domains Of Mathematics In Grade 2	(P)	Katherine Winters
62	Does The Relationship Between Visual Spatial Skills And Mathematical Ability Persist Or Change During Primary School?	(P)	Laura Outhwaite
63	Cognitive Markers Of High And Low Mathematical Performance In Preschool Children		Merel Bakker
64	Assessing The Influence Of Task-Context On The Neural Coding Of Quantities		Michael Slipenkyj
65	Fraction Reduction Is Cued By Division But Not By Multiplication		Shawn Tan
66	Form Perception Predicts Septinary Addition Achievement		Shijia Fang
67	Children’s Math Abilities And The Relation To Risky Decision Making: A Study Proposal	(P)	Shirley Duong

1:40 - 2:45 Symposia session 5

S13	**Expanding examinations of spontaneous mathematical focusing tendencies** 1: Michele Mazzocco, University of Minnesota 2: Alex Silver, University of Pittsburgh 3: Richard Prather, University of Maryland 4: Jake McMullen, University of Turku, Finland	**RB2200**
S14	**Home numeracy and early math skills in Latin America: Findings from Chile, México, and Uruguay** 1: María Inés Susperreguy, Pontificia Universidad Católica de Chile. 2: Diana Leyva, Davidson College 3: Dinorah de León, Universidad de la República, Uruguay 4: Carolina Jiménez Lira, Universidad Autónoma de Chihuahua	**TB446**
S15	**Neuroscience of Dyscalculia** 1: Bert De Smedt, University of Leuven, Leuven, Belgium 2: Karin Kucian, University Children's Hospital, Zurich 3: Teresa Iuculano, Centre National de la Recherche Scientifique & Université de Paris, La Sorbonne 4: Mojtaba Soltanlou, Department of Psychology, University of Tuebingen, Tuebingen, Germany	**TB447**

3:10 – 4:15 Symposia session 6

S16	**Individual Differences in Fractions Knowledge** 1: Priya B. Kalra, University of Wisconsin-Madison 2: David W. Braithwaite, Florida State University 3: Jake McMullen, University of Turku Discussant: Martha W. Alibali, University of Wisconsin-Madison	**RB2200**
S17	**Beyond number sense: Exploring the contribution of domain-general cognitive processes to the development of mathematical thinking** Discussant: Rebecca Merkley, Carleton University 1. Ilse Coolen, Université Paris Descartes 2: Eric Wilkey, University of Western Ontario 3: Kelly Mix, University of Maryland 4: Gavin Price, Vanderbilt University	**TB446**
S18	**Leveraging gesture to enrich math learning for diverse learners** 1: Ruth B. Church, Northeastern Illinois University 2: Elizabeth M. Wakefield, Loyola University, Chicago 3: Susan W. Cook, University of Iowa 4: Shereen O. Beilstein, University of Illinois Urbana-Champaign	**TB447**

4:30 pm - 6:15 pm: Poster Session (P3: RB Foyer) and Lightning talks (L2: RB 2200)

4:30 pm Lightning Talks Session 2

4:30 pm Collaboration Pitches	C4. **Effects of attitudes, mindset, and anxiety on children's maths performance** - Dawn Short, Abertay University C5. **Home Numeracy Experiences In Many Countries** - Jo-Anne LeFevre, Carleton University C6. **Working memory and math performance: the influences of SES and parenting practices** - Kerry Lee, The Education University of Hong Kong
5:00 pm Data Blitzes	L13. **Move over worksheets: Parents want preschool to be math fun and engaging** - Michele Stites, University of Maryland Baltimore County L14. **Preschool Children's Changes over Time in Affective Attitudes towards Mathematics: A Latent Transition Analysis** - Xiao Zhang, University of Hong Kong L15. **Partial Number Word Knowledge on the Give-N Task** - Connor O'Rear, University of Notre Dame L16. **Number gesture, finger gnosia and manual dexterity : Which contribution to verbal number knowledge development?** - Laurence Rousselle, University of Liege L17. **Which is more, 123 or 321?: A study on preschool children's understanding of place value** - Pierina Cheung, National Institute of Education, Singapore L18. **Finger games to improve basic numerical skills in preschool children as a precursor of arithmetic learning later** - Line Vossius, Research Unit 'Enfances', Liege, Belgium
5:45 pm Data Blitzes	L19. **Conceptions of math and art are linked to avoidance of the domains** - Rachel Jansen, University of California Berkeley **L20. Measuring mathematical ability during the transition to college -** Dominic Kelly, University of Michigan **L21. Birth of the First Mathematical Concepts. (Mathematics About 2 Million Years Ago) -** Said Boutiche, Université de Boumerdes **L22. What Explains the Covariance Between Arithmetic and Reading? A Multivariate Model** – Vivian Singer, Universida Alberto Hurtado **L23. Collecting Surveys and Consent Forms from Parents for Basic Cognitive Research; What Worked, What Didn't Work, and a Few Surprises…** - Sheri-Lynn Skwarchuk **L24. What are we missing in math assessments? Validating an IRT based math assessment in kindergarteners.** - Alexa Ellis, University of Michigan

4:30 pm Poster Session 3			
68	Cross-Notation Symbolic Number Comparison With Single- And Double-Digit Numbers		Irina Surducan
69	Re-Inverting Inversion: Natural Offloading In Number Transcoding?		Julia Bahnmueller

70	Improving Numeracy In Children With Down Syndrome Through Computer-Based Cognitive Training		Marco Zorzi
71	Spatial Biases Induced By Mental Arithmetic And The Impact Of Task Difficulty		Maria Glaser
72	Involving Parents In Children's Learning And Perceptions Of Math Through Board Games		Martin Buschkuehl Brandon Smith
73	Arithmetic Learning In Children – An Fmri Training Study		Merel Declercq
74	Is Bilingualism Really A Plus? Investigating Addition Mechanisms In Children Using Fnirs And Eye-Tracking	(P)	Mona Anchan
75	One-Year Follow-Up On A Classroom-Based Mindfulness Program For Math Anxiety		Nadine Yildiz
76	Non-Symbolic Addition In An Artificial Algebra		Nicola Morton
77	The Development Of Symbolic Magnitude Understanding In Early Childhood	(P)	Nicole Scalise
78	Mathemarmite: A Video Game To Train Children Count		Pedro Cardoso-Leite
79	Exploring The Symbolic Math Processing In Immersion And Non-Immersion Students		Renée Whittaker
80	Testing The Specificity And Extent To Which State-Level Math Anxiety Explains The Link Between Trait-Level Math Anxiety And Online Math Performance		Richard Daker
81	Fraction Education Based On Cognitive Neuroscience Theory And 4A-Instructional Model Intermediated By A Lesson Study	(P)	Rogéria Toledo
82	Representing Numerical Information Across Different Formats In The Adult Brain		Ruizhe Liu
83	Using Mathematics Applications As Digital Home Intervention Tool	(P)	Sabrina Shajeen Alam
84	Approximate Number System Acuity In Girls With Turner Syndrome: A Model For Pathways To MLD		Sarah Lukowski
85	Variables That Influence The Algebra Performance Of University Students		Sarah Powell
86	Representation And Processing Of Exponential Expressions		Sashank Varma
87	Cognitive Support For Learning Fractions By Analogy		Shuyuan Yu
88	Evaluating The Neural Correlates Of Fraction Arithmetic: An Fmri Study	(P)	Silke M. Bieck
89	Number Sense In Children With Cerebral Palsy		Silvia Cristina De Freitas Feldberg

90	Componential Vs. Holistic Processing Of Fractions: A Cross-Language Difference Of Fraction Reading Order In English And Korean		Soo-Hyun Im
91	Nonsymbolic Number Processing In Children With Hearing Loss		Stacee Santos
92	The Brain Correlates Of Numerical Order Processing And Their Relationship To Arithmetic Performance In Children: A Functional MRI Study		Stephan E. Vogel
93	Influences Of Stimulus Complexity On Infant Number Discrimination: Shapes Vs. Faces		Taylor Williams
94	From The Eye Of Children With Mathematics Learning Disability: Do They Perceive Arithmetic Word Problems Differently?		Terry Tin-Yau Wong
95	Knowing How And What To Count: Children's Conceptual Counting Mistakes Are Uniquely Related To Early Numeracy		Theresa Elise Wege
96	Early Numerical Skills And School Trajectory		Victor Koleszar
97	How Is Finger Counting Related To Addition Learning In First Graders?		Vitor Geraldi Haase
98	The Number-Weight Illusion		Wolf Schwarz
99	Perceptions Of The Magnitude Of Mathematical Language Terms In Preschoolers And Adults	(P)	Yemimah King
100	Different Roles Of Number-Quantity Processing In The Development Of Children's Arithmetic Skills		Yiyun Zhang
101	Where And Under What Conditions Do Spatial And Numerical Cognition Converge And Diverge In The Brain? An fMRI Meta-Analysis.		Zachary Hawes

Day 3: Tuesday June 18

8:00 am – 9:00 am: MCLS Business Meeting [everyone welcome; light breakfast] RB2200

9:00 - 10:05 Symposia session 7

S19	**Early numerical and non-numerical abilities and their relation with mathematical education** 1: Wei Wei, Zhejiang University, China 2: Sara Caviola, University of Leeds 3: Tali Leibovich-Raveh, University of Haifa 4: Krzysztof Cipora, University of Tuebingen, Tuebingen,	**RB2200**
S20	**Mathematical discourse - The symbols we use to communicate mathematical ideas** 1: Sarah Powell, University of Texas 2: Heather Douglas, Carleton University 3: Erica Zippert, Vanderbilt University 4: Discussant: M. Gail Headley, University of Delaware	**TB446**
S21	**From the math lab to the math class: can we improve math learning by targeting specific cognitive mechanisms?** 1: Flávia H. Santos, University College Dublin 2: Ipek Saralar, University of Nottingham 3: Ann Dowker, Oxford University, England 4: Dror Dotan, Tel Aviv University, Israel	**TB447**

10:25 - 11:30 Symposia session 8

S22	**Early Mathematical Screening Tools: Bridging the Research-Practice Gap** 1: Marcie Penner, King's University College at Western University 2: Brianna Devlin, University of Delaware 3: Stephanie Bugden, University of Pennsylvania 4: Rebecca Merkley, Carleton University	**TB446**
S23	**Unpacking Manipulatives: Recommendations for the Mathematics Classroom** Chair: Helena Osana, Concordia University 1: Anne Lafay, Concordia University 2: Andrea M. Donovan, University of Wisconsin—Madison 3: Emmanuelle Adrien, Concordia University Discussant: Martha W. Alibali, University of Wisconsin—Madison	**RB2200**
S24	**Cognitive Underpinnings of Mathematics versus Reading Skills: Similarities and Differences** 1: Tuire Koponen, University of Jyväskylä, Finland 2: Xiujie Yang, Chinese University of Hong Kong 3: Xiao Zhang, The University of Hong Kong Discussants: Kiran Vanbinst & Lien Peters	**TB447**

11:50 - 1:30 pm: Lunch + Poster session (P4) in RB Foyer

102	The Contributions Of Cognitive, Numeracy, And Motivational Factors For Middle Childhood Math Performance		Allison Liu
103	Individual And Developmental Differences In The Neurocognitive Integration Of Number Notations And Their Relation To Math Competence	(P)	Darren Yeo
104	Reverse Distance Effects Do Not Exist		Eli Zaleznik
105	Learning Under Pressure: Impacts Of Stereotype Threat Vs. Incentives On Conceptual Math Learning		Emily Lyons
106	Symbols Are Special: An Fmri Adaptation Study Of Symbolic, Nonsymbolic And Non-Numerical Magnitude Processing In The Human Brain		H Moriah Sokolowski
107	Mathematics Anxiety, Achievement, And Teacher Influences In A Developing Nation		Elayne Teska
108	Impact Of Association, Interference, And Priming On Math Story Problems		Jill Turner
109	Math Anxiety Changes In Response To Math Learning, Task, And Difficulty		Kelly Trezise
110	Do School Psychologists Believe They Know Enough Mathematics?		Kelsey Gould
111	The Role Of The Base-10 System In Processing Magnitudes Using The Number Line Estimation Task	(P)	Kelsey J. Mackay
112	The Effect Of Formal Math Instruction On Research Findings: A Cross-Educational Study	(P)	Kiran Vanbinst
113	Number Accuracy And Arithmetic In Two Children With Mathematics Learning Disabilities After A Computerized Number Line Intervention		Laetitia Marcon
114	Inducing A Mathematical Formula Buffers Against Overgeneralization		Lauren N. Sprague
115	Gender Differences In Math And Spatial Anxiety And Self-Concept In Early Elementary School		Lindsey Hildebrand
116	Bias Towards Fraction Components And Math Achievement In Low-Income College Students		Linsah Coulanges
117	How Chilean Children's And Parents' Beliefs About Who Does Math Influence Math Learning		M. Francisca Del Rio
118	Fingers Dexterity Predicts Early Math Skills Development: Insight From 3D Human Motion Analyses		Maëlle Neveu
119	Parent And Child Spontaneous Focus On Number And Mathematical Talk During Play Activities	(P)	Mary Depascale
120	Flexible Attention To Numerical And Spatial Magnitudes In Early Childhood		Mary Fuhs
121	Neural Correlates For The Outcome Of Spaced Versus Massed Learning In Arithmetic		Mengyi Li

122	Exploring Differences In Domain-Specific And Domain-General Abilities Between Mathematicians And Non-Mathematicians.	(P)	Michaela A. Meier
123	Abacus Training Decreases The Prevalence Of Developmental Dyscalculia In China		Yujie Lu
124	One, Two, Three, What? Investigating The Distance Effect In Sequential Number Processing: A P300 Study	(P)	Nathaniel Shannon
125	The Relation Between Math-Talk And Math-Gestures For Parent-Child Dyads		Raychel Gordon
126	Fingers Come In Handy: Does Finger Use Support Learning A Pseudo-Number-Word Sequence?	(P)	Roberta Barrocas
128	Measuring Preschool Children's Affective Attitudes Towards Mathematics		Xiao Zhang
129	Effects Of A Non-Symbolic Fraction Intervention On Proportional Reasoning	(P)	Roberto A. Abreu-Mendoza
130	Sex Differences In Early Executive Function Components Vary By Measurement Type		Sammy Ahmed
131	Measuring The Quality Of Parent-Child Interactions And The Relation To Preschool-Aged Children's Math Skills		Shirley Duong
132	Linguistic Influences On Number Line Estimation: Digit Identity And Inversion Effects		Sophie Savelkouls
133	Word-Problem Solving In English Language Learners		Stephanie Hadden
134	Rules Of Order: Evidence For A Fundamental Bias When Processing The Ordinality Of Numbers		Sylvia Gattas
135	Enhancing Multi-Digit Number Knowledge Through Number Board Games		Winnie Wai Lan Chan
136	Assessing Math Performance Errors In Young Girls: Considering Age, Race And Self-Efficacy When Designing Math Interventions		Yvette Harris
137	Intelligence Mediates The Relationship Between Exact Arithmetic And Verbal Working Memory		Zhang Tingyan

1:40 - 2:45 Symposia session 9

S25	**What I Can Bring to my Math Classroom: Putting Numeracy Research to Work** Chair: Helena Osana, Concordia University 1: Martha W. Alibali, University of Wisconsin—Madison 2: Sarah Powell, University of Texas at Austin 3: Nancy C. Jordan, University of Delaware 4: Tracy Solomon, Hospital for Sick Children	**RB2200**

S26	**A variety of early grade mathematics assessments and their uses in South Africa** 1: Hanrie Bezuidenhout & Elizabeth Henning, University of Johannesburg, South Africa 2: Ingrid Mostert, University of Johannesburg, South Africa 3: Lara Ragpot, Trinity Western University & Caroline Fitzpatrick, Université Sainte-Anne 4: Ingrid Mostert, University of Johannesburg, South Africa	**TB447**
S27	**Linguistic influences on early numerical development** 1: Mojtaba Soltanlou, University of Tuebingen, Tuebingen 2: Krzysztof Cipora, University of Tuebingen, Tuebingen, Germany 3: Jacob Paul, Utrecht University, Utrecht, Netherlands 4: Victoria Simms, Ulster University, Northern Ireland 5: Thomas Gallagher-Mitchell, Liverpool Hope University	**TB446**

3:10 – 4:15 Symposia session 10

S28	**Is touch screen technology a double-edged sword in mathematics education?** 1: Joanne Lee, Developmental Psychology, Department of Psychology Wilfrid Laurier University 2: Adam K. Dubé, Learning Sciences, McGill University 3: Marjorie W. Schaeffer, Department of Psychology, University of Chicago Discussant: Erin Maloney, School of Psychology, University of Ottawa	**TB447**
S29	**Early symbolic numerical skills: theoretical and educational implications.** 1: Francesco Sella, University of Sheffield, UK 2: Rose M. Schneider, University of California, San Diego, USA 3: Camilla Gilmore, Loughborough University, UK 4: Silke M. Göbel, University of York, UK	**TB446**
S30	**Understanding the Factors Affecting Mathematics Development and Supporting Children Through Home and School Interventions** Chair: Sheri-Lynn Skwarchuk, University of Winnipeg, Canada 1: Maureen Vandermaas-Peeler, Elon University, 2: Sarah Melo, Faculty of Education, University of Manitoba 3: Prentice Starkey, WestEd, San Francisco, California 4: Jalisha Braxton, University of Chicago, Chicago, Illinois, USA	**RB2200**

Symposia Abstracts

S1: Home numeracy activities and mathematical achievement

HomeNumeracy158.1

Discussant:

- Kerry Lee, The Education University of Hong Kong

Presenters:

- Venera Gashaj, University Pompeu Fabra, Barcelona
- Sum Kwing Cheung, The Education University of Hong Kong
- David Munez, National Institute of Education, Singapore
- Kerry Lee, The Education University of Hong Kong

Abstract:

Children enter grade school with different competencies in mathematics. Although some children who entered school with lower performance increase rapidly with formal instructions in mathematics, others lag and do not catch up with their peers. Given the importance of mathematics for higher studies and future employment, much effort has been devoted to identifying factors that contribute to early differences in mathematical performance. Findings on the role of home numeracy practices have been mixed. This symposium contains three presentations that explore factors that may contribute to variation in findings. Two presentations will focus on the interplay between home numeracy practices and other variables known to affect mathematical performance. The last presentation examines issues related to the measurement of home numeracy. Venera Gashaj (Universitat Pompeu Fabra) will present a study that examines the predictive power of early numeracy skills, home numeracy, and mathematical anxiety for mathematics achievement at the beginning of 2nd grade. Conducted with a normative sample of 85 children, correlation and regression analyses showed that all three predictors have unique and important influence on mathematical achievement. However, the relations were nuanced and only attained significance for some aspects of mathematical achievement. Home numeracy only predicted sequences, whereas math anxiety tended to affect written computation. Overall performance on the mathematics achievement test and performance on the equations subtest were best predicted by early numeracy skills.

Sum Kwing Cheung and Ricci Wai-tsz Fong (The Education University of Hong Kong) will report data collected in Hong Kong. Many Chinese parents hold high academic expectations regarding their children's mathematical performance. Their study examined the relation between parents' sense of perfectionism towards their children's learning, frequency of home numeracy activities, and children's numeracy skills. Kindergarteners (N=107) were tested on their general cognitive and numeracy skills. Their parents completed a home learning questionnaire. Results showed that after controlling for children's gender, age, non-verbal intelligence and executive functions, children's numeracy skills were negatively associated with parents' maladaptive perfectionism towards children's learning but positively associated with engagement in home numeracy activities. Parents' adaptive perfectionism was not a significant correlate.

The home numeracy environment is often measured by questionnaires completed by parents. David Munéz (Nanyang Technological University) will report on a study that examined whether one such instrument, based on Sénéchal and LeFevre's home literacy model, functions in an equivalent manner for children with average versus poor mathematics performance at 1st grade. The findings showed that a 3-factor structure (direct, indirect, and play-based numeracy activities) best fitted the data. The average and poor achievers exhibited similar factor structures but different intercepts. Overall, the findings show differential item functioning and suggest that latent means in average and poor achievers cannot be compared in a straight-forward manner.

The discussant (Kerry Lee, The Education University of Hong Kong) will draw on the three studies and provide insight regarding the role of home numeracy, its measurement, and how best to proceed with future research.

Talks:

Basic Numerical Skills, Home Numeracy, and Math Anxiety predict Math Achievement in 2nd grade

- Venera Gashaj, Qendresa Thaqi, Fred W. Mast, Claudia M. Roebers

Roles of parents' sense of perfectionism learning and home numeracy activities in young children's numeracy skills

- Sum Kwing Cheung, Ricci Wai-tsz Fong

Factor structure of HNE and kindergarteners' math achievement: a multigroup analysis

- David Munez, Kerry Lee, Rebecca Bull

Home numeracy activities and mathematical achievement: A critical discussion

- Kerry Lee

S2: Numerical skills and cognition in kindergarten: Predictors of individual differences in math ability and growth in math skills in early elementary school.

EarlyMathSkills162.4

Presenters:

- Nathan Lau, Western University, Canada
- Andrew Ribner, University of Pittsburgh, USA
- Rebecca Bull, Macquarie University, Australia
- Daniel Ansari, Western University, Canada

Abstract:

For many children, kindergarten marks the first time they are expected to attend to and gain a mastery of academic content knowledge. Despite striking differences in a range of educational experiences, skills, and knowledge before children enter kindergarten, there is evidence of substantial rank-order stability in mathematical skills from when children enter school to later years. This makes it particularly important to understand the factors that result in some children starting on a low growth trajectory in math as they enter primary school. We present three large-scale longitudinal studies from different countries looking at the independent contributions of early numerical skills and executive functioning/working memory (measured at kindergarten) in predicting growth trajectories and final outcomes in math achievement in the early years of elementary school. In the first talk, Nathan Lau (PhD candidate, Western University, Canada) presents "Predictive Relationships between Measures of Early Numerical Skills and Later Mathematics Achievement – A Longitudinal Study." This study examines the relationship of symbolic and non-symbolic skills in kindergarten, and their relationship to later arithmetic achievement in grade 1. Multiple cross-lagged panel models contrast two views – first, that early approximate number system (ANS) acuity facilitates the acquisition of symbolic numbers, and that ANS acuity also predicts later mathematical achievement. Second, that early symbolic and non-symbolic number development are separate processes, and that it is earlier symbolic number growth that facilitates later ANS development and later achievement. In the second talk, Andrew Ribner (PhD candidate, New York University, USA) presents "Executive Function Predicts Trajectory of Mathematical Skill Development in Early Elementary Grades: Evidence from Latent Growth Mixture Modeling." Emerging evidence has demonstrated children's early executive function (EF) skills might attenuate the stability in math over the course elementary years, whereby children with high levels of EF have lower levels of stability in math over time, allowing them to grow at a faster rate than a peer with lower levels of EF. This study uses data from the Early Childhood Longitudinal Study-Kindergarten Cohort 2010-11 to examine EF as an antecedent to characteristics of growth in math skills. Latent growth curve and growth mixture models are used to explore both normative and common heterogeneous patters of growth in math across early elementary grades. In the third talk, Rebecca Bull (Professor, Macquarie University, Australia) presents "Identifying and Combining Symbolic and Non-symbolic Quantities: Longitudinal Prediction of Mathematical Ability". This study presents data from the Singapore Kindergarten Impact Project which examines the contribution of classroom, home, and child factors in predicting longer-term developmental outcomes. Growth curve and growth mixture modelling are used to examine the unique contribution of early numerical skills in predicting variation of growth trajectories and final math outcomes, above and beyond the variance accounted for by domain-general skills such as working memory. The findings from all studies have implications regarding what early indicators of numerical ability and cognition may be most sensitive and specific to predicting later low achievement in mathematics. This will form part of the discussion to be led by Daniel Ansari (Professor, Western University, Canada).

Talks:

Predictive Relationships between Measures of Early Numerical Skills and Later Mathematics Achievement – A Longitudinal Study.

- Nathan Lau, Rebecca Merkley, Paul Tremblay, Samuel Zhang, Stefanie De Jesus, Daniel Ansari

Executive Function Predicts Trajectory of Mathematical Skill Development in Early Elementary Grades: Evidence from Latent Growth Mixture Modeling.

- Andrew Ribner

Identifying and Combining Symbolic and Non-symbolic Quantities: Longitudinal Prediction of Mathematical Ability

- Rebecca Bull, Kerry Lee, David Munez

S3: Understanding Mathematical Notations and Representations

MathLearning63.2

Presenters:

- Dirk Schlimm, McGill
- Ulises Xolocotzin Eligio, Cinvestav
- Juan Pablo Mejía Ramos, Rutgers University, USA
- David Landy, Indiana University

Abstract:

Notations, and mathematical representations more generally, play a critical role in the development of mathematics. Some of the oldest records of human writing are notches on bones, a simple notation to keep track of quantities; we use the Arabic notation system, based on the digits from '0' to '9', throughout our daily lives; and breakthroughs in mathematical research have sometimes been attributed to the discovery of more sophisticated notation systems (e.g., Brown, 2005). But what features do good mathematical notations and representations have? When there is flexibility in which notations and representations to use, how do students choose, and what are the consequences of these choices? To date, mathematical cognition researchers have not devoted a great deal of attention to these questions. This symposium seeks to address this. It comprises four presentations. First, Dirk Schlimm (McGill, Canada), a philosopher of mathematics, will offer a historical review of the different suggestions that mathematicians and philosophers have offered for what makes a 'good' representation. He will pay particular attention the logical notations of the nineteenth century mathematicians Babbage, Boole, Frege and Peirce, and note that some of their answers are incompatible. Second, Ulises Xolocotzin Eligio (Cinvestav, Mexico), Ana Medrano (Cinvestav, Mexico) & Matthew Inglis (Loughborough, UK) will report a series of studies that compared how children interact with the same algebraic problems represented in two different notation systems, t-charts and diagrams. Surprisingly, the more complex diagrammatic notations led to more correct responses. Third, Juan Pablo Mejía Ramos (Rutgers, USA) & Keith Weber (Rutgers, USA) will discuss undergraduate students' use of diagrams when constructing mathematical proofs in calculus contexts. Some mathematics education researchers and mathematicians, based on somewhat flimsy evidence, have proposed that there are systematic individual differences in diagram use, leading to the suggestion that students and mathematicians either exhibit a 'visual style' or an 'analytic style' (e.g., Hadamard, 1945). Mejía Ramos and Weber report a study which tested this account and find it wanting. Finally, David Landy (Indiana, USA) will describe a study which concerns how graduate students create new mathematical representations while solving advanced problems. A network analysis of the transitions between representations reveals different clusters of representation use which, perhaps surprisingly, often cut across problem content. Together, the four talks in the symposium suggest that mathematical cognition researchers could productively devote more attention to how notations and representations are used in mathematics, and to the methods by which students could be helped to engage with different representations more successfully.

Talks:

Historical views on good representations

- Dirk Schlimm

Different visual representations in early algebra tasks

- Ulises Xolocotzin Eligio, Ana Medrano, Matthew Inglis,

Undergraduate mathematics students' use of diagrams when writing proofs in calculus

- Juan Pablo Mejía Ramos, Keith Weber

Dense patterns in expert construction and use of ad-hoc representations of single problems

- David Landy

S4: A tricky mathematical problem: Developing rigorous and valid measurements of the preschool home numeracy environment

EarlyMathSkills142.3

Presenters:

- Victoria Simms, Ulster University, UK
- Camilla Gilmore, Loughborough University, UK
- David Purpura, Purdue University, USA
- Sanne Rathé, KU Leuven, Belgium

Abstract:

There is general consensus that the home learning environment is important for children's development over and above early formal educational experiences (Rossbach, 2005; Weinert, 2006). More specifically, recent research suggests children's experiences in the home or pre-school environment form the foundation for mathematical learning in primary school (Melhuish et al., 2013; Burchinal et al., 2008). However, findings on this topic are mixed with emerging evidence sometimes indicating a weak or negligible relationship between the home numeracy environment (HNE) and mathematical outcomes (e.g., Blevins-Knabe, Austin, Musun, Eddy, & Jones, 2000 (Study 3); Blevins-Knabe & Musun-Miller, 1996; Missall et al., 2015; Thompson, Napoli & Purpura, 2017). It is therefore essential that this topic is rigorously explored in order to generate a scientific evidence base to inform parents and early educators.

These conflicting results may be influenced by a number of factors, in particular, the lack of consensus of the definition of HNE and the wide variation in the tools used to measure HNE. This symposium draws together an international group of researchers who have taken different approaches to measuring preschoolers' HNE. Simms discusses the development of a preschool HNE questionnaire and its application to longitudinal research. Gilmore reports findings of a study that utilised three different approaches to measuring HNE and investigated the relationship between these metrics and mathematical achievement. Purpura explores HNE questionnaire data from parents of pre-schoolers to assess measurement error using this type of tool. Rathé longitudinally investigates the relationship between HNE and other mathematical outcomes in order to discuss methodological issues in this domain.

This symposium aims to generate discussion on measurement issues in this field. The literature on HNE has policy and practice implications, therefore ensuring that academics have consensus on the construct and methods that they use are essential. We see this symposium as a facilitator of this important discussion.

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This symposium aims to generate discussion on measurement issues in this field. The literature on HNE has policy and practice implications, therefore ensuring that academics have consensus on the construct and methods that they use are essential. We see this symposium as a facilitator of this important discussion.

Talks:

Developing a measure of preschoolers' home numeracy environment

- Victoria Simms, Abbie Cahoon,

Item-level variability in the assessment of the home numeracy environment: A graded response model analysis

- David J. Purpura, Giulia Borriello, Sara A. Schmitt,

Multiple measures of the home numeracy environment

- Camilla Gilmore, Amy Bennett, Matthew Inglis,

Spontaneous mathematical focusing tendencies and their relation to the home numeracy environment

- Sanne Rathé, Joke Torbeyns, Bert De Smedt, Lieven Verschaffel

S5: Numerical Cognition: Domain-General and Domain-Specific Processes

NumericalCognition157.1

Presenters:

- Elien Bellon, KU Leuven
- Ian Lyons, Georgetown University
- Jamie Campbell, University of Saskatchewan
- Angélique Roquet, Aix-Marseille Universite

Abstract:

This collection of papers will consider roles for domain-general and domain-specific processes in numerical cognition. Domain-general includes cognitive mechanisms not specialized or unique for numerical skills (e.g., metacognitive monitoring; executive control), whereas domain-specific numerical cognition entails representations or processes unique to number processing (e.g., quantity codes; inter-operation interference).

Bellon, Fias and De Smedt used both behavioral and fMRI methods to investigate primary school children's metacognitive judgements (calibration of confidence) during arithmetic in addition to the role of numerical magnitude processing. Metacognition was found to be a stable and unique predictor of arithmetic performance in both second and third grade, and predicted the growth between the grades in 120 typically developing children. They further investigated in 147 typically developing third graders whether this role of metacognitive monitoring was specific to arithmetic or whether it was also the case for spelling.

Lyons, De Smedt, Tieberghien and Fias pursued the problem size effect (PSE) in simple multiplication. A representational similarity analysis (RSA) approach using fMRI clearly distinguish between representation and process-based accounts. RSA, but not univariate, fMRI results provided clear evidence in favor of the representation-based over the process-based account of the PSE in multiplication. Results distinguished still further between competing representation-based accounts, favoring the view that individual multiplication problems are stored as individual memory traces sensitive to input frequency over a strictly magnitude-based account of memory encoding.

Campbell, Chen and Zhou pursued the finding that Chinese adults' memory for arithmetic facts (e.g., 2 + 3 = 5) is less susceptible to retrieval-induced forgetting (RIF) from practice of multiplication counterparts (e.g., 2 × 3 = 6) compared to Canadians. Does this difference generalize to the associative confusion effect (ACE; slow response times) observed when equations to be verified appear with the correct answer to the other operation (e.g., 2 + 3 = 6, 2 × 3 = 5)? The ACE was substantially larger in Canadian adults we tested compared to Chinese adults, but the Chinese nonetheless presented a robust ACE. Both groups are susceptible to inter-operation interference, but the Canadians more so.

Roquet, Poletti Lemaire report a lifespan study of domain-general control mechanisms in numerosity estimation. Children 7-13 years old as well as younger and older adults saw two collections of dots and decided which collection included the largest number of dots. Successive items varied on whether numerosity and visual features were congruent or incongruent. Participants were slower on incongruent items (i.e., visual features mismatched numerosity) than on congruent items (i.e., visual features matched numerosity). The results showed that sequential modulations of congruency effects changed with children's age and, in older adults, with efficiency of executive control processes.

Collectively, the presentations suggest important roles for both domain-general and domain-specific processes in numerical cognition and that exploring the theoretical utility of this distinction is a worthwhile objectives.

Talks:

More than number sense: The additional role of metacognition in arithmetic.

- Elien Bellon, Wim Fias, Bert De Smedt,

Disentangling neural sources and cognitive explanations of the problem size effect in mental multiplication.

- Ian Lyons, Bert De Smedt, Kerensa Tieberghien, Wim Fias,

Inter-operation interference in arithmetic memory across cultures.

- Jamie Campbell, Yalin Chen, Zijun Zhou,

Sequential modulation of executive control processes in numerosity comparison: A lifespan study.

- Angélique Roquet, Céline Poletti, Patrick Lemaire,

S6: Number line estimation: Understanding strategy use, digit placement, and gamification for typical and atypical number lines.

NumberLine26.1

Presenters:

- Korbinian Moeller, Leibniz-Institut für Wissensmedien, Tuebingen, Germany
- Hilary Barth, Wesleyan University, CT, USA
- Koen Luwel, KU Leuven, Belgium
- Sabrina Di Lonardo, Carleton University

Abstract:

What factors influence number line estimation (NLE)? This symposium will address questions related to NLE performance and strategy, discussing findings not only relevant to the number line task itself, but also to our understanding of numerical estimation development.

In the classic number-to-position version of the number line task, a horizontal line is presented with vertical markers at each end. Participants are asked to estimate the location of a target number by marking its location on the line. With educational games gaining increasing interest, Moeller et al. investigated whether a gamified version of the NLE task on fractions would influence performance and experience. By presenting the task in a gamified version, performance on the task did not differ in comparison to a non-gamified version and the task maintained its reliability, but flow and learning experience were higher. As children age, they are asked to estimate larger target numbers. Barth discusses how past research has assumed that performance depends on the numerical magnitudes of these target numbers because numerals are thought to be translated into mental magnitude representations. However, she suggests a strong leftmost digit effect in NLE, leftmost digit identity, which has been found to influence estimation placements in both children and adults. When aspects of the number line itself are changed, how are strategy and performance effected? Luwel et al. found that when children and adults estimated on typical and atypical range number lines overall estimates were less accurate for the atypical number lines, including around self-created benchmarks, and estimates were best fit by less complex power models. By hindering the application of benchmark-based strategies, performance was negatively affected in both children and adults. Di Lonardo et al. found similar performance patterns when adults estimated on atypical range number lines. Interestingly, for reverse direction (i.e., right-to-left) number lines performance improved. Although participants appeared to miscalculate internal benchmarks, eye-tracking data suggested they continued to use these benchmarks to guide estimates. On typical range number lines, participants appeared to use a proportion strategy compared to atypical range number lines where participants appeared to use a benchmark-based strategy. Traditional direction number lines had first fixation patterns that suggested a leftward bias; this bias was not seen in the reverse direction. Taken together, these talks suggest that NLE is influenced by numerical processes, spatial processes and presentation of the number line, and that understanding strategies aid in understanding performance.

Talks:

Same, but different - Investigating effects of gamification on NLE performance using eye-tracking

- Manuel Ninaus, Kristian Kiili, Korbinian Moeller, Silvia Kober,

Digit dependence in numerical estimation

- Hilary Barth

Benchmark-based strategy use in atypical number lines

- Koen Luwel, Dominique Peeters, Goedele Dierckx, Lieven Verschaffel

Fixated in unfamiliar territory: Mapping estimates across typical and atypical number lines

- Sabrina Di Lonardo, Matthew Huebner, Katherine Newman, Jo-Anne LeFevre,

S7: Improving mathematics using cognitive training: From basic mechanisms to translation

CognitiveTraining58.1

Presenters:

- Korbinian Moeller, University of Tubingen, Germany
- Roi Cohen Kadosh, University of Oxford, England
- Geetha B. Ramani, University of Maryland, College Park, USA
- Torkel Klingberg, Karolinska Institutet, Sweden

Abstract:

Mathematics is considered as one of the most complex human cognitive abilities. Solving mathematical problems poses a challenge to approximately 20% of the population and performance is associated with important life consequences. For example, impaired mathematical skills lead to low education, increased unemployment, reduced salary and job opportunities, and additional costs in mental and physical health. It is therefore paramount to expand the current research of mathematics to possible cognitive interventions that increase mathematical skills in order to examine any potential behavioural benefits. In addition, we should increase our knowledge of the underlying mechanisms that are associated with mathematical cognition and learning.

The current symposium highlights four projects that aim to advance our knowledge of both basic and translational science to improve mathematical performance.

Korbinian Moeller will describe two intervention studies which included training on either complex arithmetic multiplications or fraction magnitude estimation. Transfer effects to untrained items were only present following training of multiplications as compared to fraction magnitude training. At the neural level, training of multiplications led to increased activation in areas associated with long-term memory (e.g., hippocampus), whereas fraction magnitude training led to increased activation of areas subserving number magnitude processing (e.g., intraparietal sulcus). These results highlight a dissociation in terms of cognitive strategies and neural processing as a function of mathematical learning.

Roi Cohen Kadosh will present two studies that examined the involvement of the non-associative cortex in arithmetic by targeting primitive mechanisms—lower visual channels, which are mainly subcortical. Exposing only one monocular channel to a visuospatial training resulted in enhanced subtraction performance, but not multiplication performance when these arithmetic problems were presented to the trained monocular channel. These results highlight the link between visuospatial abilities and mathematical subtraction, which can already occur by primitive low-level visual channels.

Geetha B. Ramani will discuss the benefits of tablet-based training games for improving mathematical knowledge in a diverse population of kindergarten-aged children. Ramani and colleagues found that training domain-general skills (working memory) led to improvements in working memory, while training domain-specific skills (numerical knowledge) led to improvements in numerical knowledge, as well as working memory. These observed transfer effects were observed over and above an active control and were maintained for several weeks.

The last speaker, Torkel Klingberg, will address the issue of individual differences, by examining the relationship between baseline cognitive performance and the benefit of cognitive training in nearly 4000 children (age 6-8 years). Children were randomized into a training paradigm involving mathematics, working memory, non-verbal reasoning or spatial rotation. The results suggest that the advantage from these different cognitive training paradigms is dependent on baseline differences in characteristics of the individuals' cognitive performance. These findings highlight the potential to personalized cognitive training depending on traits to further improve the efficacy of cognitive interventions in the field of mathematics.

Overall, this symposium will further our understanding of the cognitive and neural mechanisms that are involved in mathematical learning and cognition and highlights new advancements to allow progress in basic and translational studies.

Talks:

Differential effects of training facts or magnitude on the behavioural and neural Level

- Korbinian Moeller

Eye See, I think: The Causal Role of Primitive Low-Level Visual Channels in Cognitive Transfer to Arithmetic

- Roi Cohen Kadosh,

Improving Kindergarten Children's Math and Working Memory Skills

- Geetha B. Ramani

Cognitive Training and Learning of Mathematics–the role of interindividual differences

- Torkel Klingberg

S8: Language, culture, and numerical thinking in non-industrialized cultures

Presenters:

- Isabelle Boni, UC Berkeley
- Rose M. Schneider, UC San Diego
- Benjamin Pitt, UC Berkeley
- Tania Cruz, UC Berkeley

Abstract:

The timing of number learning is determined by more than verbal counting

Isabelle Boni & Steven T. Piantadosi

Mastery of counting depends on children's ability to recite the verbal count list ("one", "two", "three", etc.). American children succeed in the Give-N tasks around age 4, but much later (ages 6-10) in the Tsimane'', an indigenous culture in the Bolivian Amazon. We found that Tsimane' children learned the list at a later age than US children but that upon acquiring this list, children were still delayed in passing Give-N tasks. Our results suggest that knowledge of the verbal count list must precede other learning developments which are crucial for fully understanding and using counting and cardinality.

Do Children Use Language Structure to Discover the Recursive Rules of Counting?

Rose M. Schneider (UC San Diego), Jessica Sullivan (Skidmore College), Priyanka Biswas (UC San Diego), Franc Marušič (University of Nova Gorica), Rok Žaucer (University of Nova Gorica), & David Barner (UC San Diego)

We tested how children extract recursive counting rules from a count list's grammatical structure in languages with transparent (Cantonese, Slovenian, and English) and more opaque (Hindi and Gujarati) number word morphology. Specifically, we asked whether a count list's relative transparency affects acquisition of the recursive successor function governing counting. With 577 3.5- to 6.5-year-olds, we explored the relationship between recursive counting and successor knowledge within and across languages. We find that while recursive counting knowledge is affected by language transparency and frequency of count list exposure, nevertheless children who demonstrate such knowledge are more likely to understand the successor function.

Math ability varies independently of number estimation in the Tsimane'

Benjamin Pitt, Samuel Cheyette, Steven T. Piantadosi, & Edward Gibson

What are the cognitive underpinnings of mathematical ability? One hypothesis is that mathematical ability may be supported by the approximate number system (ANS). Here we tested this claim in the Tsimane', a non-industrialized culture with high variability in their number knowledge and education. Math ability was positively correlated with ANS performance, consistent with previous findings. However, when controlling for participants' education or ability to sustain attention, the relationship between the ANS and math ability disappeared. Non-numerical abilities practiced (or selected for) in educational settings may produce the correlation observed between the ANS and math ability.

No knowledge of counting without education

Tania Cruz, Frank Mollica, & Steven T. Piantadosi

We used natural variability in the amount of education Tsimane' children received in order to test the relationship between education and counting knowledge, independent of age. In a large sample of Tsimane' children (N=581, aged 3-13), perhaps one of the largest indigenous samples studied, children who passed Give-N tasks were only found among those with some schooling. Children with no formal education never passed Give-N tasks, independent of age -- even some as old as 8. This suggests that becoming a full-counter may require instruction, whether formal or informal, and that understanding of number depends strongly on cultural factors.

S9: Whole Number Bias: Developmental, Contextual, Linguistic and Neural Perspectives

Presenters:

- David W. Braithwaite, Florida State University
- Jake McMullen, University of Turku, Finland
- Kexin Ren, Temple University, USA)
- Miriam Rosenberg-Lee, Rutgers University, USA

Abstracts:

Whole Number Bias: Developmental, Contextual, Linguistic and Neural Perspectives
David W. Braithwaite (Florida State University) & Robert S. Siegler (Teacher's College, Columbia University, USA)

Whole number bias – the tendency to apply whole number properties when processing rational numbers – has been posited to account for learner's difficulties grasping this new class of numbers. In this symposium, we show that the effects of whole number bias diminish over the course of schooling, yet vary considerably between individuals; time pressure induces this bias in adults; verbal labels modulate it; and neuroimaging can characterize it. Together, these talks reveal a flexible, dynamic role for whole number bias in explaining the development of rational number concepts.

Whole Number Bias Impedes Understanding of Fraction Equivalence
Jo Van Hoof (KU Leuven), Lieven Verschaffel (KU Leuven), Wim De Neys (Université Paris Descartes, France) & Wim Van Dooren (KU Leuven, Belgium).

The concept of equivalence is critical to understanding fractions. This study found evidence that whole number bias impedes understanding of fraction equivalence. Fourth to eighth grade children performed fraction number line estimation and comparison tasks. On both tasks, children treated fractions with smaller components (e.g., 1/2) as smaller than equivalent fractions with larger components (e.g., 12/24). These effects decreased with grade, but varied substantially within grades. The results are consistent with a componential-to-holistic shift in children's understanding of fractions.

Intuitive Errors in Learners' Fraction Understanding: A Dual-Process Perspective on the Whole Number Bias.
Kexin Ren & Elizabeth A. Gunderson (Temple University, USA)

Previous correlational dual process studies suggested the intuitive nature of the whole number bias in learners' response latencies. In the present study we introduced a time pressure manipulation to experimentally elicit intuitive reasoning in a fraction comparison task with educated adults. Results show that the whole number bias has an intuitive character, as does the detection of conflict between whole number-based and correct answers.

The Impact of Decimal Labeling on Decimal Comparison Biases
Miriam Rosenberg-Lee (Rutgers University, USA, Organizer)

In learning decimals, decomposed labels ("three tenths and four hundredths") and common-unit labels ("thirty-four hundredths") emphasize different aspects of place-value, and provide more information than informal labels ("point three four"). Fifth- and sixth grade children practiced labeling decimals using these three label types. As predicted, decomposed labels increased the tenths-hundredths compatibility effect. Yet, unexpectedly, common-unit labels decreased the string-length congruity effect by increasing fraction-biased responses (e.g., .2 > .34), suggesting that these children believe that all "tenths" are bigger than "hundredths".

Probing the Neural Basis of Whole Number Bias in Decimals

The string-length congruity effect suggests that difficulties comparing decimals like .8 vs. .27 arise because they contradict prior whole number knowledge (more digits => larger number). The semantic congruity effect suggests, instead, that participants must overcome the automatic activation of corresponding whole number quantities (8 and 27). Consistent with this second view, in university students, whole number distance between quantities (e.g., 19) better accounted for reactions times that absolute difference (e.g., .53). We also discuss preliminary neuroimaging results that further differentiate these explanations.

S10: Are inhibitory skills important for mathematical performance?

InhibitorySkills92.1

Presenters:

- Caron Clark, University of Nebraska
- Kerry Lee, The Education University of Hong Kong
- Sum Kwing Cheung, The Education University of Hong Kong
- Bert de Smedt, University of Leuven, Belgium

Abstract:

Although some aspects of executive functioning (EF, especially working memory and updating) have consistently been found to be related to mathematical performance, the role of inhibitory abilities is less consistent. Some have argued that this is due partially to the use of inappropriate measures of inhibitory abilities or the use of mathematical tasks with little inhibitory demands. Here, we present three studies that utilized more sensitive measures of inhibitory or mathematical abilities. In the first presentation, Caron Clark (University of Nebraska-Lincoln) will report on a functional MRI study examining children's neural response patterns when engaged in learning a new mathematical concept involving binary numbers. Conducted with 8 to 11-year-olds, children with stronger visuo-spatial working memory, but not inhibitory control performance, recruited brain regions implicated in EF (the anterior cingulate cortex) when they learned the novel concept. These children also showed better mastery of the new binary number concept. These findings bolster evidence for a central role of working memory in children's mathematics acquisition.

In the second presentation, Kerry Lee (Education University of Hong Kong) will report on findings from a study conducted with 76 fifth-grade children. The children were asked to verify the accuracy of simple arithmetic sentences. They completed this task either in silence or while listening to a pre-recorded sequence of numbers. The children also completed separately a set of arithmetic word-problems that contained irrelevant numerical information. These problems were chosen because having to deal with irrelevant information was expected to impose greater inhibitory demands than questions found in general mathematical achievement tests. Accuracy deteriorated in the presence of irrelevant information ($t = 12.34$). Furthermore, both the accuracy and RT on the arithmetic verification task were affected negatively by auditory distraction ($t = 2.65$). However, the magnitude of deterioration in neither the verification nor the word problems were correlated with auditory distraction.

In the last presentation, Sum Kwing Cheung (Education University of Hong Kong, and J. Zhang, University of Macau) investigated the roles of EF, mathematical anxiety, and mathematical fact fluency on children's algorithmic computational accuracy in timed and untimed situations. 128 Chinese 3rd grade children were administered mathematical tests and a self-reported questionnaire on mathematical anxiety. Teachers reported on the children's EF. The results showed that the ability to inhibit impulses failed to predict timed or untimed performances when considered together with other components of EF. The ability to plan and organize, mathematical anxiety, and mathematical fact fluency were significant correlates in the timed condition, but only the latter two were significant correlates in the untimed condition.

Despite the use of different inhibitory and mathematical measures, all three studies suggest that the role of inhibitory control is limited in mathematical learning and computation. Main issues for discussion (Bert De Smedt, KU Leuven, Belgium) are: (1) Are findings affected by the appropriateness or the validity of the inhibitory measures? (2) Is the role of inhibition time-limited? (3) How best to proceed with future research?

Talks:

Children's working memory is associated with their recruitment of central executive brain regions to support mathematics concept acquisition

- Caron Clark

Susceptibility to distraction and mathematical performance

- Kerry Lee, Jeremy Ng Lan Kong

Children's performance on algorithmic computation task in timed and untimed situations: Does executive functioning matter?

- Sum Kwing Cheung, Juan Zhang

Are inhibitory skills important for mathematical performance? A critical discussion.

- Bert de Smedt

S11: Current Directions in Symbolic Number Processing

SymbolicProcessing126.1

Presenters:

- Hans-Christoph Nuerk, University of Tuebingen, Germany
- Erin Maloney, University of Ottawa
- Krzysztof Cipora University of Tuebingen, Tuebingen
- Tom Faulkenberry, Tarleton State University, Texas

Abstract:

Though efforts to understand how humans process symbolic numbers began over 50 years ago with Moyer and Landauer (1967), these efforts are still alive and well today. Understanding symbolic number processing is an important first step to many questions in mathematical cognition, and knowledge gained from these questions flows downstream to inform our understanding of more complex mathematical reasoning tasks, including mental arithmetic, estimation, fraction tasks, and others. This symposium will feature four talks from well-known researchers in the field of mathematical cognition, reflecting diverse international perspectives as well as multiple career stages. The talks will represent a snapshot of current efforts to understand single-digit and multi-digit number processing, with work spanning a variety of methodological and statistical perspectives.

Presenters:

Hans-Cristoph Nuerk (Professor, University of Tuebingen, Germany)

Title: Automatic place-value activation in magnitude-irrelevant parity judgement

Description: Dr. Nuerk will talk about a recent experiment in which participants were asked to judge parity of either the decade or unit digit of a two-digit number. Similar to experiments with magnitude judgement, Nuerk and his colleagues found evidence of automatic activation of place-value, a finding which is remarkable in this context since parity decisions do not depend on magnitude representations. Dr. Nuerk will situate these results within our broader understanding of two-digit number processing.

Erin Maloney (Assistant Professor, University of Ottawa, Canada)

Title: Similar but not the same: Examining differences in symbolic distance effects arising in commonly-employed tasks

Description: Dr. Maloney will present recent work comparing performance on two common variants of the symbolic comparison task: comparison with a fixed standard versus simultaneous presentation. She will present evidence that these two tasks may indeed tap into different cognitive processes, which has important consequences for our use and subsequent understanding of these tasks.

Krzysztof Cipora (Postdoctoral scholar, University of Tuebingen, Germany)

Title: Distance and size effect - how they relate to math skill: A look at professional mathematicians

Description: Dr. Cipora will present recent results examining distance and size effects in professional mathematicians and potential differences between this group and the more commonly studied general population. He will also present a novel bootstrapping method to investigate the distance effect at the individual level, providing an important methodological innovation to our analytic toolbox.

Tom Faulkenberry (Associate Professor, Tarleton State University, USA)

Title: A hierarchical Bayesian model of individual difference structures for the size-congruity effect

Description: Dr. Faulkenberry will discuss recent work on understanding the size-congruity effect from a cognitive psychometrics perspective. Specifically, he will describe a hierarchical Bayesian model for estimating the structure of individual differences in the size-congruity effect, and use this model to argue that the size-congruity effect may be universal and invariant (i.e., everyone exhibits it).

Talks:

Automatic place-value activation in magnitude-irrelevant parity judgement.

- Hans-Cristoph Nuerk, Mojtaba Soltanlou, Stefan Smaczny, Silke Göbel, Krzysztof Cipora

Similar but not the same: Examining differences in symbolic distance effects arising in commonly-employed tasks.

- Erin Maloney, Carleton university

Distance and size effects – how they relate to math skill: A look at professional mathematicians

- Krzysztof Cipora, Mateusz Hohol, Klaus Willmes, Bartosz Brożek, Edward Nęcka, Hans-Christoph Nuerk,

A hierarchical Bayesian model of individual differences in the size-congruity effect

- Tom Faulkenberry

S12: Language: A tool for learning arithmetic

MathAndLanguage54.1

Presenters:

- David J. Purpura, Purdue University
- Kiran Vanbinst, University of Leuven
- Chang Xu, Carleton University
- Jason C. Chow, Virginia Commonwealth University,

Abstract:

Language skills are very important in this globalizing world. Language (dis)abilities are also a hot topic in (research in) education, as a continuously increasing number of children grow up in multilingual environments. It is well-known that language skills play a crucial role in learning to read (Roth, Speece, Cooper, 2002), but more recent evidence suggests that they also contribute to individual differences in learning mathematics (LeFevre et al., 2010; Purpura & Reid, 2016). This symposium aims to enrich our understanding of how language skills play a role in early education, when children acquire numerical skills and formally learn to solve basic arithmetic.

The first two presentations focus on preschoolers who have not yet received formal reading and arithmetic instruction. Pupura and Hornburg performed a longitudinal study that explored the role of language and early reading in acquiring numerical skills. They found that especially mathematical language was important. Vanbinst et al. investigated precursors of arithmetic and reading before formal instruction and found that the overlap between these early academic abilities might be driven by a common reliance on language skills.

The subsequent presentations focus on children who have recently started primary education. Xu, Lafay et al. investigated whether vocabulary knowledge contributed to the early math development of children who started learning mathematics in their first (L1) or second (L2) language. The results differed for L1 versus L2 learners, and implications for supporting L2 learners will be discussed. In the final presentation, Chow will present an intervention study in which first graders' numerical skills were trained. Training ensured progress on several mathematical measures, but the intervention effect appeared to be moderated by language skills. This symposium will be finalized by a critical and compendious conclusion of all the presented findings.

Talks:

Longitudinal prediction of individual early numeracy skills: The relation of mathematical language and early literacy

- David J. Purpura**,** Caroline Byrd Hornburg

Arithmetic and Reading: Related Building Blocks

- Kiran Vanbinst , Elsje van Bergen, Maaike Vandermosten, Klara Schevenels, Pol Ghesquière, Bert De Smedt,

The role of math-specific vocabulary for arithmetic fluency and word-problem solving for children learning mathematics in their first or second language

- Chang Xu*, Anne Lafay* , Jo-Anne LeFevre , Prof. Helena P. Osana, Sheri-Lynn Skwarchuk, Heather Douglas, Prof. Judith Wylie, Prof. Victoria Simms, Renee Whittaker, Jill Turner, Stephanie Hadden, Sarah Macintosh

*co-first authors

Math equivalence intervention improves first-grade problem-solving performance

- Jason C. Chow, Joseph H. Wehby

S13: Expanding examinations of spontaneous mathematical focusing tendencies

SpontaneousFocusing103.1

Presenters:

- Michele Mazzocco, University of Minnesota
- Alex Silver, University of Pittsburgh
- Richard Prather, University of Maryland
- Jake McMullen, University of Turku, Finland

Abstract:

Recent research has revealed differences in tendencies of children to focus on mathematical aspects in everyday situations when not guided to do so. These differences predict mathematical development in children from pre-school age to lower secondary school. For example, children's tendency of Spontaneous Focusing On Numerosity (SFON) has been found to predict individual differences in early numeracy and mathematical development throughout primary school. Likewise, Spontaneous Focusing On quantitative Relations (SFOR) has been found to predict rational number development and algebra knowledge in primary and lower secondary school. This symposium brings together four studies examining factors influencing SFON and SFOR tendency, including perceptual salience (Mazzocco), competing mathematical features (Prather), and contextual support (Silver, McMullen).

First Mazzocco and colleagues will provide evidence for the importance of considering perceptual salience of number when examining SFON tendency. Based on a series of studies examining the relation between perceptual salience and attention to number, they find that manipulating experimental materials can affect the frequency of attention to number in children and adults. These results suggest that the intentional design of materials may be an effective way to promote greater "spontaneous" attention to number in naturally occurring materials.

Second, Silver and colleagues will examine the role of parents' attitudes toward math and children's general cognitive abilities on preschool-aged children's spontaneous focusing on number (SFON). They found that for children whose parents have high positive math attitudes, SFON tendency differs based on executive function, i.e., children with high executive function focus more on number than children with low executive function. These findings suggest that only when a child's environment supports math, their tendency to focus on number is affected by their own ability to inhibit irrelevant information.

Third, Prather will examine how SFOR tendency in early primary school may be related to arithmetic conceptual knowledge, using novel tasks aimed to examine spontaneous focusing on additive and multiplicative relations. The study represents the first efforts to examine specifically how SFOR tendency may be related to early arithmetic development. Preliminary results suggest a positive relationship between SFOR for additive relation and knowledge of the relation to operands arithmetic principle.

Finally, McMullen and colleagues will present evidence of the effectiveness of an intervention aimed at enhancing SFOR tendency. Students in the experimental condition participated in five lesson designed to guide their attention to multiplicative relations in their everyday lives. Results suggest that the activities are effective in enhancing students' SFOR tendency. Results of a follow-up measure that examines students' long-term fraction development will be presented.

Talks:

The Effects of Perceptual Salience on Attention to Number.

- Michele Mazzocco, Jenny Chan, Sarah Lukowski

The Influence of Parent and Child Factors on Preschool-aged Children's Spontaneous Focusing on Number

- Alex Silver, Leanne Elliott, Melissa Libertus

Arithmetic knowledge from the spontaneous focus on relations

- Richard Prather

Enhancing students' spontaneous focusing on multiplicative relations

- Jake McMullen, Saku Määttä, Erno Lehtinen, & Minna M. Hannula-Sormunen

S14: Home numeracy and early math skills in Latin America: Findings from Chile, México, and Uruguay

EarlyMathSkills35.1

Presenters:

- María Inés Susperreguy, Pontificia Universidad Católica de Chile.
- Diana Leyva, Davidson College
- Dinorah de León, Universidad de la República, Uruguay
- Carolina Jiménez Lira, Universidad Autónoma de Chihuahua

Abstract:

Studies conducted in North America (Gunderson & Levine, 2011; LeFevre et al., 2002; LeFevre et al., 2010; LeFevre et al., 2009; Skwarchuk et al., 2014), Europe (Kleemans et al., 2012), and Asia (Pan et al., 2006; Qi et al., 2017) have found a close relation between children's acquisition of early numeracy skills and the home learning environment. Children whose parents report higher frequencies of engaging in numeracy activities tend to perform better on math assessments than children whose parents report engaging in numeracy activities less often. In Latin America, the amount of research conducted on home numeracy and young children's math skills has been gradually increasing over the last few years (e.g., De León, 2016; Jiménez Lira, 2016; Susperreguy et al., 2018). Findings from these studies, however, have been inconsistent across countries. For example, while studies in Uruguay and Chile found evidence of a link between home numeracy and math skills (DeLeón, 2016; Leyva, 2018; Susperreguy et al., 2018), initial research conducted in Mexico found no relation between the two variables (Jiménez Lira, 2016). This symposium presents the results from four studies conducted in Chile, Mexico, and Uruguay exploring the association between home numeracy activities and children's early math skills through different methodologies and with families from diverse socio-economic status (SES) and cultural backgrounds.

The first talk "Home Numeracy and Chilean Children's Numeracy Skills Growth from Preschool to Kindergarten" (María Inés Susperreguy Ph.D. Associate Professor at the Pontificia Universidad Católica de Chile), investigates the role of home numeracy activities in predicting the growth of Chilean children's numeracy skills from the end of pre-kindergarten to the end of kindergarten.

The second talk, How Do Low-Income Chilean Parents Support Preschoolers' Math in a Grocery Game? (Diana Leyva, Ph.D. Assistant Professor at Davidson College, USA) examines associations between parents' math support in a grocery game at the beginning of pre-kindergarten and gains in children's math skills from pre-kindergarten to the end of kindergarten in a sample of low-income Chilean families.

The third talk, "Mathematical intervention for parents of preschool children" (Dinorah de León, Universidad de la República, Uruguay) investigates whether children's math outcomes can be improved through a math intervention with preeschoolers' parents. Two schools in Montevideo, Uruguay participated. A total of 140 families were randomly assigned to one of three groups. Two of the groups entailed 3 biweekly numerical-activities workshops (experimental group) and the reading-activities workshop (active control group). Preliminary results show that both workshop groups (math and literacy) tended to improve math scores.

Finally, the fourth talk, "Home numeracy and symbolic math skills in preschool: re-examining the relationship" (Carolina Jiménez Lira, Ph.D. Professor at Universidad Autónoma de Chihuahua) discusses results from a correlational study conducted with 3-,4-, and 5-year-old preschool children from low and high SES backgrounds in Chihuahua, Mexico. Children completed cardinality, number recognition and comparison tasks while parents completed the home numeracy questionnaire (Skwarchuk et al., 2014). Preliminary analyses suggest that patterns of results vary across SES.

Talks:

Home Numeracy and Chilean Children's Numeracy Skills Growth from
Preschool to Kindergarten

- María Inés Susperreguy, Sabrina M. Di Lonardo, Chang Xu, Heather Douglas, Jo-Anne LeFevre

How Do Low-Income Chilean Parents Support Preschoolers' Math in a
Grocery Game?

- Diana Leyva

Math Intervention for Parents, Learning through Activities Workshops

- Dinorah de León

Home Numeracy and Literacy Practices and Early Math Skills in Mexican Preschool Children.

- Carolina Jiménez Lira, Elia Verónica Benavides Pando, Martha Ornelas Contreras, Humberto Blanco Vega,

S15: Neuroscience of Dyscalculia

Dyscalculia55.1

Presenters:

- Bert De Smedt, University of Leuven, Leuven, Belgium
- Karin Kucian, University Children's Hospital, Zurich
- Teresa Iuculano, Centre National de la Recherche Scientifique & Université de Paris, La Sorbonne
- Mojtaba Soltanlou, Department of Psychology, University of Tuebingen, Tuebingen, Germany

Abstract:

Dyscalculia is a learning disorder with a deficit in mathematical ability despite normal intelligence. Its prevalence is about 6% and this disorder has several individual and social consequences. For instance, individuals with dyscalculia need more educational support, earn and spend less, and have more troubles with the law (Parsons & Bynner, 2005). While most of our knowledge about dyscalculia comes from behavioral and cognitive levels, little is known about neurobiological correlates of this disorder (Butterworth et al., 2011). However, by further accessibility of neuroimaging techniques and its application in the field of numerical cognition during the last decade, neural correlates of dyscalculia have provided fruitful information about the underlying mechanism of the brain of individuals with dyscalculia.

However, there is still a need for integrating the findings obtained from these imaging studies. For instance, some neuroimaging studies, on the one hand, showed that individuals with dyscalculia have decreased brain activation in parietal areas such as intraparietal sulcus – an area related to magnitude processing – (for a review see Butterworth et al., 2011; Peters et al., 2018). Interestingly, children with dyscalculia revealed increased activation – similar to typically developing children – in parietal areas including the intraparietal sulcus after 5 weeks of number line training (Kucian et al., 2011). On the other hand, Rosenberg-Lee and colleagues (2015), however, observed increased activation in several brain areas in frontal and parietal cortices, and also hyper-connectivity in the intraparietal sulcus and multiple brain areas in children with dyscalculia. This hyper-connectivity disappears after five weeks of number line training (Michels et al., 2018) or after eight weeks of cognitive tutoring (Iuculano et al., 2015), which suggests a functional reorganization of these brain areas.

Against the background of these conflicting findings, we would like to propose a symposium on the neuroscience of dyscalculia in order to discuss state-of-the-art findings in this field. The talks will cover several issues about the neuroscience of dyscalculia. Specifically, the symposium will consist of 4 speakers which will focus on the following themes: (1) Bert De Smedt will talk about the added value of structural brain imaging measures for predicting individual differences in children's arithmetic fluency; (2) Karin Kucian will talk about the neurostructural correlate of math anxiety in the brain of children with and without developmental dyscalculia; (3) Teresa Iuculano will talk about the multiple facets of neural aberrancies in developmental dyscalculia; and (4) Mojtaba Soltanlou will talk about the neural correlates of arithmetic training in children with dyscalculia.

Talks:

The added value of structural brain imaging measures for predicting individual differences in children's arithmetic fluency

- Bert De Smedt, Brecht Polspoel, Maaike Vandermosten

Neurostructural correlate of math anxiety in the brain of children with and without developmental dyscalculia

- Karin Kucian, Ursina McCaskey, Michael von Aster, Ruth O'Gorman Tuura

Multiple facets of neural aberrancies in Developmental Dyscalculia: implications for remediation

- Teresa Iuculano

Arithmetic training improves neural functionality in children with dyscalculia

- Mojtaba Soltanlou, Thomas Dresle, Christina Artemenko, Ann- Christine Ehlis, Hans-Christoph Nuerk

S16: Individual Differences in Fractions Knowledge

Fractions84.1

Discussant:

- Martha W. Alibali, University of Wisconsin-Madison

Presenters:

- Priya B. Kalra, University of Wisconsin-Madison
- David W. Braithwaite, Florida State University
- Jake McMullen, University of Turku

Abstract:

Understanding fractions is critical to mathematical development. However, many children struggle with fractions even after years of instruction. This symposium will explore individual differences in children's fractions knowledge, including predictors of differences in overall performance (the first talk), effects of differences in cognitive parameters on fractions learning (the second talk), differences in adaptive knowledge among high performers (the third talk), and differences in how children respond to a fraction intervention (the fourth talk).

One of the difficulties learners have understanding fractions is that they are inherently relational: they are defined not by the size of individual components, but by the multiplicative relations between those components. Thus, we hypothesized that individual differences in children's relational reasoning abilities should predict fraction knowledge. We administered a battery of math-specific and domain-general cognitive abilities assessments to 2nd- and 5th-grade children (N = 201, mean age = 8.04 years and N = 150, mean age = 10.92 years), including the analogy subtest of the Test of Relational Reasoning Jr. Findings indicate significant effects for relational reasoning over and above other measured abilities.

This study employed a computational model of fraction arithmetic learning, FARRA (Braithwaite, Pyke, and Siegler, 2017), to investigate individual differences in children's fraction arithmetic. FARRA predicted four distinct patterns of performance, as well as effects of math achievement on the distribution of the patterns. Analyses of two empirical datasets confirmed the predictions. The findings highlight three cognitive parameters that may affect learning in fraction arithmetic: effective learning after committing errors, behavioral consistency versus variability, and presence or absence of initial bias.

This study highlights individual differences in exceptional rational number knowledge and skills. Results indicate that even among those with high levels of rational number conceptual and procedural knowledge, some children are more able to adaptively apply their knowledge and skills on novel tasks than others. This difference appears at least partially driven by flexibility in switching between fraction and decimal representations.

We examined individual differences in the effectiveness of an intervention aimed at dampening the strength of fourth graders' natural number bias when reasoning about fractions. Using refutational texts meant to confront and replace misconceptions about the size of fractions – that larger component numbers leads to larger magnitudes (i.e. 1/9 > 1/7 because 9>7). Despite the intervention being effective overall, examining the differing effects of the intervention revealed that some students went on to over-apply the new heuristic (i.e. smaller numbers = larger magnitude).

Talks:

Relational Reasoning Predicts Fraction Knowledge

- Priya B. Kalra, Percival G. Matthews, Edward M. Hubbard

Modeling Individual Differences in Fraction Arithmetic

- David W. Braithwaite, Elena R. Leib

Individual Differences in Rational Number Knowledge Among High Performers

- Jake McMullen, Erno Lehtinen, Minna M. Hannula-Sormunen, and Robert S. Siegler

S17: Beyond number sense: Exploring the contribution of domain-general cognitive processes to the development of mathematical thinking

CognitiveProcesses138.1

Discussant:

- Rebecca Merkley

Presenters:

- Ilse Coolen, Université Paris Descartes
- Eric Wilkey, University of Western Ontario
- Kelly Mix, University of Maryland
- Gavin Price, Vanderbilt University

Abstract:

There is a growing body of evidence suggesting that a sense of number is acquired, rather than innate and domain-specific (see Leibovich et al., 2017 for a review). This points to the need to understand the role of domain-general learning mechanisms in children's acquisition of number concepts. In this symposium, we will explore the development of mathematical thinking in relation to attention, executive functions, and spatial skills.

First, Gaia Scerif will present a talk titled A one-way street? Testing bidirectional relationships between emerging attentional control and mathematical cognition. She will report on the findings from a longitudinal project investigating the cognitive and educational foundations of preschool mathematics development. Results replicated previous findings that early number knowledge and executive function processes are correlated with and predict each other longitudinally. However, results also showed that executive function at time one predicted growth in number knowledge at time two, albeit weakly, but number knowledge did not predict growth in executive function. This suggests that the finding that domain-general cognitive processes predict math achievement longitudinally does not necessarily imply a causal relationship. Further research is needed to uncover the mechanisms underlying the bidirectional relationships between domain-general cognitive skills and math achievement.

Then, in Attention to Number: The convergence of numerical magnitude processing, attention, and mathematics, Eric Wilkey will present results from two studies that investigated the influence of congruency between numerical and non-numerical magnitude in the nonsymbolic number comparison task. Results showed (1) the congruency manipulation is essential for this task's relation to math (2) functional activation related to the congruency manipulation correlates with math rather than activation related to number. Further, this relation exists in the inferior frontal gyrus (IFG) rather than in parietal structures typically found to be involved in numerical cognition. This suggests the need to incorporate attentional factors into our models of numerical cognition in addition to domain-specific numerical representation processing.

Kelly Mix will then present a talk titled "Developmental Relations between Spatial Skill and Mathematics". She will present on individual differences in longitudinal data from studies exploring the intertwined development of spatial and mathematical thinking.

Rebecca Merkley will lead a discussion on how these findings can inform theories of the development of mathematical cognition. Future directions for research in this area will also be discussed.

Talks:

A one-way street? Testing bidirectional relationships between emerging attentional control and mathematical cognition.

- Ilse Coolen

Attention to Number: The convergence of numerical magnitude processing, attention, and mathematics

- Eric Wilkey

Developmental Relations between Spatial Skill and Mathematics

- Kelly Mix

S18: Leveraging gesture to enrich math learning for diverse learners

MathLearning114.4

Presenters:

- Ruth B. Church, Northeastern Illinois University
- Elizabeth M. Wakefield, Loyola University, Chicago
- Susan W. Cook, University of Iowa
- Shereen O. Beilstein, University of Illinois Urbana-Champaign

Abstract:

A large body of research has found that gestures, the hand movements that accompany speech, can reveal children's understanding of abstract math concepts, and that gesturing can also play an important role in changing how children think about math (e.g., Church, Ayman-Nolley & Mahootian, 2004; Cook, Duffy & Fenn, 2013; Cook & Goldin-Meadow, 2006; Flevares & Perry, 2001; Goldin-Meadow, Alibali, & Church, 1993; Goldin-Meadow, Cook, & Mitchell, 2009; Novack, Congdon, Hemani-Lopez, & Goldin-Meadow, 2014; Perry, Church, & Goldin-Meadow, 1988, 1992; Singer & Goldin-Meadow, 2005).

To date, however, less work has thoroughly examined the educational implications that stem from studies of gesture in children's cognitive representations of math concepts. As a result, scholarship documenting the role of gesture in math learning has not been translated into educational practice. This symposium, Leveraging gesture to enrich math learning for diverse learners, brings together researchers in educational psychology and gesture studies to consider the mechanisms that underlie the role of gesture in math learning, as well as the efficacy of gesture-based instructional interventions for learners from diverse backgrounds.

The proposed talks feature presenters from various stages in their careers, from graduate students to post-doctoral scholars to tenured professors, all focusing on the role of gesture in mathematics learning and instruction. Studies in this symposium target the temporal relationship between speech and gesture, as well as possible modality effects in the use of gesture in math instruction. We assess the possible mechanisms driving gesture's role in learning through neuroimaging and behavioral measures. Finally, an overarching goal for the symposium is to outline concrete tools that can be leveraged to enrich math learning for students from diverse backgrounds.

Specific topics addressed in the symposium include comparison between hearing and deaf learners from varied socio-economic backgrounds; identifying the neural network that is recruited in solving pre-algebraic math problems learned through a gesture strategy, as assessed through Magnetic Resonance Imaging; the difference between learning that takes place in person and learning that takes place online; and comparison between instruction using gesture and instruction with concrete manipulatives. Specific mathematical concepts addressed in the symposium include mathematical equivalence, fraction magnitudes, and polynomial multiplication.

Talks:

Examining gesture as a teaching tool in on-line instruction for deaf and hearing children

- Ruth B. Church, Jenny Lu, Ryan Lepic, Michelle Hurst, Theodora Koumoutsakis, Zena Levan, Susan Levine, Susan Goldin-Meadow

Why does gesture help children learn mathematical equivalence?

- Elizabeth M. Wakefield, Eliza L. Congdon, Miriam A. Novack, Susan Goldin-Meadow, Karin H. James

Sixth graders learn from specific gestures, in the lab and online

- Susan W. Cook, Martha W. Alibali, Todd Pruner

How object manipulation, gesture, and their combination support children's fraction understanding

- Shereen O. Beilstein, Michelle Perry

S19: Early numerical and non-numerical abilities and their relation with mathematical education

EarlyMathSkills174.5

Presenters:

- Wei Wei, Zhejiang University, China
- Sara Caviola, University of Leeds
- Tali Leibovich-Raveh, University of Haifa
- Krzysztof Cipora, University of Tuebingen, Tuebingen,

Abstract:

A prevailing idea in the existing literature is the presence of a bound between the early markers of numerical cognition and math education. In particular, extensive interest has been placed on the concept of magnitude representation, often measured by means of comparison tasks, and the numeric properties of a set of items, irrespectively from the type of numerical notations (symbolic or non-symbolic stimuli). The first two presentations will present data from two large scale studies (N>1300) in primary school children showing how these comparison measures account for individual differences in math achievement.

Wei and Zhou will present a study aimed to explain why children in urban areas outperform children attending schools in rural areas in arithmetic achievement. The results showed that after controlling for scores on a word rhyming task, there were no longer region differences in arithmetic performance, whereas controlling for scores on magnitude comparison tasks and general cognitive tasks did not eliminate region differences in arithmetic. These results suggested that urban children's advantage in arithmetic was likely due to their advantage in phonological processing.

Similarly, Caviola and colleagues investigated the relation between non-symbolic and symbolic magnitude comparison tasks and math achievement, by also taking into account domain-general variables, such as working memory, which has been consistently found related to math achievement. Results showed that there is no robust evidence to suggest that non-symbolic magnitude comparison measures have any specific relation whatsoever to math achievement, when symbolic magnitude comparison measures or domain-general factors are taken into account.

Other two important signatures of elementary number processing will be the focus of the last two presentations, respectively: the subitizing, i.e. the ability to perceive the quantity of up to 3-5 items in a quick manner and the Spatial Numerical Association of Response Codes (SNARC). Several studies found evidence in favor of a correlation between subitizing ability and overall math performance. Therefore, measuring subitizing for individuals can be valuable to inform both educational and neuro-cognitive studies. So in the third talk, Leibovich will present and discuss a novel method developed to measure Individual Subitizing Range.

Cipora will conclude the symposium by presenting a detailed overview of the past 25-years of research focused on the relation between SNARC effect and math achievement. The SNARC effect will serve as an illustrative example of two important issues relevant to investigations on the relation between elementary numerical processing and math skills. Firstly, math performance needs to be carefully operationalized, and the conclusions should be limited to specific operationalization, not generalized over math achievement in general. Secondly, group level effects need to be clearly differentiated from diagnostic usefulness.

Talks:

Arithmetic performance in rural vs. urban schools in Chinese regions are accounted for by early phonological processing.

- Wei Wei, Xinlin Zhou

Magnitude comparison skills and mathematical learning: a large cross sectional study in primary school children

- Sara Caviola, Lincoln J. Colling, Irene C. Mammarella, Dénes Szűcs

Using subitizing as an index of individual implications: method and educational relevancy

- Tali Leibovich-Raveh

SNARC and math skill – how signatures of elementary number processing relate to math skill, and how they do not

- Krzysztof Cipora

S20: Mathematical discourse - The symbols we use to communicate mathematical ideas

MathematicalDiscourse29.1

Discussant:

- M. Gail Headley, University of Delaware

Presenters:

- Sarah Powell, University of Texas
- Heather Douglas, Carleton University
- Erica Zippert, Vanderbilt University

Abstract:

Mathematical ideas are primarily communicated via written symbols, but little is known about how to measure children's symbol knowledge, how children's symbol knowledge relates to the development mathematical skills, or how it is supported by caregivers in everyday informal contexts. Join us as we explore these questions from multiple perspectives. The collection of presentations examines levels of knowledge for specific math symbols (e.g., =, x, >), children's understanding of the rules and conventions for combining mathematical symbols in text, and children's ability to make connections between written and oral representations of mathematics. First, Sarah Powell introduces a tool designed to assess a broad range of mathematical symbol knowledge including knowledge of the symbol name, its meaning, and its application. Comparing children in grades 1, 3, 5, Powell describes differences in symbol knowledge and the shifting influence of symbol knowledge on computational skill as children develop. Next, Heather Douglas extends symbol knowledge from labelling and defining symbols to consider children's understanding of mathematical orthography; that is, how symbols are combined to make meaningful math text (e.g., is this meaningful + 2 1 = 3?). Douglas discusses how a novel cognitive task was employed to examine the relation between mathematical orthography and mathematical skill amongst children in grades 2, 3, 4 and 6. Then, Erica Zippert explores how caregivers and preschoolers discuss math text during the informal context of tablet storybook reading. Zippert quantifies the added benefit of built-in dialogic questioning on caregiver-preschooler number and spatial talk. Finally, discussant Gail Headley, will highlight connections amongst the presentations and propose questions to provoke discussion and challenge our understanding of mathematical discourse, the symbols we use to communicate mathematical thinking, and the role of symbol knowledge in mathematical development.

Talks:

Mathematical Symbol Knowledge in Grades 1, 3 and 5

- Sarah Powell

Mathematical Orthography Knowledge in Children

- Heather Douglas, Jill Turner, Renee Whittaker, Chang Xu, Jo-Anne LeFevre,

Promoting Parent-Child Math Talk Via Dialogic Reading Prompts – Will it Work on a Tablet?

- Erica Zippert, Zachary Stuckelman, Georgene Troseth,

S21: From the math lab to the math class: can we improve math learning by targeting specific cognitive mechanisms?

MathLearning53.1

Presenters:

- Flávia H. Santos, University College Dublin
- Ipek Saralar, University of Nottingham
- Ann Dowker, Oxford University, England
- Dror Dotan, Tel Aviv University, Israel

Abstract:

Mathematical cognition can have important implications on math education practices, but the relation between cognition and education is still poorly understood. Mathematical proficiency is based on a large variety of cognitive mechanisms – visual and verbal number processing, memory, spatial thinking, and more. Correspondingly, there is a large variety of math difficulties whose origin is cognitive, and developmental dyscalculia is a heterogeneous phenomenon. Understanding the cognitive origins of mathematical performance and mathematical disorders may lead to effective pedagogical interventions.

Here, we present four different intervention methods that aim to improve numerical and mathematical abilities. These used different specific methods and designs, targeted different sub-domains of mathematics (basic number processing, arithmetic, and geometry), and involved different populations (children and adults, with typical and atypical mathematical performance). Yet crucially, all four intervention programs exploited our understanding of certain aspects of mathematical cognition: one program, Low-Interference Memorization, teaches the multiplication table by capitalizing on the sensitivity of verbal memory to similarity. A second program, the Numeracy Musical Training, stimulates the core numerical cognition systems by exploiting the properties of musical sounds. A third program, the RETA 3D Shapes Teaching Model, teaches orthogonal and isometric drawings through realistic, exploratory, technology-enhanced and active lessons to improve spatial thinking. Last, the Catch Up Numeracy program focuses on assessing primary school children with low mathematical attainment on ten separate components of numeracy, and then giving them half an hour a week of individualized teaching that focuses on the components where they show weaknesses.

All four intervention programs were effective – they improved the mathematical performance of the target population. The lessons we learned from those interventions are: First, accurate cognitive assessment of individuals with developmental dyscalculia is crucial to create tailored intervention methods. Second, cognitive-driven intervention can generate slightly different cognitive effects among individuals with typical and atypical mathematical development. Third, the intervention outcome is affected by general factors such as the duration and frequency of training, the sensory modality, and the participant's motivation to engage the program. Altogether, our results show how having a cognitive theory can help creating effective training programs. Future research should continue exploring further evidences for efficacy, replicability and the applicability of such programs in different cultures.

Talks:

Can Numeracy Musical Training improve numerical cognition in preschool children?

- Flávia H. Santos, and Eder R. Silva

Improving middle school students' understanding of geometrical shapes: An experimental study of the RETA model

- Ipek Saralar, Shaaron Ainsworth, Geoff Wake

Catch Up Numeracy: a componential approach to implications for interventions for children with arithmetical difficulties.

- Ann Dowker

Memorizing the multiplication table can be made easier by reducing similarity-induced interference

- Dror Dotan, Shani Medina, Naama Friedmann

S22: Early Mathematical Screening Tools: Bridging the Research-Practice Gap

EarlyMathSkills193.6

Presenters:

- Marcie Penner, King's University College at Western University
- Brianna Devlin, University of Delaware
- Stephanie Bugden, University of Pennsylvania
- Rebecca Merkley, Carleton University

Abstract:

One in ten children persistently struggle to learn mathematics (Mazzocco & Myers, 2003). Early identification of children at risk for math learning difficulties is key to improving their mathematics and broader educational outcomes. A numeracy screener is a test designed to identify which individual students are currently struggling, or at risk of struggling, to gain numeracy skills. Screeners are used to select children to receive intervention and to gage their progress. In this symposium, we will address screening tools to help educators and educational researchers identify children likely to struggle with mathematics, with the ultimate goal of providing effective math interventions. The multidisciplinary talks, by teams of researchers and educators, discuss practical issues from selection through to implementation of numeracy screeners. The goal of this symposium is to bridge the gap from research to practice, providing educators and educational researchers with the knowledge to thoughtfully select evidence-based screening tools and to successfully implement math screening in school settings.

In Comparing Apples to Oranges? Assessing the Construct and Concurrent Validity of Measures of Magnitude Comparison Performance, Marcie Penner (Associate Professor, Department of Psychology, King's University College at Western University) will evaluate the different performance measures for a commonly used numeracy-screening task – number comparison (i.e., determining which number/set of items is more). The goal of this research is to better inform the selection of numeracy screening measures for educators and educational researchers.

In Using Quantile Regression to Predict Early Number Sense, Brianna Devlin (Ph.D. student, Department of Education, University of Delaware) will demonstrate how quantile regression is a useful tool to investigate mathematical development and to identify children likely to struggle to gain numeracy skills. Using quantile regression, Devlin et al., determined demographic variables (including gender) that predict the development of number sense from preschool to 1st grade.

In A Two-Minute Test of Symbolic and Non-Symbolic Numerical Magnitude Processing Can Accurately Predict Children With And Without Persistent Developmental Dyscalculia, Stephanie Bugden (Post-Doctoral Fellow, Department of Psychology, University of Pennsylvania) will present the results of an efficacy study of the Numeracy Screener, a simple, 2-minute paper and pencil assessment of symbolic (Arabic numerals) and non-symbolic (dot arrays) number comparison abilities. The Numeracy Screener accurately predicted children with persistent developmental dyscalculia from typically developing children, and from children who had exhibited inconsistent math performance.

In Understanding Educator Experiences Implementing Screeners to Assess Students' Early Math Skills: A Research-Practice Collaboration, Rebecca Merkley (Assistant Professor, Institute of Cognitive Science, Carleton University) will describe a collaborative project between university-based researchers, school board researchers, and educators. The aim of the project was to test whether training educators to implement two numeracy screeners with Kindergarten students would help them to identify students at risk for falling behind their peers and subsequently target their math instruction. Feedback from educators suggested they found the screeners reasonably easy to implement and informative for their practice. Their feedback also highlighted aspects of implementation of the school that could be improved and future research directions for the school board and university researchers.

Talks:

Comparing apples to oranges? Assessing the construct and concurrent validity of measures of magnitude comparison performance

- Marcie Penner, Aaron L. Cecala, Melissa Elfers

Using quantile regression to predict early number sense

- Brianna Devlin, Haobai Zhang, Amber Beliakoff, Alice Klein, Nancy C. Jordan

Predicting developmental dyscalculia from a 2-minute test of symbolic and non-symbolic numerical magnitude processing

- Stephanie Bugden, Nadia Nosworthy, Lisa Archibald, Daniel Ansari

Understanding educator experiences implementing screeners to assess students' early math skills: A research-practice collaboration

- Rebecca Merkley, Jennifer A. McDonald, Jacqueline Mickle, Daniel Ansari

S23: Unpacking Manipulatives: Recommendations for the Mathematics Classroom

MathLearning156.6

Chair:

- Helena Osana, Concordia University

Discussant:

- Martha W. Alibali, University of Wisconsin—Madison

Presenters:

- Anne Lafay, Concordia University
- Andrea M. Donovan, University of Wisconsin—Madison
- Emmanuelle Adrien, Concordia University

Abstract:

Manipulatives are concrete objects (e.g., blocks, tokens) often used in elementary classrooms to represent mathematical concepts. Although manipulatives can support students' learning, they can also impede learning in some cases. The reasons behind these discrepant findings remain unclear. The research presented in this symposium will examine the relationship between instructional factors - the physical affordances of manipulatives, instructional sequencing, and the explicitness of teacher support - and young children's learning with manipulatives. The symposium will provide theoretical insights on children's mathematical development and generate empirically-validated recommendations for practice. Central themes and directions for future research will be addressed by Martha W. Alibali (University of Wisconsin-Madison), who will serve as Discussant for the session.

In the first paper, Anne Lafay (Concordia University), Helena P. Osana (Concordia University), and Olivia Hadjadj (Université de Strasbourg) address the physical affordances of manipulatives on children's number representation and numeration understanding. The authors describe a study in which second-graders (N = 99) with and without mathematics difficulties were provided manipulatives that differed in terms of their detachability (denominations could be physically decomposed or not) and countability (units could be counted individually or not). Children used the manipulatives to represent two- and three-digit numbers, after which they completed a number decomposition task with written numerals. The authors report that performance on number representation was higher when children used the non-detachable manipulatives, but only for those with mathematical difficulties. Performance on the number decomposition task was not related to manipulative type.

In the second paper, Andrea M. Donovan (University of Wisconsin-Madison) and Emily Fyfe (Indiana University) examine the effects of helping children make connections between objects (e.g., blocks) and symbols (e.g., written numbers) on their mathematics learning. The authors describe a study that examined differing instructional methods and their influence on children's knowledge of these connections as well as performance. Children ages 5 to 8 (N = 138) learned about place value in one of four conditions: Concrete (base-ten blocks), Comparison (compare blocks to numbers), Two-Step Fading (blocks, transition to numbers), and Three-Step Fading (blocks, transition to pictures, transition to numbers). Condition differences were minimal but favored the Three-Step Fading condition.

In the third and final paper, Emmanuelle Adrien (Concordia University), Helena P. Osana (Concordia University), David H. Uttal (Northwestern University), and Arielle Orsini (Concordia University) describe a study that investigated how type of instruction influences children's quantitative interpretations of a target manipulative. First-graders (N = 63) were randomly assigned to three instructional conditions: direct instruction, guided exploration, or control. The instructional objective was for children to assign a specific referent (i.e., 2) to the target manipulative. After instruction, children in the direct instruction condition solved more word problems using the prescribed quantitative referent relative to the other conditions. The authors use the findings to suggest that when the objective is to use a manipulative in a prescribed way, direct instruction is more effective than guided exploration.

Talks:

The Effects of Detachability and Countability of Manipulatives on Second-Graders' Number Knowledge

- Anne Lafay, Helena P. Osana

Concrete Connections: Testing the Effects of Differing Instructional Methods on Children's Ability to Connect Concrete Objects and Abstract Symbols During Math Learning

- Andrea M. Donovan

How Does Type of Instruction Influence Children's Use of Manipulatives?

- Emmanuelle Adrien, Helena P. Osana, David H. Uttal, Arielle Orsini

S24: Cognitive Underpinnings of Mathematics versus Reading Skills: Similarities and Differences

MathAndLanguage164.3

Discussants:

- Kiran Vanbinst & Lien Peters

Presenters:

- Tuire Koponen, University of Jyväskylä, Finland
- Xiujie Yang, Chinese University of Hong Kong
- Xiao Zhang, The University of Hong Kong

Abstract:

Early reading and mathematics achievement predicts later school achievement and even life quality and socioeconomic status in adulthood (Ritchie & Bates, 2013). Thus understanding individual differences in children's reading and mathematics skills is important. Although reading and mathematics are skills of different domains, they are related (Davis et al., 2014) and share a large amount of covariance (Singer & Strasser, 2017). This symposium explores the issue of similarities and uniqueness of reading and mathematics learning in terms of underlying cognitive underpinnings. The three studies included in the symposium examined a wide range of cognitive skills as predictors of reading and mathematical performance, such as vocabulary, metalinguistic skills, numerical skills, and general cognitive abilities. The symposium covered various populations in terms of culture (Finnish and Filipino children) and age (preschool, lower grades, and intermediate grades).

The speakers of the symposium include three researchers from multiple career stages in two countries. Tuire Koponen, PhD, is a researcher at the University of Jyväskylä in Finland. She will present a longitudinal study of 200 Finnish children who were followed up from Grade 1 to Grade 2, in which she found that rapid automatized naming (RAN) and verbal counting were strongly associated with the shared variance of reading and arithmetic fluency. Other unique predictors were phonological awareness, number comparison, and processing speed. Xiujie Yang is a PhD student at the Chinese University of Hong Kong in China. She will present a longitudinal study of 164 young Filipino children. She found that phonological awareness, RAN, and vocabulary knowledge were discriminating precursors but were associated disjunctively with the level and growth rate of early numeracy and print knowledge. Xiao Zhang, PhD, is an associate professor at the University of Hong Kong in China. Based on a sample of 378 Finnish children who were followed up between kindergarten and fourth grade, he found that RAN significantly explained the common variance in reading and mathematics growth trajectories and the unique variance in mathematics trajectories.

Identifying cognitive skills that explain common and unique variance in reading and mathematics skills has crucial theoretical and practical significance. It sheds light on the question of why reading and mathematics skills are related. It provides guidance on designing cost-effective interventions for children with different needs. It helps to identify children who are at risk of developing comorbidity of reading and mathematics learning disabilities.

Talks:

Cognitive Correlates of the Covariance in Reading and Arithmetic Fluency: Importance of Serial Retrieval Fluency

- Tuire Koponen, Kenneth Eklund, Riikka Heikkilä, Jonna Salminen, Lynn Fuchs, Douglas Fuchs, Mikko Aro

Developmental trajectories of early numeracy and print knowledge in young Filipino children: The roles of phonological awareness, rapid automatized naming, and vocabulary knowledge

- Xiujie Yang

Does Rapid Automatized Naming (RAN) Explain Common or Unique Variance in Reading and Mathematical Development?

- Xiao Zhang, Tuire Koponen, Pekka Räsänen, Kaisa Aunola, Marja-Kristiina Lerkkanen

S25: What I Can Bring to my Math Classroom: Putting Numeracy Research to Work

MathLearning154.5

Chair:

- Helena Osana, Concordia University

Presenters:

- Martha W. Alibali, University of Wisconsin—Madison
- Sarah Powell, University of Texas at Austin
- Nancy C. Jordan, University of Delaware
- Tracy Solomon, Hospital for Sick Children

Abstract:

Teachers often wonder what instructional strategies "work best" for children learning mathematics. Although there is no single approach that is effective for all children, productive learning environments are created when teachers adhere to instructional strategies and principles that have been empirically validated. With a focus on translating scientific findings for practitioners, the papers in this symposium will describe the positive effects of specific pedagogical strategies (e.g., gestures, visual representations, formative assessment) that have been shown to support children's mathematics learning.

In the first paper by Martha W. Alibali and Anna Bartel (University of Wisconsin-Madison), the authors focus on two instructional practices-visual representations and teacher gesture-that can support students' encoding of mathematics problem structure. They present evidence that these practices can (1) guide students' attention to key elements and structural relations within problems, and (2) highlight shared elements and structures across problems. Alibali and Bartel argue that these instructional practices are beneficial because they help students schematize relevant aspects of problem structure.

The second paper, by Sarah Powell (University of Texas at Austin), focuses on students' proficiency with setting-up and solving word problems. Research indicates that teaching students to understand the structure of word problems leads to better problem solving (Powell, Berry, & Barnes, 2019), and in this talk, Powell addresses what this looks like. She demonstrates how she taught elementary students three additive word-problem structures with a combination of explicit modeling, dialogue, gestures, visual representations, and authentic practice opportunities. She will highlight the word-problem attack strategy and teaching students to use equations to represent a word problem's structure.

The importance of early number sense is addressed by Nancy C. Jordan (University of Delaware) and Alice Klein (WestEd) in the third paper. Research shows that number sense is malleable and early intervention leads to improved math achievement in school. Moreover, core deficiencies in number sense underlie math difficulties. In their talk, the authors describe the development and validation of the Screener for Early Number Sense (SENS), an assessment tool to help teachers (preK, K, and 1st grade) identify children who may be at-risk for math difficulties and provide targeted instruction on specific number concepts. Jordan and Klein present the SENS along with evidence-based instructional activities that support number sense.

In the final paper, Tracy Solomon (Hospital for Sick Children) and colleagues describe the JUMP Math program, a unique, Canadian approach to K-8 math instruction, and show how its central tenets are empirically supported. The authors report the results from two randomized-controlled studies involving 1400+ elementary students and their 200+ teachers in 60 schools in two different Canadian school boards. The results revealed positive effects of JUMP Math instruction on growth in elementary math achievement. The authors also report data on program implementation and teacher feedback about why JUMP Math works, which will be followed by a discussion of implications for policy and practice.

Talks:

Instructional Supports for Encoding Mathematics Problems: Visual Representations and Teacher Gesture

- Martha W. Alibali, Anna Bartel

How to Teach Students to Understand Word Problems

- Sarah Powell

The Screener for Early Number Sense: Helping Teachers Identify and Support Children at Risk for Mathematical Difficulties

- Nancy C. Jordan, Alice Klein

Keeping an Open Mind About How to Approach K to 8 Math Instruction: The Effectiveness of the JUMP Math Program

- Tracy Solomon, Annie Dupuis, Arland O'Hara, Min-Na Hockenberry, Jenny Lam, Geraldine Goco, Bruce Ferguson, Rosemary Tannock

S26: A variety of early grade mathematics assessments and their uses in South Africa

EarlyMathAssessment232.1

Presenters:

- Hanrie Bezuidenhout & Elizabeth Henning, University of Johannesburg, South Africa
- Ingrid Mostert, University of Johannesburg, South Africa
- Lara Ragpot, Trinity Western University & Caroline Fitzpatrick, Université Sainte-Anne
- Ingrid Mostert, University of Johannesburg, South Africa

Abstract:

Early grade mathematics assessment instruments in South Africa have been used for different purposes – some to establish associations, another to reflect on impact of a teacher training intervention and another to inform large-scale learning materials design.

Although cognitive skills, such as executive functions and logical reasoning are known contributors to mathematics learning, a recent study in Soweto, Johannesburg, found that mathematics vocabulary of a cohort of 70 children in kindergarten classes was a stronger contributor to number concept development. Using a standardized, interview-based test, researchers found that a custom-designed vocabulary test contributed more to numeracy development than children's logical reasoning and their executive functions. Children in the one (of the two) language groups performed better on the pre- and the post-test.

Classroom engagement, an important indicator of executive functioning, predicts achievement in North American children. We examined how classroom engagement contributes to achievement in a sample of 1,211 South African children enrolled in kindergarten through grade 3. Multiple regression analyses revealed that classroom engagement predicts math and reading grades, b=.28 (95% CI, .22-.35) and b=.34 (95% CI, .36-.49), respectively. These results were statistically adjusted for child age, sex, race and previous term grades, teacher-child conflict and teacher experience, and family configuration, maternal education, and home language. The present findings point to the importance of addressing child engagement.

Measuring impact of interventions in early grade mathematics teaching is both challenging and expensive. The paucity of validated instruments, in the appropriate language, exacerbates this. In an evaluation of Grade R (Reception) teacher training intervention, an interview-based assessment of children's number concept was administered to 622 Grade R children. The instrument (validated for 5 languages) was translated into isiXhosa. Using an experimental design, the learner results in the intervention group showed modest gains – with the major shifts being in the lower levels (2-3) of the Marko-D framework. The research design suggests a cost-effective way to measure impact of mathematics interventions on learner outcomes in number.

Early grade mathematics materials development can either take into account the intended national curriculum expectations for children at a particular age or draw on assessment data from children. Adopting the latter approach we analysed data from the Early Grade Mathematics Assessment (EGMA) administered to 1038 learners from 11 rural schools in the Eastern Cape province of South Africa. In relation to addition, findings revealed that 90% of learners at the end of Grade 1 and 65% of learners at the end of Grade 2 are not proficient in addition between 1 and 20. This contradicts the national expectations and resulted materials developed with significantly different starting points to those developed only based on the national curriculum.

Talks:

Children's number concept development and mathematics vocabulary in kindergarten

- Hanrie Bezuidenhout, Elizabeth Henning

Associations between classroom engagement skills and early grade mathematics achievement

- Caroline Fitzpatrick, Lara Ragpot

Cost and validity constraints of assessing early grade number concept at large scale in multiple languages

- Nicky Roberts

The use of assessment data to inform the starting points of materials development

- Ingrid Mostert, Kimberly Porteus

S27: Linguistic influences on early numerical development

MathAndLanguage151.2

Presenters:

- Mojtaba Soltanlou, University of Tuebingen, Tuebingen
- Krzysztof Cipora, University of Tuebingen, Tuebingen, Germany
- Jacob Paul, Utrecht University, Utrecht, Netherlands
- Victoria Simms, Ulster University, Northern Ireland
- Thomas Gallagher-Mitchell, Liverpool Hope University

Abstract:

Research indicates that there may be substantial influence of language on early numerical development. Languages of different structure may have positive or negative impact on learning numerical information. In order to develop understanding of linguistic influences on numerical development this symposium will discuss the results of four studies that focus on languages that vary in their complexity. All studies measure performance in basic numerical skills (such as symbolic number comparison or arithmetic) and compare two groups of children who use different languages.

Soltanlou and Cipora discuss performance in symbolic comparison tasks between Polish and German speaking preschoolers. Paul summarises findings from a study assessing indigenous Australian 5-6 year-olds and non-indigenous Australian children on a variety of cognitive and arithmetic tasks. Simms reports findings of a study investigating 6-7 year-old children who learn mathematics in either their first (English) or second (Irish) language. Gallagher-Mitchel discusses age and language effects on number line estimation by comparing German and English 8-11 year-olds performance.

The results from each study provide insightful information into the development of numerical understanding and the complex nature of the influence of language on development. The results of each study will be discussed in light of the complexities of cross-cultural research and ramifications for education.

Talks:

Linguistic influences on Early Symbolic Knowledge Acquisition in Preschoolers

- Mojtaba Soltanlou, Krzysztof Cipora, Katarzyna Lipowska, Frank Domahs, Hans-Christoph Nuerk, Maciej Hama

Culture-Independent Prerequisites for Early Arithmetic

- Jacob Paul, Robert Reeve, Fiona Reynolds, Brian Butterworth

Age, cross-linguistic, and modality effects on children’s number line estimation

- Thomas Gallagher-Mitchell, Tanja Dackermann, Carlos Romero-Rivas

Understanding numbers in a second language: The story of Irish language learning

- Victoria Simms, Judith Wylie, Chang Xu, Anne Lafay, Jo-Anne LeFevre, Helena P. Osana, Sheri-Lynn Skwarchuk, Heather Douglas, Renee Whittaker, Jill Turner, Stephanie Hadden, Sarah Macintosh

S28: Is touch screen technology a double-edged sword in mathematics education?

MathAndTechnology79.1

Discussant:

- Erin Maloney, School of Psychology, University of Ottawa

Presenters:

- Joanne Lee, Developmental Psychology, Department of Psychology
- Adam K. Dubé, Learning Sciences, McGill University
- Marjorie W. Schaeffer, Department of Psychology

Abstract:

Parents often turn to technology to support their children's math learning (Radesky & Christakis, 2016). With many thousands of "educational" applications (apps) available (e.g., over 80,000 in Apple's iTune Store, Apple, 2015), families and schools have many options from which to choose. But are these apps effective? In this symposium, we explore if and when math apps can support children's math skill development. We examine the contingency between learning outcomes and the quality of apps and how they are used. Specifically, we discuss the content (talk 1), design elements (talk 2) and context (talk 3) of apps to examine the underlying mathematical skills and processes afforded by educational math apps. The impact of apps for children between 3 and 11 years old and use in both school and home settings are considered.

To provide appropriate learning experiences for children, we need to better understand ways to capitalize on this pervasive technology and how content and use can reach high pedagogical and developmental standards.

Talks:

Do Math Apps "Teach" Numeracy Skills to young children?

- Joanne Lee, Sylvia Andrade, Calandra Li, Alexandra Negotei, Ruth Aruliah, Eileen Wood

Are Math Games Helping or Hurting Children's Flexible Mathematical Thinking?: Testing The Role of Attention in Flexible Strategy Use.

- Adam K. Dubé, Run Wen, Chu Xu, Gulsah Kacmaz, Armaghan Montazam, Aishwarya Nair, Sabrina Shajeen Alam

Can a math app increase students' math achievement?

- Marjorie W. Schaeffer, Christopher S. Rozek, Talia Berkowitz, Susan Levine, Sian Beilock

S29: Early symbolic numerical skills: theoretical and educational implications.

EarlyMathSkills43.2

Presenters:

- Francesco Sella, University of Sheffield, UK
- Rose M. Schneider, University of California, San Diego, USA
- Camilla Gilmore, Loughborough University, UK
- Silke M. Göbel, University of York, UK

Abstract:

It has been argued that both humans and non-human animals are born endowed with the ability to represent numerical information approximately. However, only humans have developed language-dependent systems to represent numerical information in an exact manner. In Western societies, children gradually learn how number words and Arabic digits represent exact numerical quantities along with the arithmetic rules and principles characterising the numerical system. Most of the research has focused on later arithmetical and mathematical skills while less attention has been dedicated to understanding the conceptual knowledge necessary to establish a mature comprehension of the symbolic numerical system. In the present symposium, we delineate the building blocks of the early symbolic numerical knowledge in young children. Such investigation is crucial as the acquisition of numerical symbols in the early years of education is one of the most important predictors of later mathematical achievement. The first talk (Sella) describes how the mastering of different numerical concepts relate to the understanding of the exact numerical magnitude represented by number words and Arabic numbers. The second talk (Schneider) focuses on the causal mechanisms underlying children's acquisition of the successor function (i.e., the understanding that for any natural number n, its successor is n+1). The third talk (Gilmore) investigates the contribution of verbal counting, digit recognition, understanding of cardinality, symbolic to non-symbolic quantity mapping and ordinality to arithmetic skills in preschool children. The fourth talk (Göbel) focuses on the transcoding between the (verbal) number words and (visual) Arabic digits by exploring the frequency of mirror writing in primary school children. Each talk provides theoretical and methodological insights to clarify the complex interaction between specific numerical concepts as children learn the Arabic numerical system. Each speaker will also discuss the educational implications of the theoretical findings and offer practical recommendations to support the acquisition of symbolic numerical knowledge. The combination of the four talks provides a detailed overview of the development of early symbolic numerical skills in young children with the aim to promote the discussion of this topic among cognitive scientists and experts in education.

Talks:

Making sense on number words and Arabic numbers

- Francesco Sella, Daniela Lucangeli, Roi Cohen Kadosh, Marco Zorzi

Sources of knowledge in children's acquisition of the successor function

- Rose M. Schneider, Jessica Sullivan, David Barner

The relationship between pre-schoolers' basic numeracy skills and early arithmetic performance

- Camilla Gilmore, Sophie Batchelor

Mirror writing of digits and its relation to mathematical performance in primary school children

- Silke M. Göbel, Francina J. Clayton, Nitaya Khanijou, Mariel Rios Diaz, Hanna Weiers

S30: Understanding the Factors Affecting Mathematics Development and Supporting Children Through Home and School Interventions

MathLearning75.3

Chair:

- Sheri-Lynn Skwarchuk, University of Winnipeg, Canada

Presenters:

- Maureen Vandermaas-Peeler, Elon University,
- Sarah Melo, Faculty of Education, University of Manitoba
- Prentice Starkey, WestEd, San Francisco, California
- Jalisha Braxton, University of Chicago, Chicago, Illinois, USA

Abstract:

In developing mathematical competence, environmental factors such as background, confidence and experience, access to quality mathematics programming, and emotional triggers such as mathematics anxiety affect mathematics learning. This symposium will expose a broad range of barriers affecting mathematics learning, using a range of research methods, and how teachers, researchers and curriculum support experts at different career stages from around North America are impacting mathematical growth within their own cultural learning context. If accepted, we propose a symposium, where four researchers share their research to improve our understanding of the environmental contexts and other factors that affect mathematics learning. This presentation will be an excellent addition to the Education Day of the MCLS conference. The symposium will be chaired by Sheri-Lynn Skwarchuk, who is a school psychologist, professor and advocate for children having mathematical difficulties. Maureen Vandermaas-Peeler, psychology professor, will present on parental guidance of preschoolers' inquiry and mathematical activities in the home. Sarah Melo is a Master's student and teacher and she will discuss her intervention work with parents as they lead number talks at home with their children. We will focus on mathematical interventions in school and Prentice Starkey, Centre Co-Director from WestEd in San Fransisco, will share findings on preparing high-needs children for standards-based math instruction in Elementary School through involvement in two years of mathematics enrichment. Finally, Jalisha Braxton, a Doctoral student from the University of Chicago, will present her work on adult math anxiety, and the implications when negative feelings toward math are not addressed in childhood. Collectively, the researchers have approached mathematical learning from differing vantage points- Vandermaas-Peeler and Melo are working with parents to encourage math learning in the home. Starkey is focusing on state-wide interventions with at-risk children in school. Finally, Braxton is focusing on math anxiety in adult learners, in hopes of reducing concerns about approaching mathematics later in life. We hope this symposium will be relevant to researchers, educators, curriculum specialists and policy analysts working on improving children's understanding of mathematics at home and school. Discussion of broad contextual factors and how to mediate them through educational interventions is hoped to elucidate an appreciation of the complexities of mathematics learning; providing opportunities for reflection on enhancing mathematics learning for all.

Talks:

Parent Guidance of Preschoolers' Inquiry and Mathematics in Activities at Home

- Maureen Vandermaas-Peeler

Parent Journeys Through Number Talks with Their Children

- Sarah Melo

Preparing High-Need Children for Standards-Based Math Instruction in Elementary School Through Two Years of Mathematics Enrichment: Evidence from a RCT at a State Level of Scale

- Prentice Starkey, Alice Klein, Kylie Flynn, Ben Clarke, Jessica Turtura, Thomas Cook, Jamie Thomas

Calculated Avoidance: Math Anxiety Leads to Math Avoidance in Effort- Based Decision-Making

- Jalisha Braxton, Kyoung whan Choe, Christopher Rozek, Marc Berman, Sian Beilock,

Lightning Talk Abstracts:

L1: Math and the brain: Lessons from functional neuroimaging

Presenter: Marie Arsalidou, National Research University, Moscow
Authors: Marie Arsalidou

Math is a core subject in most school curricula in primary, secondary and university education; yet some thrive with it and others angst over it. Given such prolonged math experience how does the adult brain process arithmetic and how does a child's brain compare. Importantly how do these brain regions differentiate from other fundamental cognitive functions, such as working memory. This paper will address these questions by examining functional magnetic resonance imaging (fMRI) data on healthy children and adults that performed numerical, arithmetic and working memory tasks. Activation Likehihood Estimation (ALE) is a quantitative meta-analysis approach that evaluates concordance of brain across many fMRI studies. Data from over 100 fMRI studies on mathematical cognition were examined. Results show comparable brain areas in posterior parts of the cortex, such as the inferior parietal lobule for adults and children, whereas anterior parts of the cortex, such as the dorsolateral prefrontal cortex show suprathreshold clusters in adults, but not children. An area rarely highlighted in mathematical cognition that shows high values of being detected is the anterior insular cortex. Concluding this paper will discuss evidence-based education and potential implications for students learning mathematics and teacher's professional training.

L2: Pupillometric Indices of Arithmetic Approximation in College-Aged Adults

Presenter: Amanda L. McGowan, Michigan State University
Authors: Amanda L. McGowan, Madison C. Chandler, Matthew B. Pontifex

Although pupil size has been shown to modulate proportionally to problem difficulty in tasks requiring exact arithmetic functions, the degree to which pupillary metrics elucidate cognitive resources during numeric approximation tasks remains in question.

To this end, pupil size as an index of cognitive resources was recorded concurrent with behavioral measures in response to an approximate arithmetic task in a sample of 46 college-aged young adults (31 female, mean age = 18.8 ± 1.0 years). The approximate arithmetic task consisted of 216 problems presenting operands a + b in which participants were instructed to use approximation to indicate whether the problem sums were greater than or less than 100. Problems were equally distributed across small-split (i.e., ± 2 or 5%), large-split (i.e., ± 10 or 15%), and massive-split conditions (i.e., ± 50 or 55%).

Replicating previous behavioural findings, participants exhibited faster reaction time and increased response accuracy with greater split size problems. Novel to the present investigation was that pupil size as indices of cognitive resources similarly increased proportionately with the size of the split for each problem. Moreover, analysis of pupil size following bifurcation into high- and low- performers demonstrated that high-performers exhibited larger pupil size relative to low-performers for small-split problems, which may suggest enhanced cognitive resource modulation during difficult problems.

Such findings suggest that pupil size varies with problem difficulty during approximate calculation tasks. Moreover, pupil size as an index of cognitive resources may be useful in further elucidating individual differences in arithmetic approximation performance beyond overt behavioural measures.

L3: Effects of different transcranial electrical stimulation protocols on arithmetic learning
Presenter: Jochen Mosbacher, University of Graz
Authors: Jochen Mosbacher, Stefan Halverscheid, Roland H. Grabner

The acquisition of procedural and fact knowledge is among the most important processes in the development of arithmetic competencies. However, for many, this is a challenging process. Hence, interest in means to support it is growing and one promising method is transcranial electrical stimulation (tES) applied during learning. However, tES research in arithmetic learning is still scarce. In this study, we compared direct (tDCS) and alternating current (tACS) stimulations with sham stimulation regarding their effectiveness in enhancing the acquisition of procedural and fact knowledge of novel arithmetic problems.

Participants (N=112) received one of five active stimulations (left frontal or parietal tDCS or theta-band tACS, and parietal alpha-band tACS) or sham stimulation while solving five blocks of a novel arithmetic task. Thereby, 80 procedural learning problems (occurring once) were intermixed with four fact learning problems (appearing 29 times each). Stimulations were applied for 25 minutes during blocks two and three. Accuracy and mean response latencies were calculated for all blocks, and the number of repetitions needed until fact problems were consistently solved correctly by fact retrieval were assessed.

Stimulation groups differed in the number of repetitions needed to learn new arithmetic facts ($F=3.058$; $p=.013$; $\eta p2=.128$), with persons receiving frontal theta-band tACS needing less repetitions ($M=17.4$; $SD=6.0$) than those receiving sham stimulation ($M=22.8$; $SD=5.1$; $p=.002$). Furthermore, an interaction block*stimulation on response latencies in fact learning problems emerged ($F=2.230$; $p=.019$; $\eta p2=.103$), whereby frontal theta-band tACS led to a stronger decrease in response latencies than sham stimulation.

Of the five active stimulations compared, only frontal theta-band tACS showed beneficial effects on learning and may be specifically capable of enhancing acquisition and application of new arithmetic fact knowledge.

L4: Development of a Negative Priming effect in a non-symbolic numerical comparison task
Presenter: Arnaud Viarouge, University Paris Descartes
Authors: Arnaud Viarouge, Olivier Houdé, Grégoire Borst

Negative priming paradigms consist in investigating the deleterious impact of a prime item on the subsequent probe item, when the latter requires to activate a perceptual feature which was interfering with the correct response in the former. Negative priming effect thus provides evidence for the role of inhibitory control processes in the task at hand. Recent research on numerical estimation points to a crucial role of inhibitory control, in particular to extract the numerical aspects of non-symbolic representations of number from other continuous non-numerical dimensions of magnitude, such as item size or total surface area. So far, studies have investigated the implication of inhibitory control processes in the classic non-symbolic numerical task by contrasting performance in incongruent trials (i.e., non-numerical dimensions of magnitude interfere with numerosity) to performance in congruent (i.e., non-numerical dimensions of magnitude are congruent with numerosity) ones. However, a few studies failed to observe such congruency effect. Forty-seven primary school children (mean age = 7.92 years, SD = .87) and thirty-two adults (mean age = 27.86 years, SD = 6.13) performed a non-symbolic comparison task adapted to a negative priming paradigm. Probe items consisted in number/Size congruent pairs of arrays of dots, while prime items could either be number/size incongruent (test condition) or with equal dot size in both arrays (control condition). We observed negative priming effects both in school-age children and in adults. Additionally, the amplitude of the negative priming effect was larger in children than in adults. These results provide converging evidence for the role of inhibition in numerical estimation through development, and have educational implications for the investigation of the predictive values of basic numerical representations and executive functions for general math achievement.

L5: Investigating the modality specific cognitive abilities predictive of arithmetic ability
Presenter: Rosemary Penford, University of Cambridge
Authors: Rosemary Penford, Jenny Gibson

Mathematics is complex, with multiple cognitive abilities utilised to solve even relatively simple problems. Research highlights working memory, executive function, intelligence, and numerical acuity as possible predictors of mathematical ability however, findings are inconsistent. While the impact of modality of stimuli presentation has been investigated for working memory and intelligence, it is limited for executive functioning and numerical acuity. Significantly, cognitive interventions have yet to result in substantial far transfer to improved mathematical outcomes possibly because key numerical cognitive ability or specific deficits have yet to be identified, or multiple abilities need to be targeted. The current study therefore examines which modality specific cognitive abilities are predictive of arithmetic ability.

This quasi-experimental study investigates pathways between intelligence, number cognition, executive functions and arithmetic competence in both auditory and visual modalities, for children ($N = 182$) across development (4- to 18- years; $M = 11.60$ years, $SD = 4.06$).

Structural equation modelling highlighted direct paths between both modality specific latent executive functioning and working memory variables, and arithmetic ability, with latent auditory executive functioning and working memory showing the strongest associations (auditory: $B = .59$; visual: $B = .38$). Links between intelligence variables were indirect through bimodal executive functioning and working memory. Paths between age and arithmetic ability were also indirect, through bimodal intelligence and executive functioning and working memory. This model represented a good to reasonable fit, c2(41) = 48.07, $p = .208$, c2/df = 1.17, RMSEA = .032 90% CI [.000, .063], CFI = 0.986, TLI = 0.978, SRMR = .055.

Given its complexity, looking to identify a single construct that underpins mathematical outcomes may be erroneous. This study highlights executive functioning and working memory as a group of abilities with a strong association to arithmetic ability, particularly in the auditory domain. This finding may have implications for future interventions which predominantly display stimuli visually.

L6: Rules of Order: Evidence for a fundamental bias when processing the ordinality of numbers
Presenter: Selvia Gattas, Georgetown University
Authors: Selvia Gattas, Ian Lyons

Research on how people process numerical order carries implications for our basic theoretical understanding of what a number means and our practical understanding of the foundations upon which more sophisticated mathematics are built. Previous work has consistently shown that one's sense of ordinality is linked to the count-list, leading to a general assumption that participants are strongly biased to see sequences of numbers that match the count-list (2-3-4, 5-6-7) as being in order. One relatively unexamined consequence of the link between ordinality and the count-list is a bias to see all non-count-list sequences as not in order (even when they actually are: 1-3-5, 2-4-6). Here, we disentangled these factors using a novel paradigm that manipulated the rules for determining whether numerical sequences are 'in-order'. While we found strong biases to see ordered, non-count-list sequences as 'not-in-order' (single-digits: $d=1.25$, double-digits: $d=1.50$), we saw only weak biases to see count-list sequences as 'in-order' (single-digits: $d=0.33$, double-digits: $d=0.19$). Furthermore, the non-count-list bias provided a stronger and more consistent explanation for the reversal of the distance-effect (single-digits: $d=0.42$, double-digits: $d=0.65$), relative to the countlist bias (single-digits: $d=0.28$, double-digits: $d=0.22$). These dataprovide evidence that over-reliance on the count-list in guiding our sense of numerical order may restrict our broader sense of what it means for numbers to be ordered, which in turn provides a novel explanation for a common phenomenon in numerical cognition. More broadly, this work helps describe how people think about one of the foundational principles of mathematics - numerical order.

L7: Spontaneous Gestures When Explaining Fraction Comparison Problems
Presenter: Michelle Hurst, University of Chicago
Authors: Michelle Hurst, Ryan Lepic, Susan C. Levine, Ruth B. Church, Susan Goldin-Meadow

Children's verbal strategies and manual gestures while explaining math problems provide substantial insight into their knowledge and can be leveraged for instruction (Goldin-Meadow, 2009). Here, we used a novel paradigm to explore children's gestures about fractions, a particularly difficult aspect of math education (Ni & Zhou, 2005), with the goal of exploring the kinds of gestures and explanations children use and what they tell us about their knowledge.

Third graders (N=31) completed fill-in-the blank fraction problems and verbally explained their answers. Although the task had several items, for simplicity, we describe only 2/3<(blank)/9, as it showed substantial variability and was related to overall performance.

Children's explanations were broadly coded as Relational ("two-thirds is almost whole") or Componential ("nine is bigger than three"). We coded five gesture types: Component (referencing specific components; e.g., numerator alone), Holistic (referencing fractions as a unit), Within-Fraction (linking a fraction's numerator and denominator), Between-Fraction (linking across fractions), and Representational (e.g., pie-chart).

Most of the children who were correct produced at least one gesture type (14/19 children). The most common gesture type was Holistic (n=11/19), followed by Within-Fraction (n=8/19), Component (n=7/19), Representational (n=5/19), and Between-Fraction (n=3/19). Additionally, 17/19 children provided Relational explanations.

In contrast, children who were incorrect rarely produced gestures (n=2/12). The produced gesture types were: Component (n=2) and Between-Fraction (n=1). Furthermore, their explanations were mixed: 4/12 children described Componential explanations, 3/12 Relational, and 5/12 other (e.g., "I don't know").

Overall, although incorrect children provided a variety of explanations in their speech, they were much less likely than correct children to gesture while explaining their reasoning. This suggests that gestures produced when explaining solutions to these fraction problems may be important for reflecting children's fraction understanding. In follow-up studies, we plan to investigate whether particular gestures may also be useful for instruction.

L8: Predictors of Fraction Word Problem Solving
Presenter: Haobai Zhang, University of Delaware
Authors: Haobai Zhang, Brianna Devlin, Nancy Jordan

Although solving word problems is specified as a significant competency by U.S. benchmarks, few studies have focused on the underlying mechanisms of children's fraction word problem-solving development. The present study identified predictors of fraction word-problem-solving performance at the end of sixth grade (N = 292) using multivariate regressions. A constellation of cognitive variables, measured in third grade, including verbal ability, nonverbal reasoning ability and number line estimation ability along with demographic variables of age and special education status significantly predicted children's fraction word problem scores.

Multivariable quantile regression was also applied to examine the conditional differences at quantiles across the distribution. Verbal ability, nonverbal reasoning ability, number line estimation ability were consistently significant predictors at all quantiles across the distribution. After comparing the strength of relation at different quantiles, nonverbal reasoning ability mattered most for children who scored at the lower end in fraction word problems (below 0.25 quantile) in predicting scores. The effect of special education was also significantly stronger for lower-scoring children (.05-.25 quantiles) than higher-scoring children (above .8 quantile). More importantly, we found differential effects when examining demographic predictors at quantiles. Although income was not a significant predictor in the OLS regression (B= -.259, p= .387), there were increasingly significant effects below the 0.25 quantile (B= -.877, p = .023) meaning low-income status significantly predicted fraction scores negatively for children with poorer fraction performance. This effect faded away as children scored above 0.3 quantile. Age as a significant predictor in the OLS regression (B= -.259, p= .0046) did not predict word problem accuracy significantly for children scoring below 0.5 quantile.

Quantile regression analysis allowed for detecting predictors that influence children at certain quantiles, especially among lower-achieving children, which were missed using typical regression models. These results illuminate underlying factors for fraction word problem-solving, potentially guiding future intervention.

L9: Spatial Representations of Symbolic Fractions and Non-Symbolic Ratios: SNARC Effects and Number Line Estimation

Presenter: Rui Meng, University of Wisconsin
Authors: Rui Meng, Percival Matthews

Recent research on numerical cognition has begun to systematically detail the ability to perceive the magnitudes of symbolic fractions and non-symbolic ratios. The current study extended this line of research by investigating spatial representations of symbolic fractions and non-symbolic ratios with two behavioral measures: the Spatial-Numerical Association of Response Codes (SNARC) effect and number line estimation. The two research questions were: 1) what are the similarities and differences of spatial representations between symbolic fractions and non-symbolic ratios? 2) do the SNARC effect and number line estimation rely on a shared cognitive mechanism? Participants completed four tasks: magnitude comparison with symbolic fractions, magnitude comparison with non-symbolic ratios, number line estimation with symbolic fractions, and number line estimation with non-symbolic ratios. There was no significant difference of the SNARC effect between symbolic fractions and non-symbolic ratios. Both symbolic fractions and non-symbolic ratios were fitted better with a linear model for the number line estimation. Individual participant's symbolic fractions and non-symbolic ratios performances were significantly correlated with each other. On the other hand, performance was more accurate for symbolic fractions than non-symbolic ratios. The percent absolute errors were significantly smaller for symbolic fractions than non-symbolic ratios. Results suggested the existence of both shared and specific spatial representations of symbolic fractions and non-symbolic ratios. Moreover, individual participant's SNARC effects and number line estimation performances were not correlated with each other. Findings further elucidate the relations between different spatial representations for symbolic fractions and non-symbolic ratios, but cast doubt on the prospect of their sharing common cognitive mechanism.

L10: Changes in Students' Fraction Arithmetic Errors from Fourth through Sixth Grades in Response to Classroom Fraction Instruction

Presenter: Kelly-Ann Gesuelli, University of Delaware
Authors: Kelly-Ann Gesuelli, Haobai Zhang, Nancy Dyson, Nancy Jordan

The majority of fraction instruction takes place between fourth and sixth grades in U.S. schools, according to widely used benchmarks (e.g., CCSS, 2010). Unfortunately, many students make little to no progress in their fraction knowledge during this critical period (Resnick et al, 2017) and thus are not prepared for algebra. Fraction arithmetic appears to be especially problematic for struggling students.

To understand fraction arithmetic difficulties, we documented growth of these skills in the intermediate grades and analyzed errors. Participants (N= 536) were selected from schools serving students of diverse SES backgrounds. The fraction arithmetic task consisted of eight addition and subtraction word problems with common denominators, which was administered five times during the study period. Latent class growth analyses revealed four distinct growth classes based on student accuracy over time: high growth, low growth, moderate growth, and consistently accurate. We then explored differences in the commonly applied "add/subtract across the denominator" strategy (e.g., 2/5+1/5= 3/10). High-growth students initially used this strategy on 50% of errors in fourth grade and on 75% of errors in fifth grade; by sixth grade, they made few errors of any kind. The low-growth students did not consistently apply the add/subtract across strategy initially (e.g. 25% of errors in fourth and fifth grade) but increased to 40% in sixth grade. The majority of their errors reflected a mix of inappropriate procedures (e.g., generating multidigit whole numbers, multiplying instead of adding, and guessing).

Overall, students who used whole number strategies on fraction arithmetic problems in fourth grade generally came to use the correct common denominator strategy by sixth grade, in response to instruction. The mix of conceptually inappropriate procedures used by students in the low-growth group suggests that these students have fundamental difficulties that should be addressed by instruction grounded in core fraction and number concepts.

L11: Specific early numeracy skills mediate the relation between executive function skills and mathematical skills
Presenter: Jenny Yun-Chen Chan, University of Minnesota
Authors: Jenny Yun-Chen Chan, Maria Sera, Michèle Mazzocco

Executive function (EF) skills (i.e., inhibition, working memory, and cognitive flexibility) are predictive of children's mathematical skills (Cragg & Gilmore, 2014), and both EF and mathematical skills are correlated with general verbal knowledge (LeFevre et al., 2010) and relational language (e.g., more, after; Schmitt et al., 2019). Number counting/identification skills and number relation skills (i.e., ordering and comparing numbers) require inhibiting irrelevant information, holding numbers in working memory, and shifting attention between numbers. These two sets of numeracy skills may be pathways through which EF influences mathematical skills. We tested whether skills in number counting/identification or number relations mediate the association between EF and mathematical skills, even when controlling for verbal knowledge and relational language. We assessed 104 kindergarteners' EF, mathematics, number counting/identification, and number relations skills; EF with Minnesota Executive Function Scale and Head Toes Knees Shoulders task, and mathematics with Test of Early Mathematics Ability (TEMA). Number counting/identification tasks involved verbal counting and numeral identification. Number relation tasks involved ordering and comparing numbers. To create three composite scores corresponding to EF, number counting/identification and number relation skills, we standardized the individual task scores and computed the domain averaged z-scores. The first analysis confirmed that, with verbal knowledge as a covariate, EF performance predicted TEMA scores (β=.35). Adding number counting/identification score as a mediator fully mediated that relation, as did the number relation score. The path weights in the two mediation models were weaker with relational language as an additional covariate, but the full mediations remained. The findings suggest that specific numeracy skills may be pathways through which EF influences mathematical skills, and that EF may share variance with relational language but still have independent influences on numeracy and mathematical skills. This has implications for research on delineating the influences of EF and relational language on mathematical skills.

L12: Giving students control: Improving the math outcomes of at-risk elementary students
Presenter: Macey Cartwright, University of Cincinnati
Authors: Macey Cartwright, Heidi Kloos,

Math proficiency is a problem that disproportionately affects Black and Hispanic students, as well as children from low-income communities (NAEP, 2017). Providing children with the opportunity to practice math as a part of their personal learning environment has the potential to help improve their math proficiency. Importantly, to maximize learning, research suggests that the practice should create student autonomy in the personal learning environment (Drexler, 2010).

Participants were third-graders (N = 18) at a school with 95% students of color (majority Black) and over 75% of students qualify for the NSLP. Students engaged in in-class math practice sessions twice per week for three months (total of 24 sessions). Practice was on the tablet application IXL (IXL Learning, 2018), paired with a practice guide to direct students to optimal topics (addition, subtraction, fractions, word problems, multiplication, and division). Children whose parents granted permission (n = 17) took an iPad home occasionally to continue their practice, typically a few days per week. In both in-class and home environments, students were given control over what they practiced.

During in-class sessions, students were placed in small groups of 2-3 students with an adult facilitator. The role of the facilitator was to keep students on track and encourage them to make good choices, during both in-class sessions and at home. Students were assessed on standardized measures of math fluency and calculation before and after the practice intervention, both of which yield a grade equivalence (GE) score.

On average, students practiced for 15 hours and 36 minutes. A paired samples t-test revealed significant improvement from pre-test to post-test on both math fluency GE ($t[17] = 6.165$, $p < .001$) and calculation GE ($t[17] = 2.233$, $p = .039$). Average math fluency GE increased from 2.88 (SD = 1.11) to 4.01 (SD = 1.40), and average calculation GE increased from 1.92 (SD = 0.38) to 2.18 (SD = 0.54). Change in fluency was significantly correlated with practice on subtraction at the Kindergarten level ($r = .535$), word problems at the first-grade level ($r = .472$), and division at the second-grade level (r = .513). Change in calculation was correlated with practice on word problems at the first-grade level (r = .510) and multiplication at the third-grade level (r = .727).

Before the intervention, students were slightly behind in math fluency. After the intervention, students had gained over one year in fluency, performing ahead of what would be expected of their grade level. Before the intervention, students were behind over one grade level in calculation. After the intervention, students had gained three months, which is expected of their progress in school. The emphasis of this practice intervention was on creating student autonomy in the personal learning environment. While students were allowed to choose their own practice problems, some choices were more closely related to learning than others. Students who chose more challenging problems (e.g. word problems and multiplication), were more likely to develop skills that reflected on standardized measures.

L13: Move over worksheets: Parents want preschool to be math fun and engaging
Presenter: Michele Stites, University of Maryland Baltimore County
Authors: Michele Stites, Sonnenschein Susan, Dowling Rebecca

Effective home-based mathematical interventions consider parents' beliefs about how children learn, their role in such learning, and their knowledge of how to teach mathematics to their children (Green et al., 2007). However, few home-based mathematical interventions take such factors into account (Neuman, 2017; Ramani & Scalese, 2018). This study examines preschool parental beliefs related to fostering mathematical cognition in the home. This includes a comparison of literacy and mathematical activities sent from the preschool to the home, activity preference, parental mathematics confidence, and viewpoints about their role in fostering mathematical competencies.

A mixed method approach using a 49 question, online, multiple choice and open ended survey was used. Descriptive statistics and repeated measures ANOVAs were used to compare the number of mathematical and literacy based materials sent home to parents, their satisfaction with the materials, activity preference, and parental comfort level with mathematics. Open ended responses were used to better understand what parents need to reinforce mathematics in the home.

Of the 105 parents who responded to the survey, most indicated that mathematical items are not frequently sent home. Parents also reported feeling uncomfortable reinforcing mathematics and being dissatisfied with the lengthy worksheet type activities sent from the school. Qualitative analysis indicated that parents are willing to engage in mathematical activities with their preschool children if the items sent home are engaging to the children, do not take significant amounts of time, and have clear directions.

This research demonstrates that parents believe that they play a role in supporting mathematical cognition. However, parents need guidance from preschools in the form of detailed, interactive, quick activities in order to overcome their lack of mathematical confidence and time constraints. This study provides insight into how best develop the mathematical cognition of young children using effective home-based interventions.

Our intervention will build upon prior research to increase parents' knowledge of how to engage their children to foster mathematics skill development.

L14: Preschool Children's Changes over Time in Affective Attitudes towards Mathematics: A Latent Transition Analysis
Presenter: Xiao Zhang, University of Hong Kong
Authors: Xiao Zhang, Yawei Yang

There is a general consensus among researchers that affect is the most fundamental process of mathematics attitudes. Affect is more stable than moods and feelings but less stable than beliefs and values. Most notably, preschool children's affective mathematics attitudes have not yet become stable (Fisher et al., 2012), possibly due to their rapidly changing experiences with mathematics. Although moderate relations between affect and achievement have been reported in the literature about mathematics learning, it is an empirical question whether intra-individual change over time in preschool children's affective mathematics attitudes has consequences for their later mathematics achievement. Based on a longitudinal sample of 192 Chinese preschool children, this study identified latent classes of young children with different patterns of affective mathematics attitudes, explored their movement between these latent classes over time, and examine whether such movement is related to their later mathematics performance.

The results showed that children could be classified into three classes: positive affect, neutral affect, and negative affect. Children in each class tended to remain in that class when moving from their second to third preschool years. Children who transitioned from the positive-affect class to the negative-affect class showed significantly lower performance in arithmetic word problems, number writing, and written computation at the end of preschool, compared with their peers who remained in the positive-affect class or their peers who transitioned from the positive-affect class to the neutral-affect class. Children in the former class even had significantly lower performance in arithmetic word problems and number writing than their peers who remained in the negative-affect class. The results highlight the importance of fostering and maintaining children's positive mathematics attitudes for their later mathematics achievement.

L15: Partial Number Word Knowledge on the Give-N Task
Presenter: Connor O'Rear, University of Notre Dame
Authors: Connor O'Rear, Patrick K. Kirkland, Nicole M. McNeil

The give-N task is widely used to assess the development of children's understanding of cardinality. Traditionally (e.g., Wynn, 1992), to receive credit for understanding a number word, N, children must understand that N does not apply to other set sizes. For example, a child who provides three when asked for "three" but also when asked for "four" would be classified as a two-knower. We hypothesized that N+1 givers (i.e., children who could consistently give N+1, but also provided that amount for N+2) may have "partial" knowledge, signaling a readiness to learn.

We conducted an integrative data analysis (IDA) of six previous pretest-posttest studies. Two-hundred children who were N-knowers were categorized at pretest based on whether they were N+1 givers or not (as described above). We then examined posttest give-N performance (controlling for pretest) to see whether N-knowers who could give N+1 outperformed other N-knowers who did not consistently give N+1. After the IDA we compared givers of N+1 to "full" knowers of that number by conducting a mini meta-analysis (e.g., Goh et al., 2016) of children's pretest performance on a separate measure of children's number word understanding.

In the IDA, an ANCOVA revealed a positive effect of being an N+1 giver for two-, three-, and four-knowers, $F(1, 7.339) = 12.309$, $p = .009$, partial eta squared = .626, but not for one-knowers. The meta-analysis revealed that N+1 givers perform worse than full knowers of that number on another measure of number word understanding (Mean Cohen's $d = -.335$, $p = .012$).

Children who reliably give the number above their knower level (N+1) but also give that amount for other number words may be farther along than their fellow N-knowers on the path toward developing an understanding of cardinality.

L16: Number gesture, finger gnosia and manual dexterity : Which contribution to verbal number knowledge development?
Presenter: Laurence Rousselle, University of Liege
Authors: Laurence Rousselle, Marie-Pascale Noël, Line Vossius

Several authors claim 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) while other suggest that children learn to use number gestures as arbitrary symbols and do not benefit from this iconic tool (Nicoladis, Pika and Marentette, 2010).

First, we examined longitudinally how and when children master the numerical content conveyed by verbal numbers and number gestures. We were also interested in verifying if the progress in the understanding of the cardinal meaning of number gesture can improve the progress in the understanding of the cardinal meaning og number words. Secondly, a second set of questions concerned which finger skills can help children to understand the cardinal meaning of numbers. Many authors showed that finger gnosia (Fayol, Barrouillet & Marinthe, 1998; Noël, 2005; Penner-Wilger & Anderson, 2008) and dexterity (Asakawa & Sugimura, 2009, 2011, 2014) were a good predictor of arithmetic but the definition of this last skill still differ among authors.

In this study, 47 preschoolers were tested four times in total, every four months from 3 to 4 years old using tasks assessing the understanding of cardinality ('Give-a-number' task with number words and number gestures) and assessing three digital components (finger gnosia, finger dissociation and finger coordination).

Preliminary results of growth curve analyses show that the development of the understanding of number gestures cardinal meaning significantly influences the development number words cardinal meaning. Moreover, this influence grows with age: the older the children, the more important is the influence of digital on verbal number representation in an identical task. Moreover, dissociation and coordination skills but not finger gnosia significantly influence the performance of children in the understanding of number words cardinal meaning. This influence increases as children become older.

L17: Which is more, 123 or 321?: A study on preschool children's understanding of place value
Presenter: Pierina Cheung, National Institute of Education, Singapore
Authors: Pierina Cheung, Daniel Ansari,

What do numerals such as 35 and 427 mean? An important aspect of the meaning of written numerals comes from the place value system, with the relative position of a number indicating a different value. Recent studies have revealed that by around age 4, children can identify and compare multi-digit numbers, and they reach ceiling in first grade (Mix, Prather, et al., 2013). For example, these researchers demonstrate that preschool children were able to compare digits such as 30 and 60 and determine which is more. Nevertheless, Mix and colleagues do not provide a complete picture of when children acquire place value understanding, because they did not separate out trials that require place value understanding (e.g., 14 vs. 41) versus those that do not (e.g., 30 vs. 60, which may possibly be compared by crossing out the overlapping digit and comparing the remaining digit). In the current study, we carefully manipulated the types of digit comparison that require positional knowledge of multi-digits to investigate place value development in children before school entry.

120 children (mean age = 68.6 months, 50 to 95 months) were shown different types of pairs of comparisons on a screen and asked to choose one that was more. These multi-digit comparisons included "decade-difference" (e.g., 35 vs. 45, same unit-digit but a different decade-digit), "unit-difference" (e.g., 33 vs. 32), "reverse-digit" (e.g., 18 vs. 81), and "cross-decade" comparisons (e.g., 19 vs. 22). We found two main findings. First, overall, 6-year-olds can compare the critical comparisons that require place value understanding, namely, the reverse-digit and cross-decade comparisons. Second, prior to that, at around age 5, children can do face-value comparisons (i.e., succeeded on decade-difference and unit-difference trials). This study characterizes the development of place value understanding, and documents the strategies children may use in digit comparisons.

L18: Finger games to improve basic numerical skills in preschool children as a precursor of arithmetic learning later
Presenter: Line Vossius, Research Unit 'Enfances', Liege, Belgium
Authors: Line Vossius, Christelle Maillart, Florence Binamé, Boris Jidovtseff, Laurence Rousselle

When children start preschool their existing numerical ability varies considerably. One of the school mission is to reduce these inequalities in children's knowledge (Ramani & Siegler, 2008). In different countries, numerical learning is increasingly highlighted in preschool programs and has become one of the national priorities (Starkley, Klein & Wakely, 2004; Vilani, 2018). Indeed, many authors have shown a strong relationship between numerical knowledge of preschool and the arithmetical performance later (Stevenson & Newman, 1986; Jordan, Kaplan, Ramineni & Locuniak, 2009). Moreover, early intervention targeting individual strengths and weaknesses were found to be the most efficient to reduce the prevalence of learning disabilities (Vellution & Scanlon, 2002).

In this study, 85 preschoolers aged between 48 and 60 months old were randomly divided into three groups: 27 benefitted from a numerical program based on finger game activities targeting precursors in the development of early mathematical skills (fingers used as a tool to represent the cardinal value of numbers), a pedagogical intervention for ten weeks, thirty minutes a day, five times a week. 28 benefitted from a shared reading program targeting precursors in the development of reading and writing skills, which was our academic control group. Finally, 29 participated in a global motor training, which was our non-academic control group. The age, the socio-economic level, the language spoken at home and a non-verbal reasoning measure were controlled.

In the short-term, first results showed that children in the numerical program improved their performances in cardinality processing more than others, particularly using number gestures. Children in the numerical training group exhibited larger improvement in arithmetical skills (not trained in the program) than other groups.

L19: Conceptions of math and art are linked to avoidance of the domains

Presenter: Rachel Jansen, University of California Berkeley
Authors: Rachel Jansen, Ruthe Foushee

What is math? Previous work has shown that children and adults have variable definitions of mathematics. We ask whether how broadly or narrowly a child defines math (operationalized here as the number of real-world contexts or activities they see math as relevant to) is related to their avoidance of mathematics. We chose "art" as an equivalently vague and variably-defined domain to compare to math in a within-subjects design. In an experiment with five to seven-year-olds, children sorted images of children doing various activities as math (/art) or not. The experimenter then focused the child's attention on the items they did not initially describe as involving math (art), asking "could this kid be doing math (art)?" In counterbalanced order relative to the categorization task, participants responded to a measure of avoidance wherein they were asked to choose between two games they would prefer to play based off of stimuli from Bian et al. (2017). One game was 'for children who are really, really good at math,' while the other was for children who excelled at art. For the 31 participants, more items were initially categorized as 'math' (M=3.87) than 'art' (M=3.00), but children were more reluctant to expand their definitions for math than for art, indicating that fewer items could be math (M=1.87) than art (M=2.81) in the second round of sorting. As expected, children who chose the math game (n=17) identified more activities as math than art, while those who chose the art game (n=14) identified more activities as art than as math, indicating that preference for a domain may be related to having a broader conception of it. Data collection is ongoing.

L20: Measuring mathematical ability during the transition to college

Presenter: Dominic Kelly, University of Michigan
Authors: Dominic Kelly,

Although some evidence points to a small but consistent sex difference in mathematical ability, others have argued that this effect is confounded by test design. College admissions partially depend on the accurate measurement of mathematical ability. To address this topic, we both replicated an existing meta-analysis (Lindberg et al., 2010) and extended its scope to determine whether the magnitude of sex differences in performance in mathematics examinations in the final years of secondary education are moderated by test design.

Our study was a meta-analysis of research on sex differences for 11th and 12th graders' mathematics performance published between 1990 and 2015. Studies needed to include 11th to 12th graders, or of an equivalent age, and contain original data. We retrieved 3593 unique records covering the years 2007 to 2015, of which 314 met our inclusion criteria. In total, 46 pieces of research published or submitted between 1990 and 2015 passed the eligibility screening; 29 of which were not previously included in Lindberg et al. (2010).

From these 46 studies, 99 effect sizes (expressed as Cohen's d) were produced and the total N was 281,193 (152,620 female). A random-effects model was used and conservative adjustments were made for sample size and publication bias. Overall, the weighted effect size was $d=0.25$, $p<.001$ (CI: 0.214 to 0.293, SE=0.02). Effect sizes that came from studies that used only multiple-choice assessments ($d=0.326$, $p<.001$) were compared with studies that used either a mixed design or solely non-multiple choice questions ($d=0.184$, $p<.001$). These two subgroups were significantly different, $Q(2)=15.36$, $p<.001$.

Mathematics tests for 11th and 12th graders show reduced sex differences when tests included non-multiple choice measures. Institutions might consider utilising non-multiple choice assessment assessments to supplement or replace multiple-choice testing to ensure that the individuals with the greatest potential are being recognized, regardless of sex.

L21: Birth of the First Mathematical Concepts. (Mathematics About 2 Million Years Ago)
Presenter: Said Boutiche, Université de Boumerdes
Authors: Said Boutiche,

Mathematics are a tool that allows us to acquire critical thinking. This one, helps us to recognize biases in the interpretation of our world, but also to get around them. Reasoning is a crucial cognitive element of doing mathematics. To do it successfully, it is necessary to understand not only what a mathematical reasoning is, but also its origin. So, This work aims at developing some arguments that show how and why the emergence of the first mathematical concepts occurred about 2 million years ago, during the temporal overlapping of Homo-Habilis with Homo-Erectus, both ancestors of the genus Homo.

At that time, according to Coolidge and Wynn (1), a significant increase in the brain size of Homo erectus occurred, with a substantial progress in cognitive capabilities. Language abilities and stone tool manufacture are the direct "visible consequences" of this cognitive progress. But there was another, less visible, consequence: the emergence of the first mathematical concepts. We intend to evidence this, first by asserting that the evolution of mathematics obeys the rule of "continuity theory". Indeed, one cannot imagine mathematics emerging out of vacuum in its current complex form. As for language, mathematics must have evolved from rudimentary earlier stages to today's complex mathematical theories and formalisms. One can therefore ask: what is the earlier mathematical stage? According to R. Dunbar, because archaic humans had large brain size, they must have lived in groups of over 120 individuals (2). The needs of these "micro societies" were permanently progressing toward better life organization (improvement of hunting techniques, hunting strategies, and social cohesion of groups).

There was also an important need for efficient resource management. If we admit that hunting and gathering were presumably the subsistence strategy employed by human societies beginning some 1.8 million years ago (3), then food resources had to be shared more or less equally in order to assure social cohesion within groups. To do this, it was necessary for Homo-erectus to construct the abstract notions of "equal quantity ", "larger than", ", "less than", "measured quantity" and "measure". We claim here, that this type of mental construction probably triggers the construction of first mathematical concepts.

L22: What Explains the Covariance Between Arithmetic and Reading? A Multivariate Model
Presenter: Vivian Singer, Universida Alberto Hurtado
Authors: Vivian Singer, Katherine Strasser, David Preiss

There is a close association between reading and arithmetic performance in school; however, the causes of this phenomenon have not been extensively studied in populations with typical development. In the present study, we set out to analyze some cognitive variables, which might explain this association. To do this, we assessed a population of 262 school-age children between 8 and 11 years of age, using the following measures: reading, arithmetic, working memory, processing speed, semantic skills, and phonological skills. We observed that the bivariate correlation between reading and arithmetic (r= .53) decreased significantly (r= .17) when the rest of the cognitive variables were included. Semantic and phonological skills were the cognitive variables that accounted for the weakening of the association between reading and arithmetic. While the impact of semantic skills was similar for reading and arithmetic, phonological skills were found to be a more powerful predictor for reading than for arithmetic. Implications for educational theory and practice are discussed.

L23: Collecting Surveys and Consent Forms from Parents for Basic Cognitive Research; What Worked, What Didn't Work, and a Few Surprises…
Presenter: Sheri-Lynn Skwarchuk
Authors: Sheri-Lynn Skwarchuk,

Written informed parental consent is necessary when conducting research with children (Tri-Council Policy Canada); but it is also desirable to have background family survey information. With busy lives, even schools have difficulty collecting routine legal paperwork. Missing survey data is a problem- the full story of the research cannot unfold without insight into the home life; and marginalized, at-risk, and non-stereotypic populations (e.g., fathers) are often missing. The quality of data comes at a significant cost to taxpayers. Given recent struggles with parent return rates (which were around 32% or lower during our latest round of testing), we reflected and intensified our efforts and resources to improve the parent voice. This data blitz will focus on what worked, what didn't work and some unexpected side-benefits about collecting parent survey data.

In order of perceived effectiveness, successes (numbered below) resulted from setting up a table at evening parent teacher conferences, where there was (1) direct parent contact, with almost all pairs of parents who routinely attended the sessions. Principals provided parents and teachers with (2) advance heads-up emails about the surveys so parents could plan their evening time accordingly, and (3) post-conference reminder emails to help parents remember to complete and return the surveys. (4) Teacher connections and buy-in helped when they sent parents to our study table to complete forms on the spot. When the timing of interviews fell behind, (5) the surveys filled the gap of boring waiting time. Parents were explicitly told about (6) our legitimate concern of needing their help. (7) Survey length was strategically marketed to receiving the long versus short form of the census, and how sometimes detailed information is needed. Some parents could not complete the surveys at the school, but our plea resulted in (8) surveys returned in self-addressed stamped envelopes. (9) One staff member knew the families and had their trust to complete the forms. Finally, (10) coloring, chart paper, books and crafts were available for waiting children.

However, some efforts went unrealized. (-1) Skip the costly give-away pencils; they went unnoticed by parents. (-2) Reports and laminated letters of support added unnecessary clutter. Care should be taken to ensure that (-3) surveys are short, and they are (-4) organized with the most important questions first; when parents ran out of time, important data went amiss.

We are grateful to our schools for their support. A principal helped at the hallway survey table, which gave her a chance to connect with families instead of sitting in her office. It was mutually decided we would return next year at all schools to continue the connection and share the study findings. Finally, one research assistant who also works a shoe store commented that distributing surveys and selling shoes require the same skill set (as she helped a parent with a shoe size and then handed her a survey). Having direct parent contact, support from the schools, positive energy, and communications about the legitimacy of the research made all the difference.

L24: What are we missing in math assessments? Validating an IRT based math assessment in kindergarteners.
Presenter: Alexa Ellis, University of Michigan
Authors: Alexa Ellis, Pamela E. Davis-Kean

Children's early math abilities are the strongest predictor, above and beyond reading, of how that individual will succeed academically (Siegler et al., 2012; Watts et al., 2014). Unfortunately, many math assessments are too narrow and cannot provide more evidence for developmental sequences or math learning trajectories (Weiland et al., 2012). Methods such as item response theory and computer adaptive testing (CAT) can provide additional information about individual skills and the ability level of a person dynamically. Math Garden is CAT math assessment often used in the Netherlands and introduces a challenging environment for children to practice counting and arithmetic (Klinkenberg, Straatemeier, van der Maas, 2011). However, Math Garden has not yet been assessed in the USA before. Therefore, the current study assesses the concurrent validity of Math Garden with a standardized behavioral task (WJ III-Applied Problems; Woodcock, McGrew, & Mather, 2001) and an unstandardized behavioral task created for this study (Early Math Assessment). Given that the WJ III-Applied Problems jumps more quickly to advanced, formal knowledge (Clements et al., 2008), and that Early Math

Assessment taps early math skills that Math Garden does not (shapes and patterns) we expected moderate correlations between the tasks. Ninety-eight kindergarten children (M(age)=5.55 years, 54% male) across four schools in southeast Michigan were tested in the fall of 2018 as part of a larger study. Children completed the Math Garden task, the WJ III-Applied Problems task, and the Early Math Assessment task. Consistent with our hypotheses, Math Garden moderately correlated with both WJ-Applied Problems ($r = .44$) and the Early Math Assessment ($r = .55$). These findings suggest Math Garden demonstrates concurrent validity with both the standardized and the unstandardized math measures examined. The moderate, not strong, correlations also suggest that these assessments measure the same construct while also measuring independent constructs of skills for early math development. Given the importance of early math skills in predicting later outcomes, Math Garden is a measure that can provide greater measurement precision for monitoring and assessing the individual differences in the early math skill trajectories.

Poster Session 1 Abstracts:

P1.1: The role of continuous visual cues in numerosity perception: A computational investigation
Presenter: Alberto Testolin
Authors: Alberto Testolin, Serena Dolfi, Mathijs Rochus, Rochus Zorzi,

Visual number sense can emerge as a high-order statistical feature from deep unsupervised learning, where the goal is to learn a hierarchical generative model of images containing a variable number of objects (Stoianov and Zorzi 2012). As in humans, numerical discrimination in deep neural networks is modulated by non-numerical visual cues, despite the existence of network neurons that seem to be specifically tuned to number (Zorzi and Testolin 2018). Here we present a series of simulations and analyses designed to more systematically study the contribution of continuous visual properties in numerical and non-numerical discrimination tasks performed by deep neural networks. For training and testing our computational models we adopted a recently proposed stimulus space (DeWind et al. 2015) that allows to carefully measure the contribution of each non-numerical visual cue (e.g., cumulative area, total perimeter, item size, convex hull, density) in different discrimination tasks. To this aim, we generated a large data set of stimuli, where the three latent dimensions "Numerosity", "Size" and "Spacing" were manipulated orthogonally. We then analysed the model responses using a generalized linear model, in order to quantify the importance of each dimension in the final decision. We also applied Representational Similarity Analysis (RSA) to the internal representations of the deep network to investigate the spontaneous emergence of numerosity codes. Our simulations show that numerosity discrimination in deep networks is modulated by continuous visual cues in a way that closely mimics the performance of human observers. Numerosity is by far the most relevant dimension for carrying out numerosity discrimination; however, as for human participants, non-numerical visual features affect the discrimination performance. When probed using discrimination tasks involving convex hull or area judgments, the contribution of the corresponding non-numerical features substantially increases, thus showing that the deep network can flexibly provide the visual cues most relevant for the task at hand. Finally, RSA reveals that the model spontaneously develops numerical coding in its internal layers, regardless of the task that needs to be carried out. Overall, the impressive match between model performance and human behaviour suggests that deep learning models represent the state-of-the-art for simulating perceptual and cognitive processes, paving the way towards understanding the computational mechanisms underlying our visual number sense and its impairment in atypical populations.

P1.2: Parental beliefs about math importance buffer against the effect of parental math anxiety in preschool-aged children
Presenter: Alex Silver
Authors: Alex Silver, Leanne Elliott, Melissa Libertus,

Previous work has linked parents' math anxiety to children's math performance in early elementary school (Maloney, Ramirez, Gunderson, Levine & Beilock, 2015). Here, we ask whether parental math anxiety and parental beliefs about the importance of math affect their preschool-aged child's math performance. 133 children (mean age = 3.88 years) and one of their parents participated in this study. Parents reported their own math anxiety (Suinn & Winston, 2003) and beliefs about the importance of math for their child (Lefevre, Skwarchuk, Smith-Chant, Fast, Kamawar & Bisanz, 2009), while each child completed a standardized math assessment (Ginsburg & Baroody, 2003). Parent math anxiety and parent beliefs about math importance were entered into a linear regression model predicting children's math performance. The overall model was statistically significant, $F(3,129)=5.88$, $p<.001$, with a significant interaction between math anxiety and beliefs about math importance ($p=.026$). Math anxious parents who believed that math was highly important had children who performed just as well as children whose parents reported low math anxiety. However, math anxious parents who believed that math was of low importance had children who performed significantly worse in the math assessment. Critically, this effect held even when controlling for parents' own math achievement. Furthermore, the effects cannot be attributed to parents' beliefs about the importance of education more generally or children's general cognitive abilities: The interaction was not significant in predicting children's math when literary importance was used as a predictor instead of math importance (p>.77), nor when math anxiety and math importance were used to predict children's vocabulary (p>.27). Although parental math anxiety can be detrimental to children's math achievement, parents who nonetheless believe in the importance of math may buffer their child from negative consequences.

P1.3: The utility of audio recordings for examining kindergarten math instruction
Presenter: Alexa Ellis
Authors: Alexa Ellis,

Research has shown during the first year of schooling, exposure to academic content is beneficial for student learning (Engel, Claessens, Watts, & Farkas, 2015). Although children's math skills in kindergarten are key predictors of success in both math and literacy (Claessens, Duncan, & Engel, 2009), math is typically underemphasized in kindergarten compared to literacy (Engel, Claessens, & Finch, 2013). A large portion of the information we know about kindergarten math instruction comes from teacher reports (Georges, 2009; Engel, Claessens, & Finch, 2013; Chiatovich & Stipek, 2016) rather than actual recordings of classroom instruction. Therefore, a persisting question is whether math instruction can be measured more precisely without questionnaire methods to better capture a child's schooling experience. We want to assess if teacher instruction can be a latent variable that examines multiple aspects of classroom math instruction. Teachers (N=18) will wear the LENA (Listening ENvironment Analysis) system for one full school day during the month of February. Classroom instruction will be measured in three different ways: content, quality, and quantity. The content of instruction will be measured by the number of math topics covered in one recording day as coded by trained research assistants. The coding system is based on an Individualized Student Instruction (ISI) coding system (Connor et al., 2009). Each content code will be taken from the ISI system and coded from the recordings. Quality of instruction will be measured using the LENA's conversational turns variable. A conversational turn is when a child vocalizes and an adult responds, or the other way around. Each time one happens, it is counted as one conversational turn. The conversational turns variable has been used in previous studies to examine relations between parents and children. Finally, quantity of instruction will be measured by the amount of time in minutes spent in the classroom on math related topics. Trained research assistants will listen to the voice recording and mark the amount of time teachers spend in math discussions. To estimate interrater reliability of the coders who kept track of the amount of time, ICCs will also be calculated for this variable (Shrout & Fleiss, 1979). We hope these three methods of observed variables will load onto one latent factor and provide researchers with a more nuanced approach to examining math instruction in the classroom.

P1.4: Modelling median estimates overstates regularity in children's number line estimation
Presenter: Alexandria A. Viegut
Authors: Alexandria A. Viegut, Percival G. Matthews,

Number line estimation (NLE) robustly predicts future math achievement, yet debate continues about how to interpret children's estimates. Different models have been proposed to capture children's estimation patterns – logarithmic, linear, cyclical power model, etc. – each with its own theoretical interpretations and motivations (Slusser, Santiago, & Barth, 2013). Typically, models are fit to group-level median estimates of children of a particular age, but individuals' model fits are given only cursory attention. Indeed, most published NLE research does not report individual estimates at all. If individuals vary widely, as some work suggests (Barth & Paladino, 2011; Berteletti et al., 2010), group-level patterns may be merely an artifact of averaging.

We investigated individual variability in NLE patterns, with attention to possible explanations of this variability. Thirty-five kindergartners (ages 4-5) completed NLE tasks on 0-10 and 0-100 ranges, as well as symbolic magnitude comparison, counting, and numeral identification tasks. In line with previous findings, group-level median estimates were best fit by a linear model for 0-10 NLE (R2lin = .98, R2log = .88) and a logarithmic model for 0-100 NLE (R2lin = .46, R2log = .59).

However, we found substantial variation in individual estimation patterns. Only nine children (26%) produced estimates which matched the group-level findings (i.e., both linear 0-10 and logarithmic 0-100). On 0-100 NLE, 40% of children produced estimation patterns which were uncorrelated or negatively correlated with the stimulus numbers. Ongoing data analysis of other tasks may reveal possible explanations for these patterns.

We found that the majority of children did not produce estimates which matched the group-level findings, despite the common practice of reporting only group-level models based on median estimates. Our results suggest that researchers should be cautious in interpreting models fit to median estimates, which may overstate the regularity in children's estimation patterns.

P1.5: Teaching Geometric Similarity with Dynamic Digital Technology: A Multiple-Case Study of Classroom Practices of English Secondary Mathematics Teachers
Presenter: Ali Simsek
Authors: Ali Simsek

Many research studies have provided evidence that dynamic digital technologies (e.g., GeoGebra) have the potential to support students' deep and lasting learning. However, teachers' integration of digital technology into the mathematics classroom is a complex phenomenon (Clark-Wilson, 2017). Researchers widely acknowledge the necessity of further research to develop a better holistic understanding of this phenomenon as teachers have not yet fully and productively use digital tools in their practice.

This paper reports ongoing PhD research investigating actual classroom practices of three English secondary mathematics teachers using dynamic digital technology to teach geometric similarity (GS). My research particularly focuses on GS due to its importance in school mathematics and an apparent lack of research on its classroom teaching with technology. Two frameworks, Structuring Features of Classroom Practice (SFCP, Ruthven, 2009) and Instrumental Orchestration (Drijvers et al., 2010) guide my data collection and analysis since they provide useful conceptual lenses for analysing classroom practice. The methods of data collection include classroom observations, teacher interviews, and the scrutiny of lesson resources. I am still in the process of analysing the data and will discuss the findings in my poster.

P1.6: The importance of representational shift: An investigation of the cognitive mechanisms and individual differences underlying math performance

Presenter: Allison Liu
Authors: Allison Liu, Christian Schunn

College dropout is a significant issue that particularly plagues students with poor math preparation (Balfanz & Legters, 2004; Bynner & Parsons, 1997). Many studies have attempted to understand the factors that contribute to math performance and create training interventions that can effectively improve math achievement. However, few studies have investigated these questions within populations similar to the lower achieving adults who are most at risk to drop out from college. Further, few have looked at many potential mechanisms at once to determine how each contributes to math performance. In the current studies, we investigated the relationships between seven cognitive mechanisms and individual differences (working memory, symbolic and nonsymbolic representational precision, symbolic integration accuracy, symbolic integration strength, math anxiety) and two types of math performance (procedural vs. applied) in 81 adults with low- to mid-levels of math achievement. Seventy-eight of these adults also participated in a second study, in which we evaluated the effectiveness of an estimation-based training program that targeted one of these cognitive mechanisms. The study also determined the factors that predicted progress during the intervention and the mechanisms that explained math improvements. Importantly, the participants' relatively low math skill level allowed for a better examination of the underlying math foundations in adults who are most likely to struggle with math in college. Across both studies, we found evidence of a representational shift that supports higher math performance in procedural and complex math; specifically, in higher math-skilled individuals, procedural math relied more on mechanisms that involved non-symbolic number representations, whereas complex math drew upon mechanisms that involved primarily symbolic number representations. These results suggest that fostering people's ability to shift between non-symbolic and symbolic number representations may be a fruitful method for improving math performance.

P1.7: Anxiety and Children's Mathematical Learning: Testing an Expressive Writing Intervention

Presenter: Almaz Mesghina
Authors: Almaz Mesghina, Lindsey Richland,

Instruction that requires students to relationally reason between problem-solving strategies is highly demanding of working memory (WM; Richland et al., 2016). Expressive writing (EW), or writing about one's deepest feelings, prior to an anxiety-inducing task can improve performance by reducing worries and freeing up WM resources for task-relevant processing (Ramirez & Beilock, 2011). However, children may not benefit from EW as they are still developing requisite emotion regulation skills (Fivush et al., 2007). Thus, EW prior to relational learning may in fact contribute to students' cognitive load and hinder subsequent learning. This effect may be greater for females, who tend to ruminate and write more emotionally than males. The current study explores whether EW reduces children's anxiety and improves learning from a mathematics lesson.

297 10- to 12-year-olds were randomly assigned within-classroom to either expressively or non-expressively write for 5 minutes prior to a video lesson on ratio. All students then watched the same 30-minute lesson, during which a teacher compares and contrasts between a correct strategy and common misconception to solve ratio problems. Students completed the same assessment at post-test (immediately following lesson) and pre-test (3 days prior) that assesses procedural and conceptual understanding. After the post-test, students reported their anxiety experienced during the lesson. One week later, students completed a WM task.

Anxiety was negatively related to procedural learning gains. Overall, expressive writers reported greater anxiety than non-expressive writers, though this effect was stronger for females. Regressions reveal that females' procedural learning was negatively impacted by EW. WM was positively related to females' gains when non-expressively writing, but did not predict gains for those who expressively wrote, suggesting that emotional disclosure may have induced worries that co-opted WM required for learning. Males' learning was unrelated to these factors. EW interventions may impede, not promote, some children's mathematical reasoning.

P1.8: The neural correlates of mathematical learning in 8- to 10-year-old children
Presenter: Alyssa Kersey
Authors: Alyssa Kersey, Elizabeth Wakefield, Susan Goldin-Meadow

The intraparietal sulcus (IPS) is a core region for numerical and mathematical processing. Individual differences in math ability and age have been linked to the neural development of this region, but it is unclear how the IPS supports the acquisition of math concepts or the generalization of newly learned mathematical knowledge. The proposed study will take a longitudinal approach to investigate the neural substrates that underlie the acquisition of mathematical equivalence in 8- to 10-year-old children. Functional magnetic resonance imaging (fMRI) will be used to measure children's neural activity while solving math problems before and one week after a targeted training session. The training session will mimic previous, well-established paradigms for teaching mathematical equivalence using speech and gesture strategies. Previous work suggests that about half of the children will learn mathematical equivalence. Children's knowledge of mathematical equivalence will be assessed immediately before, immediately after, and one week after training. The behavioral assessments and fMRI problem-solving paradigm will consist of problems in the trained format and an unfamiliar format, which will allow us to test for generalization. During the imaging session, children will also complete simple addition problems to independently localize the mathematics network, including the IPS. A 2 (time: pre vs post) x 2 (learners vs non-learners) whole-brain ANOVA will be used to identify regions that show changes in neural activity following the acquisition of mathematical equivalence. Targeted region-of-interest analyses within the math network will complement this whole-brain approach. If the IPS is involved in the acquisition of mathematical concepts, learners, but not non-learners should show increased activation during post-training problem solving. Children who can generalize beyond trained problems should also show this increase in activity for untrained problem formats. Another possibility is that frontal regions of the brain will support the acquisition of mathematical equivalence and/or generalization.

P1.9: Navigating the relations between spatial processes and performance on numerical and mathematical tasks
Presenter: Andie Storozuk
Authors: Andie Storozuk, Sabrina Di Lonardo, Heather Douglas, Rebecca Merkley, Helena Osana, Sheri-Lynn Skwarchuk, Chang Xu, Jo-Anne LeFevre, Erin Maloney

People vary in their ability to generate, recall, maintain, and transform visual-spatial information. Those with stronger spatial ability also perform better in mathematics. This relation occurs throughout development, across a variety of tasks, and helps to predict individuals' entry into and success in STEM careers. Because neither spatial processing nor mathematical processing are homogenous constructs, we explored the relations between specific spatial abilities and a range of numerical and mathematical outcomes, to better understand precisely where the relations exist.

Canadian children (N=342; 192 girls) in grade 2 (mean age 7.8) or 3 (mean age 8.6) completed a series of tasks designed to assess their numerical, mathematical, and spatial processing abilities. Spatial processing was measured with a spatial span task and a matrix reasoning task; respectively, these assess memory for visual-spatial sequences versus visual-spatial reasoning. We conducted multiple regression analyses, predicting performance on a variety of numerical and mathematical tasks with the two spatial measures, controlling for grade, gender, verbal WM, and location.

Performance on the spatial span and matrix reasoning tasks related to arithmetic fluency, math problem solving, number line, and math symbol knowledge tasks. Each task is a complex measure that invokes a range of cognitive processes. However, only the spatial span task was related to performance on the number ordering task, suggesting a more specific link between memory for visual and numerical sequences. Neither spatial span nor matrix reasoning related to performance on the symbolic comparison task. Symbolic comparison may reflect a mental representation of number that is relational but not intrinsically spatial. Results will be discussed in the context of current theories of mathematical cognition.

P1.10: Investigating the influence of graphical and textual framing on problem solving accuracy and strategy use
Presenter: Anna Bartel
Authors: Anna Bartel, Andrea Donovan, David Menendez, Sarah Brown, Tara Hogseth, Martha Alibali

In solving mathematical problems, people often integrate textual and graphical information. However, different types of graphs may elicit different interpretations, and these interpretations may also depend on the problem phrasing. This experiment examined accuracy and strategy use in students presented with story problems about constant change with either congruent or incongruent textual and graphical information. We tested this using a 2 (word problem phrasing: discrete or continuous) x 3 (graphical display: bar [discrete], line [continuous], or none) between-subjects design. Participants ($N = 158$) were randomly assigned to one of the six conditions. We examined whether participants used the widely-used but inefficient Summation strategy (based on a discrete framing), or generated the rarer, but more efficient Average strategy (based on a continuous framing). In the bar graph condition, problem phrasing influenced accuracy, with congruent information (discrete text + bar graph) yielding significantly better accuracy than incongruent information (continuous text + bar graph), $\beta = 1.88$, $\chi2 = 5.15$, $p = .02$. Discovery of the Average strategy was relatively rare, but participants who received congruent continuous information (continuous text + line graphs) had the highest probability of using the Average Strategy ($M = 39.3\%$, $SE = 3.3\%$). In every other condition, the Summation strategy was used more frequently. In sum, graphical representations were important cues for both strategy use and strategy discovery. Congruent continuous information promoted discovery of the efficient Average strategy, and congruent discrete information fostered accurate application of the Summation strategy. There findings indicate that people integrate textual and graphical information for mathematical problem solving, and that congruent information promotes success in generating and applying effective problem-solving strategies.

P1.11: Is computationally-complex behavior embedded in the ANS?

Presenter: Anna J Wilson
Authors: Anna J Wilson, Georgina E Carvell, Nicola J Morton, Matthew N Grice, Simon Kemp, Randolph C Grace.

Many organisms exhibit computationally complex behaviour that is adaptive, and could not be achieved without some process or representation which provides the equivalent of mathematical computation. For example honeybees have been shown to navigate spatially using path integration (Srinivasan, 2015). Gallistel's (1990) computational-representational theory provides an influential account of such behavior, positing that organisms represent relevant environmental variables (e.g. direction or distance travelled) as real numbers stored in engrams, and that these representations can be used to perform arithmetic operations. Our group builds on these ideas by proposing that organisms' computationally-complex behavior suggests that their perceptual systems may represent an algebraic field (a mathematical object consisting of two commutative groups connected by a distributive property, a structure which generalizes the intuitions underlying arithmetic). Our research with human observers in a non-symbolic 'artificial algebra' task has shown that they can learn arithmetic relations between nonsymbolic stimulus magnitudes without explicit instruction, consistent with an algebraic field representation. We are currently replicating these results with non-humans (pigeons). Overall, these results suggest that an expanded approximate number system (ANS) which includes implicit knowledge of algebraic structure might be able to explain organisms' ability to perform computationally-complex behavior.

P1.12: Patterns in Parents' Broad Early Math Support

Presenter: Ashli-Ann Douglas
Authors: Ashli-Ann Douglas, Erica Zippert, Bethany Rittle-Johnson

Early math skills (i.e., patterning, numeracy and spatial) predict later math achievement; however, little work has examined parents' home support of these skills or how support changes over time. The current study compared parents' math support in their child's preschool and kindergarten years, and will explore its relations to parents' math-related beliefs during both years.

Thirty-four parents (91% mothers) completed surveys about their math support and beliefs at the start of their child's preschool year (time 1) and end of their kindergarten year (time 2). Parents rated the frequency of their patterning, numeracy, and spatial support on a 6-point scale (0 = never, 1= once a month or less, 2= 2- to 3-times a month, 3= 1- to 2-times a week, 4= 3- to 4-times a week, 5 = daily).

Time 1 and time 2 math support (i.e. averaged composite of patterning, numeracy and spatial support) were strongly correlated, $r(28) = .67$, $p < .001$; however, this support was less frequent at time 2 ($M = 2.50$, $SD = .64$) than time 1 ($M = 2.85$, $SD = .64$), $t(29)= -4.07$, $p < .001$. At time 2, numeracy support ($M = 3.44$, $SD = .86$) was more frequent than spatial ($M = 2.72$, $SD = .69$), $t(33) = 6.37$, $p < .001$ and patterning support ($M = 2.51$, $SD = .94$), $t(33) = 6.80$, $p < .001$, while spatial and patterning support were comparable, $t(33) = 1.87$, $p =.07$.

Findings suggest that parents' math support in the preschool year is especially important given its relationship with their later math support. Additionally, parents' math support decreases from the preschool to kindergarten year and parents continue to provide patterning support infrequently during the kindergarten year. Further research should explore how to promote more frequent early math support (especially about patterning) among parents.

P1.13: Task-evoked connectivity of the putative number form area in typically developing kindergartners

Presenter: Benjamin Conrad
Authors: Benjamin Conrad, Gavin Price

A putative "number form area" (NFA) in the ventral occipito-temporal cortex (vOTC) is suggested to preferentially process Arabic digits. Category specificity in vOTC areas is thought to arise from interactions with other regions involved in a particular domain, but this aspect of NFA function has been largely unexplored. We address this issue using fMRI measurements of task-evoked connectivity in typically-developing kindergarteners during a symbol classification task. We hypothesized that connectivity between the NFA and a number "network", including intraparietal and prefrontal cortices, would be greater during digit versus letter processing, and that the degree of connectivity would relate to individual differences in number symbol processing.

During 3T fMRI, participants (n=49, Mean age 6.1±0.4yo) saw digits, letters, or scrambled symbols, deciding whether they "knew the name" of the stimulus. Measures of rapid digit naming, symbolic-nonsymbolic number mapping, and implicit number processing were collected. Functional connectivity was measured using beta-series correlation (BSC) using right and left NFA ROIs as seed regions. A group-level contrast of right NFA connectivity during digit versus letter trials resulted in a single positive cluster peaking in the right hippocampus, extending into right lingual gyrus. The same contrast for left NFA revealed an overlapping cluster which peaked in the right lingual gyrus, as well as a second cluster in left putamen. No significant association was found between the behavioral measures and connectivity from the right or left NFA during digit trials.

It should be noted that these are preliminary analyses of data from an ongoing study projected to scan 120 individuals, and thus should be interpreted with caution until data collection is complete. Nonetheless, these results do not support our hypotheses, however, it is possible that these long range connections are not yet fully formed in kindergarten, and that relations between functional connectivity and behavior emerge over development.

P1.14: The ERP Effects of Shared Components in Fraction Comparisons
Presenter: Brian Rivera
Authors: Brian Rivera, Mona Anchan, Jonjing Kim, Firat Soylu

The study of fractions has become a popular topic in numerical cognition. Part of this interest stems from wanting to minimize the difficulties learners encounter when first using fractions. One of these difficulties occurs during comparison of two fractions, when the numerical values of each component (numerators and denominators) and the value fractions represent as a whole communicate conflicting information. A similar conflict, the unit decade effect, is seen in comparison of two double digit whole numbers, when ones' place in the two number have an opposite magnitude order compared to the whole values of the two double-digit numbers. This componential interference underlies some of the errors beginners make when using fractions. Additionally, fraction comparisons are subject to shared component interference in numerator (2/4_2/6), denominator (2/5_3/5), or across (2/3_3/6) creating a Stroop-like effect between the matching magnitude of a fraction's components and the mismatch magnitude of the whole fraction (Meert, Grégoire, & Noël, 2010). This phenomenon has not yet been studied using neuroimaging methods. Event Related Potentials (ERPs) can provide great detail in understanding the timing of how components influence fraction processing. In this proposed study, an N400 paradigm is used to examine the role that shared components play in a fraction magnitude comparison task. The N400 paradigm allows the investigation of differences across matching (2/4_3/6) and mismatching (2/4_3/5) magnitude comparisons and it can capture effects of shared components across these comparisons (e.g., 3/9_1/3 vs. 3/9_2/3). A mass univariate analysis will be used to determine ERP differences between the shared and non-shared fraction comparison cases across both match and mismatch conditions. We predict a condition (Match/Mismatch) x component (Shared/Nonshared) interaction, where the shared component cases in the mismatch condition will show higher reaction times and lower accuracy when compared to the match condition. Additionally, it is hypothesized that shared components will modulate the latency of the N400 across match/mismatch comparisons showing componential interference.

P1.15: Underpinnings of early addition: investigating number partners understanding
Presenter: Brianna Devlin

Authors: Brianna Devlin, Nancy Jordan,

Early competence with number operations in kindergarten, including symbolic addition, predicts math achievement and growth in primary school. Additional research must identify precursors of arithmetic knowledge in order to target intervention. One likely precursor is the understanding of number partners (Fuson, 1992), that is, that whole numbers are made up of smaller sets of cardinal values (e.g. Inside 7, there is 5 and 2, 4 and 3, etc.). This understanding may help children use the count-on method to add, as well as decomposition to reason about symbolic addition problems. Precisely when and how this understanding develops, and how it is linked to early addition, has received little attention. The proposed study aims to uncover the origins and covariates of number partners understanding, map the development of this understanding across the early years, and establish a link between number partners understanding and symbolic addition skills.

Data will be collected from 75 preschool and pre-K children at the start and end of their school year. At the first time point, we will assess core number knowledge including subitizing, counting, cardinality and numeral recognition, as well as number partners understanding in non-symbolic and symbolic formats. At the second time point, we will assess number partners understanding and early addition skill.

Multiple regression will identify significant early predictors of number partners' growth and establish a relationship between number partners and addition. A repeated measures model will map number partner's growth over the school year at the two grades. We hypothesize that cardinality and symbolic mapping will predict number partners understanding; children will understand number partners with small, nonsymbolic sets before the same symbolic representations; knowledge of number partners will be linked to addition performance and advanced strategies. Results will add to our understanding of human numerical cognition and help to focus early intervention work.

P1.16: Is writing handedness involved in the neural representation of symbolic number?
Presenter: Celia Goffin
Authors: Celia Goffin, H. Moriah Sokolowski, Daniel Ansari

A key question in the field of numerical cognition is how the human brain represents numerical symbols (e.g., Arabic digits). A large body of research has implicated left parietal regions in symbolic number processing. One possible explanation for this lateralization of neural activity is the handedness of participants. Specifically, participants in neuroimaging research are almost exclusively right handed. The current study sought to investigate whether number representation in the brain is associated with hand preference for handwriting.

To address this question, we used functional Magnetic Resonance Imaging (fMRI) to compare brain activation of a group of right handed participants ($n = 25$) with a group of left handed participants ($n = 25$) during the passive viewing of symbolic numbers. We predicted that the right-handed group will show left-lateralized activation in the parietal lobe. In contrast, the left-handed group will show relatively greater right-lateralized activation in the parietal lobe.

At the whole-brain level, the right-handers demonstrated the previously obtained left-lateralized effect within the intraparietal sulcus (IPS). The left-handers showed some evidence of reverse lateralization of this effect in the IPS. When the groups were compared directly, we found no regions that demonstrated group-level differences. In a follow-up region of interest analysis within the left and right parietal lobes, we calculated laterality indices for each participant. There was some evidence that the right-handed group was more likely to show left-lateralization than the left-handed group, and the left-handed group was more likely to show right-lateralization than the right-handed group.

These findings provide some preliminary evidence that handwriting is a factor in the mechanisms that underlie symbolic numerical representations. Further research is needed to determine the extent to which handwriting handedness is involved in symbolic numerical representation.

P1.17: Endpoint reversal and digit dependence in numerical estimation
Presenter: Chenmu Xing
Authors: Chenmu Xing, Katherine Williams, Hilary Barth

Number line estimation (NLE) is often assumed to depend on target numerals' magnitudes, not the identities of their component digits. But recent work shows that adults' and children's placements are strongly influenced by leftmost digit identity (Lai, Zax, & Barth., 2018); for example, "302" is systematically placed far to the right of "299" on a 0-1000 line. Little is known about the scope of this left digit effect (LDE) in numerical estimation. We assessed whether the LDE is also present in an atypical NLE task using both "forward" (0-1000) and "reverse" (1000-0) number lines.

Participants ($N = 76$ adults) completed both a 0-1000 and a 1000-0 NLE task, with order counterbalanced. There were 120 target numerals, including eight critical "hundreds pairs" (e.g., 798/802, with analogous pairs at 200, 300, 400, 500 600, 700, 800, and 900). Pairs were not presented together.

The LDE was assessed by calculating individuals' difference scores from each hundreds pair (placement for larger numeral – placement for smaller numeral). Preregistered analyses revealed an LDE on both the 0-1000 and 1000-0 tasks with large effect sizes. On the 0-1000 task, a greater LDE was observed for paired numerals in the 500-1000 range compared to those below 500. There was no statistical evidence that task order or gender moderated the LDE nor did they interact with line type.

These findings demonstrate that the leftmost digit effect in NLE is robust in the face of multiple potential moderators including the direction of the response line. This work extends previous findings that specific digits, not overall numerical magnitudes, influence number line estimation.

P1.18: Small vs. Large: An Examination of Gevers et al. (2006) Using Word Primes
Presenter: Craig Leth-Steensen
Authors:

Gevers, Verguts, Reynvoet, Caessens, and Fias (2006)'s intermediate coding model of the spatial numerical association of response codes (SNARC) effect assumes that smaller and larger numbers implicitly activate small and large categorical codes, which in turn are associated with left and right response codes respectively. The proposed research will act as a test for Gevers et al. (2006)'s model by explicitly flashing the word primes "small" and "large" prior to number stimulus onset, which should serve to activate such codes in a similar manner to number magnitude (i.e., a "small"-left, "large"-right association). Furthermore, the word primes should affect the SNARC effect by inhibiting the effect on incongruent trials (e.g., "small" is displayed before a large number) and magnifying it on congruent trials (e.g., "large" is displayed before a large number). Analyses of response times to correct trials will examine the response side (left and right) by digit (1, 4, 6, and 9) interaction (i.e., the SNARC effect), the word prime ("small" and "large") by response side interaction, and the response side by word prime by digit interaction.

P1.19: Working memory: Reliability analysis of measures within mathematics in grade school age children in the United States.
Presenter: Dana Miller-Cotto
Authors: Dana Miller-Cotto,

In education, it is well-established that working memory (WM) is correlated both concurrently and longitudinally with mathematics (Peng, Namkung, Barnes & Sun, 2016). Recent meta-analyses have revealed that the average weighted correlation between working memory and math achievement is $r = .35$. While the relationship between WM and math is well established, the way in which WM is measured has elicited many debates (Conway, Kane, Bunting, Hambrick & Engle, 2005). One of the most common ways to measure WM is the reverse number digit span, though many have questioned where this instrument accurately measures WM and whether it is age appropriate (Nutley, Söderqvist, Bryde, Humphreys, & Klingberg, 2009). The proposed study seeks to examine the reverse digit span in within the context of mathematics specifically using a reliability generalization meta-analysis. Moderators of interest include grade, age, mathematics domain, language, and type of report (published or dissertation). The proposed study will examine internal consistency as its reliability metric. Search criteria will include: working memory, mathematics, children. Articles will be screened via the abstracts during the initial phase, and further screening will be conducted by examining Method sections for reverse digit span and sample characteristics. All analyses will be conducted in Jamovi Version V.9 (2018) using the Major package for meta-analyses. From this package the reliability generalization option will be used, employing pooled overall estimates. In the event that some studies include multiple estimates in one study, weighted estimates will be used (Beretvas & Pastor, 2003). It is hypothesized that age and mathematics domain will explain variation in internal consistency estimates. Findings will contribute to ongoing debates about the viability of using reverse digit span scores in mathematical cognition research.

P1.20: Effects of attitudes, mindset, and anxiety on children's numeracy attainment
Presenter: Dawn Short
Authors: Dawn Short, Janet McLean

Children's numeracy attainment in Scotland continues to fall, with those from socially disadvantaged backgrounds most effected, contributing to the expanding attainment gap between richest and poorest children and influencing their lifelong opportunities. Many factors influence numeracy attainment, including the effects of attitudes, mindset, and anxiety. Previous studies have not focussed on deprived areas. Therefore, the current study is concentrated in areas of high social deprivation and aims to develop an intervention to improve numeracy attainment.

The current pilot study is a within subjects design. Forty-two (22 male) 5-year-old participants completed numerical symbolic-to-nonsymbolic (SNS) and nonsymbolic-to-symbolic (NSS) mapping tasks at two difficulty ratios (0.5 and 0.7 ratios), a counting task, and growth mindset and maths anxiety quiz.

Children scored higher on 0.5 than 0.7 ratio, and on SNS than NSS task, but 2x2 ANOVA found no significant differences between ratio difficulty scores ($F(1,11) = 1.31$, $p = .276$) or mapping task type scores ($F(1,11) = 3.06$, $p = .108$)

There was a significant association between maths anxiety and fixed mindset ($x2(1)= 13.41$, $p<.001$). Based on odds ratio, children with growth mindsets were 11 times less likely to have maths anxiety than children with fixed mindsets.

Pilot results were encouraging, suggesting a link between maths anxiety and mindset. However, small sample sizes and large exclusion rates mean results should be treated cautiously. Therefore, a cohort sequential longitudinal design study is underway to address these issues and fully investigate factors influencing numeracy attainment.

P1.21: A deep learning method to compare problem similarity in education.
Presenter: Dominic Mussack

Authors: Dominic Mussack, Rory Flemming, Paul Schrater, Aurélien Defossez, Brice Clocher, Pedro Cardoso-Leite.

Developing automated learning systems allows educators to scale up their efficacy, and personalized systems retain the ability to customize to the individual student. A core issue in developing adaptive learning systems is in understanding how different problems relate to one another, in order to predict performance across problems. This can be improved by having problems with features (covariates); that is problem labels beyond a simple index (e.g., problem type or parameter). Standard statistical methods, such as item response theory, while allowing the use of problem features, do not handle more complex feature sets. We develop a novel analysis method for understanding problem similarity, based on predicted performance.

To develop our similarity comparison, we borrow from deep learning methodology to create and train our model. This model consists of an embedding layer, to put features into the same space, cosine similarity between problems, and a simple linear layer across the similarity scores to produce a single similarity for each problem comparison. Then problem performance is predicted based on this similarity; if two problems are similar their performance should be similar. We apply this model to data collected from Mathemarmite (http://mathemarmite.lu), an educational game designed to teach children numeracy. Mathemarmite requires children to appropriately count using different representations (e.g., digits, fingers). However, some problems require them to count using multiple abstractions rather than just one.

We train this model on Mathemarmite dataset, as well as simulated datasets, and show how we can extract meaningful interpretation of problem difficulty from the model weights. This allows us to fully represent the complexity of the problem space, while still extracting scientifically-useful results from the analysis. By extending educational science's data analysis toolkits to take use of modern machine learning methods, we can learn from more highly structured data sets.

P1.22: Children's with different profiles of direction of effect understanding demonstrated different levels of mathematics achievement
Presenter: Eason Sai-Kit Yip
Authors: Eason Sai-Kit Yip, Terry Tin-Yau Wong,

Arithmetic principles have been gaining attention in mathematical cognition field. While understanding of some principles has been widely investigated, research on understanding of direction of effect (DE, e.g., increasing the value of either addend increases the value of the sum), remains scarce, and very few studies have examined the multifaceted nature of DE understanding. The current study aimed at identifying different profiles of DE understanding through using different DE measures (i.e., evaluation of examples, recognition, and application of procedures) and examining if children with different DE understanding profiles demonstrated different levels of mathematics achievement.

Grade 4 to 6 students (n = 110) were recruited from local primary schools. They were therefore assessed on DE understanding using the three distinct measures in addition to their standardized mathematics achievement.

The latent profile analysis using the three DE measures revealed four classes of children with different DE profiles. The classes were labeled based on their performance (H = high, L = low) in the three measures (E = evaluation of examples, R = explicit recognition, A = application of procedures), namely LER, LEA, Average, and HERA. The subsequent ANCOVA, after controlling for grade, intelligence, and the numerical magnitude understanding of whole numbers and fractions, highlighted that students who were able to recognize the DE principle in its algebraic form significantly outperformed those who failed to recognize the principle in mathematics achievement.

The current findings reveal that most primary school students have at least some understanding of the DE principle, and this understanding is associated with their mathematics achievement.

P1.23: To the math anxious, what is considered math?
Presenter: Eli Zaleznik
Authors: Eli Zaleznik, Joonkoo Park,

Math anxiety (MA), a feeling of tension or dread when confronted with math, has been shown to relate to avoidance of math courses and underdevelopment of related skills. Much research has focused on the cause and performance effects of MA, but little research has been done into the cognitive nature of MA and related physiological responses. To understand the boundaries of math anxiety, we developed a novel/familiar recognition paradigm with letters, numbers and arithmetic expressions while taking physiological (EKG and GSR) measures. We hypothesize that, if mathematical expressions tax mental efforts and serve as distractors, mathematical, and possibly numeric, stimuli will relate to lower performance. We also hypothesize that MA will relate to augmented physiological arousal when viewing mathematical stimuli.

Participants will see target sets of letters, numbers, or arithmetic expressions presented in different colors and patterns and will be instructed to categorize a test set of stimuli as novel or familiar. Different blocks will either focus on recalling the patterns or the semantic content of the target for a total of six conditions. Response time, accuracy, GSR and EKG measurements will be taken. They will also complete the Math Anxiety Rating Scale.

We will use a 3(stimuli) x 2(recall condition) x 2(MA status) mixed model ANOVA to analyze RT, with focus on the stimulus x group interaction. HR will be analyzed as the change in R-R interval compared to baseline and GSR will be measured by the number of discrete GSR events per condition. We predict that the high MA group will be slower to categorize than the low MA group when presented with arithmetic and numbers, and no difference for letters. We may see an increase in HR and more GSR events for the high MA group when presented with numeric and mathematical stimuli.

P1.24: Acquisition of French Un
Presenter: Elisabeth Marchand
Authors: Elisabeth Marchand, David Barner

How does cross-linguistic variation in grammatical structure affect children's acquisition of number words? In this study, we addressed this question by investigating the case study of young speakers of French, a language in which the number one and the indefinite article a are phonologically the same (i.e., un). The homophony of un – with both an exact (one) and inexact (a) meaning – can indeed provide children with a difficult learning problem. Here, we investigated how French-speaking children interpret un, and whether it more closely resembles the English a or one. We tested 86 monolingual French-speakers, aged 2 to 4 years, by asking them questions like, "Est-ce qu'il y a un canard dans la maison?" (Is there a/one duck in the house?) in the presence of either one or two objects. In addition, we probed whether their interpretation of un differed in two between-subject conditions in which filler items were either restricted to the non-numerical expressions des and tous (Quantifier Condition) or included the number word for two (Number Condition). We found that French-speaking children almost always accepted sets of one for un, but that their responses for sets of two were more equivocal, with many children saying "oui" (yes) when asked whether there was un, regardless of the condition in which they were in (Number vs. Quantifier). Overall, French children's interpretation of un differed from how English speakers interpret both a and one. This suggests that French-speaking children's interpretation of un reflects the ambiguity of the input to which they are exposed. We conclude that French morphological structure may pose a challenge to French children in acquiring an exact numerical meaning for un, potentially causing a delay in number word learning. We discuss studies currently in progress that test the possibility of a delay in the acquisition of one in French-speakers.

P1.25: How Preschool Teachers Use Math Talk Across Different Instructional Times and Activities
Presenter: Emily Braham
Authors: Emily Braham, Abigail Dillaha, Melissa Libertus

The amount of math talk that preschoolers hear in their classroom positively predicts growth in their math knowledge. However, in prior work, teachers' math talk was only sampled for an hour and few studies have attempted to explain individual differences across teachers. Our aims were to 1) capture differences in the frequencies and types of preschool teachers' math talk as they engaged in different classroom activities, and 2) examine how various teacher characteristics influence their math talk. We transcribed the speech of 48 teachers during large and small-group instruction, free play, meals, transitions between activities, and a semi-structured building activity. Teachers then completed questionnaires about their background, instructional practices, beliefs, and standardized assessments to measure academic skills. We will code the transcriptions for 10 broad categories of math talk: counting, cardinality, equivalence, calculation, ordering, place holding, number symbols, ages, dates, and time. We hypothesize that basic types of math talk (e.g., counting, cardinality) will occur during all activities, but that advanced types (e.g., calculation, number symbols) will be more frequent during instructional times. We will use ANOVAs to examine differences in teachers' overall math talk and particular types of math talk by activity, and linear regressions to explore the associations from teachers' math-related beliefs and skills to their overall math talk and frequency of particular types of math talk. All models will control for overall linguistic input, demographic characteristics of the teachers (e.g., education level) and classroom (e.g., classroom size). The linear regression models will additionally test the specificity to the math domain by controlling for teachers' reading and spatial skills. To account for the nested structure of the data, we will calculate intra-class correlation coefficients both within classrooms and within schools. If these analyses reveal dependence within these structures, we will use multi-level models to correct for it.

P1.26: "When will I need this in the real world?": Realistic Problem Solving in Sixth Graders
Presenter: Emily J. Rowe
Authors: Emily J. Rowe, Cheryll L. Fitzpatrick, Darcy Hallett

Word problems are the most common (Jonassen, 2003) and challenging type of problem found in formal education (U.S. Department of Education, 2008). They are partly designed to help students better understand how math can be used in everyday situations (Lave, 1992), but students perform extremely poorly on realistic word problems. Realistic problems require real world information to be taken into account, like realizing that the number of Christmas cards sold in January, February, and March is not going to be the same as the number sold in December (Verschaffel et al., 2000). Palm (2008) has shown that adding more authenticity, or a detailed back story, to a word problem substantially increases realistic responding (RR). In this study, we examine whether it is authenticity that increases RR or the problem set a student receives. It is hypothesized that when presented with only realistic word problems, student's performance will increase as it becomes easier to answer a set of questions if they are all the same type.

Grade six students (N = 160, MAge = 11) answered seven word problems from one of eight test booklets, varying in difficulty, authenticity, and problem set (e.g., mixed standard and realistic or all realistic word problems). Student's answers to the questions were coded based on a well-established coding scheme used in this line of literature (Verschaffel et al., 2000).

While data collection is ongoing: It is anticipated that RR will be the highest when students received all authentic realistic word problems presented with increasing difficulty. Consistent with previous literature, overall students will continue to perform poorly on realistic word problems. Further research is needed that continues to investigate how to improve this type of logical thinking in the school system.

P1.27: The Emergence of Gender Gaps in Math Learning during a Single High-Quality Instructional Opportunity

Presenter: Emily Lyons
Authors: Emily Lyons, Almaz Mesghina, Lindsey Richland

Introduction: Although males and females do not differ meaningfully in mathematics aptitude (see Spelke, 2005), math achievement and eventual career trajectories continue to be patterned by gender in complex and oftentimes paradoxical ways. Math-intensive fields remain heavily male-dominated (National Science Foundation, 2017), yet girls perform similarly to their male counterparts on tests of math achievement (Hyde et al, 2008; Reardon et al., 2018) and against popular expectations, often outperform boys in mathematics learning in middle and high school settings (see Easton, Johnson & Sartain, 2017; this symposium).

Multiple previous studies unexpectedly found large and consistent gender gaps showing girls learning more from a mathematics lesson. The two studies presented here aim to clarify how individual differences across students and learning contexts may contribute to this gender gap. Study 1 tested the gender gap with a controlled videotaped, interactive math lesson and examined contributions of student's prior knowledge, cognitive resources and math anxiety. Study 2 experimentally manipulated increased pressure to test impacts on the gender gap.

We implemented a pretest, lesson-and-immediate-posttest, delayed-posttest design, assessing both immediate learning and retention. Students interacted with a high-quality video-taped math lesson in their regular math classrooms - maximizing ecological validity, while allowing for controlled stimuli. We also collected measures of math anxiety and cognitive resources.

Study 1: 346 diverse 5th grade students (180 girls) completed study procedures in a non-pressured classroom context.

Study 2: 178 diverse 5th grade students (89 girls) completed study procedures. Half the students were randomly assigned (within classroom) to receive a pressure manipulation before instruction. They were told their performance on a test would determine whether their whole class would receive a desired incentive.

Study 1: Girls exhibited greater learning gains, immediately following the lesson and at a delay (both p s < 0.01). Prior knowledge and cognitive resources both predicted gains, but did not explain gender differences. Math anxiety negatively predicted gains, but also did not explain gender differences. Indeed, observed relationships between gender, math anxiety and learning are seemingly paradoxical- with girls exhibiting both higher math anxiety and larger gains- despite math anxiety negatively predicting gains in the sample as a whole.

Study 2: The no-pressure condition replicated Study 1, with girls learning more than boys immediately and at a delay (both p s < 0.05). With pressure, however, the gender gaps disappeared, with pressure predicting smaller gains among girls and larger gains among boys, findings that will be explored more completely in the paper.

Although gendered patterns of achievement are well documented, less research has considered the role of gender in shaping initial learning. Through examining the in-the-moment emergence of gender differences in learning during a single high-quality instructional opportunity in pressured and non-pressured contexts, these studies aim to elucidate factors shaping gendered patterns of math trajectories.

P1.28: The innateness of number: A case study using children's counting books
Presenter: Emily Sanford
Authors: Emily Sanford, Justin Halberda

A brief glance at an apple tree is enough to form a surprisingly accurate impression of the number of apples on its branches. What is the basis of this capacity? Can our abstract numerical representations be directly traced back to primitive early representations of number, or do we learn to construct them over the course of development? If cognitive representations of visual number must be constructed through experience from non-numerical visual features, then it must be the case that our early visual experiences provide enough evidence for us to learn a reliable relationship between number and non-numerical features. Here, we explore this assumption by making use of a surprisingly underutilized resource: the visual images that children look at when learning number from counting books. If the non-numerical visual cues in these images fail to capture number, then children could not rely on them to learn how many items are on a page. This implies that number learning must involve a more direct number signal. Much work suggests that the concept number must be constructed from early visual features rather than being innately specified, so we analyzed how well such features track cardinality across 50 children's counting books. We found that continuous features were at best weakly correlated with number (highest $r2 = .32$). A linear regression over the three most predictive features explained a modest amount of variability in the number of items, $R2 = .33$, $p < .001$. Further, a numerical estimation system that only uses evidence from non-numerical features will perform much worse than children do in typical number tasks. We show that children's number abilities go beyond that which could be provided by low-level visual features and therefore must involve either a more direct numerical extraction or an inference beyond the evidence of non-numerical features.

P1.29: Comparing response modes in number line estimation: Does it matter when you respond with a mouse or with your eyes?
Presenter: Kelsey J. Mackay
Authors: Kelsey J. Mackay, Filip Germeys, Lieven Verschaffel, Wim Van Dooren, Koen Luwel

In previous studies on number line estimation (NLE), participants respond with either a pencil in the paper-and-pencil variant, or with a mouse in the computerized variant. However, both variants allow participants to place the pencil or mouse cursor at the midpoint of the number line and use this as a benchmark to facilitate their estimation (Ashcraft & Moore, 2012; Peeters, Verschaffel, & Luwel, 2017). To determine if answering with the eyes could serve as a less biased and more valid way of responding in the NLE task, we investigated the extent to which there might be differences between responding with the mouse or with the eyes. Adult participants ($N = 33$) had to position 54 target numbers on a 0-1000 number line in while either responding with the mouse (i.e., the mouse condition) or by fixating on the number line (i.e., the eye condition). Target numbers were equally distributed along the number line. To detect possible use of benchmarks, we ensured that three target numbers were within 2% of each of the octiles of the number line. Results showed moderate and strong significant correlations in participants' accuracy ($r = .51$) and reaction times ($r = .84$), respectively, between the mouse and the eye condition. Also, participants were significantly slower and significantly more accurate in the mouse than in the eye condition. Moreover, 88% of participants self-reported that the mouse condition was easier than the eye condition. For the eye-tracking data, 5 equal-sized interest areas were made across the number line to investigate the use of benchmarks on the number line. Eye-tracking data will be presented across these interest areas for both conditions.These findings show that future NLE studies using a pencil or a mouse as a way of responding should consider the potential additional external benchmark of the midpoint.

P1.30: Physical fitness correlates with kindergarteners' mathematics other than language
Presenter: Li Wang
Authors: Li Wang, Xinlin Zhou

There have been lots of studies reporting the associations between physical fitness (PF) and academic achievements, but results were mixed. It is hypothesized that PF would have closer association with mathematics than with language based on the brain organization for physical activities, mathematics and language. A meta-analysis of their association based on 17 samples (22951 children, aged from 5 to 15) showed that physical score had a more positive random effect on mathematics than on language.

The study aims at examining the relations between PF, mathematics and language. It is hypothesized that PF would have closer association with mathematics than with language.

15 classes of kindergarteners, aging 5 and 6 years old, were recruited. The PF tests included running, jumping, balancing and ball throwing. The tests for mathematics and language included addition, subtraction, character recognition and word span.

Mixed model analysis showed that kindergarteners' total PF score correlated with mathematics but not with language. The score of jumping, balancing and ball throwing except for running were associated with mathematics, separately.

The PE has closer association with mathematics than with language. The similar brain organization might be the underlying mechanism. The result suggests that physical activities can be one of potential promoting factors for the development of mathematical abilities.

P1.31 Does it Add Up? Comparing Arithmetic Processing in Bilinguals and Monolinguals
Presenter: Mona Anchan
Authors: Mona Anchan, Brian Rivera, Nathaniel Shannon, Firat Soylu

With more than 25% of American school students coming from immigrant households where the primary language spoken at home is not English, it is problematic to expect this bilingual population to perform at the level of their monolinguals peers. As a result of using competing languages regularly, representation of math knowledge could be different in bilinguals and monolinguals. While some of these processes are being investigated in simultaneous bilinguals, it is important to investigate how consecutive bilinguals process simple mathematical tasks which form the basis of higher math. This pilot study will examine how consecutive bilingual adults process single-digit and double-digit addition problems in Spanish (first language, L1) as well as English (L2). Similar arithmetic processing will also be examined in monolinguals to check for between-group differences. Subjects will be instructed to add two Arabic numerals that appear for 1 second. Each trial allows subjects 2 seconds to provide a free-recall verbal response which is an ecologically valid demonstration of their addition skills and processing time. Monolinguals will respond in English over one session. Bilinguals will respond in English and Spanish over the course of two sessions, with the language order being counterbalanced. An event-related spectral perturbation (ERSP) analysis will be conducted to evaluate the level of different frequencies (theta, alpha, beta, gamma) followed by an ANCOVA to determine between-group differences in processing time and frequencies. We hypothesize higher theta-band and beta-band power in frontal regions, higher alpha-band power in fronto-ocular regions, and higher gamma-band power in central regions for bilinguals; these oscillations have been linked to inhibitory control processes that inhibit one language over another. We also expect higher theta activity when bilinguals process math in L1 due to its association with memory encoding. The fact retrieval connection also implies higher theta activity in parietal regions for single-digit arithmetic.

P1.32: Non-symbolic Comparison of Stimulus Magnitudes in an Artificial Algebra Without Feedback
Presenter: Nicola Morton
Authors: Nicola Morton, Anna Wilson, Randolph Grace

We have developed a non-symbolic artificial algebra task in which participants are trained using feedback to respond to arithmetic relations between non-symbolic stimulus magnitudes (e.g. difference or ratio of stimulus brightness or length; Grace et al., 2018). Here we investigated how participants would respond if no feedback was provided – that is, unsupervised training. On each trial, participants (n = 26) saw pairs of stimuli that varied in either line length or brightness (between subjects variable), and were asked to respond based on the similarity or dissimilarity of the two stimuli by clicking along a horizontal bar. Even though no feedback was provided whatsoever, responding for individual participants was very consistent. Contrary to previous results with feedback (i.e., supervised training) responding was not linearly related to differences or ratios, but instead tended toward a logarithmic relation of stimulus differences, reminiscent of number-line assignment in preschool children (Booth & Siegler, 2006). These results suggest that non-linear mapping of number persists into adulthood, and that linear mapping may be task dependent.

P1.33: Why we love or hate math: How experiences shape attitudes about math
Presenter: Rachel Jansen
Authors: Rachel Jansen, Anna Rafferty

A variety of research has investigated which specific affective constructs are related to math performance. Much of the research thus far presumes only a negative (e.g., math anxiety) or positive (e.g., self-efficacy) stance, which does not allow for expression of the full range of one's math attitudes on a given survey. In this work, we analyze data from a Quanta magazine survey in which respondents rated their attitudes toward math on a 5-point scale from 'hate' to 'love,' indicated when they formed their attitudes, and wrote short narratives about the experiences that led to their attitudes. We found that men had more positive feelings than women and that women who formed their attitudes in middle and high school had more negative feelings than other groups. Computational text analysis of the narratives revealed word usage differences depending on the valence of attitudes (e.g., those with negative feelings used words like 'inability' and 'difficulty') and gender (e.g., women said 'confused' and 'stupid' more). We then expanded the survey to collect more detailed narratives about math attitude formation and experiences with math over time in order to examine how valence, magnitude, and time of attitude formation differ based on gender and race. Specifically, the updated survey included opportunities for multiple narratives about different educational periods and rating scales for math in various contexts (school, work). Pilot results with a more diverse population are consistent with the overall trends in the previous dataset. Future work will collect a larger sample for computational text analysis to explore whether specific topics present in narratives are related to math attitude, gender, race, and time of attitude formation.

P2.34: Executive function and math achievement: A meta-analysis on early sex differences
Presenter: Dominic Kelly
Authors: Dominic Kelly, Sammy Ahmed, Abigail Richburg, Cole Anderson, Pamela Davis-Kean

There is a growing body of research that suggests children's executive functions (EF) are particularly important for the support of their emerging math skills. Many math related activities and tasks require children to activate and employ their working memory, attend to and shift their attention, and inhibit automatic and inappropriate responses. Recent research has revealed that girls tend to exhibit higher EF skills during early development, which is then linked to advantages in girls' school readiness and achievement (Mathews et al., 2009), and in 2013, Son et al, found that the relation between EF and reading achievement was moderated by sex. However, whether the relation between EF skills and math achievement during early development is moderated by gender is less understood. Therefore, we propose a meta-analysis on whether the relationship between executive functions and mathematics is moderated by sex. We expect to see that there will be a relationship between EF and mathematical achievement and that this relationship will be stronger for boys.

We will retrieve abstracts from PsychInfo and three other minor databases from 1990 to 2018. The search terms are 'executive functions' and 14 other related terms in addition to 'gender OR sex'. Abstracts for both published and unpublished work will be screened. Within these papers, any paper concerning 'math' and other related terms will be analysed. The correlation between math and EF skills will be calculated for boys and girls separately. A random-effects model will be used to reduce the risk of Type I errors. Each study will be weighted by inverse variance. To examine whether the expected interaction effect varies as a function as age, this process will be repeated for early childhood, middle childhood and adolescence. We will also test for publication bias by using p-curve analysis and a funnel plot.

P2.35: Development of Decomposed Parallel Processing in Dual Language Immersion Second Graders
Presenter: Emily Speed
Authors: Emily Speed, Kaylee Litson, Kerry Jordan

Differences levels of numerical system transparency (how similar the spoken and written number systems are) in Mandarin Chinese and English may affect how children learn and process two-digit numbers. Mandarin has a very transparent system in which the spoken and written system map precisely onto the base-10 structure in a predictable and regular pattern. In contrast, English has an irregular number system; historical sound changes have created irregularities in number-naming through the -teen and decade numbers that make it difficult for young children to learn to count, and perhaps make it more difficult for children to process two-digit numbers. Typically, English-speaking children up to about age 9 or 10 use decomposed sequential processing, in which two-digit numbers are processed decade first and then unit. Magnitude comparison judgements are then made based on the decade digit alone. Adults process both digits of a two-digit number simultaneously and in parallel; this "decomposed parallel processing" is a result of over-practice and generally increases the speed of processing in most trial conditions. Native Mandarin-speaking children begin to use decomposed parallel processing as early as age 7.

Until the last decade, few Mandarin bilingual schools existed in the U.S., so Mandarin-speaking children are predominately Chinese nationals or Chinese-American. Thus, most comparisons of English-speaking and Mandarin-speaking children have been conducted, out of necessity, in samples that have cultural differences that may affect their mathematics achievement and overall numerical cognition. Dual Language Immersion (DLI) schools have begun to proliferate across the country, particularly in Utah. DLI schools teach half of the day in English and half of the day in a target language like Mandarin or Spanish among others. Mathematics classes are held in the target language half of the day. These schools have created a small population of predominately native-English speakers who are learning mathematics in Mandarin, and thus learning to use the Mandarin numerical system fluently.

The current study is an investigation into differences in numerical processing resulting from participation in DLI education. Native English-speaking children who learn Mandarin at school through a DLI program are hypothesized to display increased evidence of decomposed parallel processing in comparison to English monolinguals.

Participants are given a modified Stroop task known as the dot-number Stroop in which magnitude comparisons are conducted on pairs of two-digit numbers, with dot size as a stand-in for physical size comparisons as in the size-congruency numerical Stroop task. Increased inverse efficiency scores on the compatible-incongruent condition of the dot-number Stroop task are indicative of use of decomposed parallel processing.

Power analysis indicates that a sample size of 24 would be required to detect an effect size of $\eta 2 = .28$ and power of .8 (as was found in Chan et al., 2011) in a 2 x 2 x 2 mixed design ANOVA for the dot-number Stroop task conducted on inverse efficiency, with congruity and unit-decade compatibility as within-participant factors and language group as a between-participant factor. Independent samples t tests will be conducted on each condition and language group.

P2.36: Testing the Motor Simulation Theory in Processing Canonical and Non-Canonical Finger Numeral Configurations

Presenter: Firat Soylu
Authors: Firat Soylu, Brian Rivera, Mona Anchan, Nathaniel Shannon

Finger-based representations are used to represent numerosities, to count, and to do arithmetic across cultures. Previous research has distinguished between two forms of finger configurations in the context of number processing; finger montring and finger counting. Montring is used to represent cardinal numerosities and often serves a communicative function. Finger counting can be ordinal or cardinal and is used both for counting and arithmetic. Previous behavioral research show that the numerical information represented in these canonical forms of finger configurations (e.g., index, middle and ring fingers for three) are identified faster and more accurately, and better prime number comparison judgments compared to non-canonical finger configurations (e.g., thumb, middle and ring fingers). Previously it was proposed that due to extensive experiences with canonical representations since early childhood, canonical configurations automatically trigger the associated numerical semantic representation, which is not the case for the non-canonical ones. A motor simulation mechanism was suggested (Di Luca & Pesenti, 2010) to explain how canonical configurations can more readily trigger the associated numerical representations. According to this explanation, the viewing of numerical configurations trigger parts of the motor circuitry that are involved in the actual execution of the finger gestures, which then allows access to the numerical information. Canonical configurations are processed faster since simulation of the motor program is easier when the action simulated is part of the motor repertoire. To test this claim we analyzed EEG and behavioral data from 38 adults. The task involved viewing three different forms of finger configurations (montring, counting, and non-canonical) and validating whether the Arabic numerals presented after the finger configurations matched in terms of the numerical values. The behavioral results showed that montring configurations were processed both faster and more accurately than counting and non-canonical ones. Mu suppression (decreases in Alpha amplitude over central electrodes) has long been used as a measure of mirror motor activity across a wide range of tasks. The results of the preliminary event-related spectral perturbation (ERSP) and inter-trial coherence (ITC) analyses to study Mu suppression showed no significant differences across the three conditions, failing to support the motor simulation explanation. However, amplitude measures are known to be vulnerable to volume conduction. Further analysis using cortical current density will be conducted to explore the local Mu suppression effects.

P2.37: Calcularis® efficacy in children with Developmental Dyscalculia barely familiar with computers.

Presenter: Flavia Santos
Authors: Flavia Santos, Liene R. Rossi, Jessica M. Nascimento

Developmental Dyscalculia is a multifactorial and heterogeneous learning disability associated with poor educational, financial and social outcomes in adulthood. Computer assisted interventions may facilitate mathematical learning. However, children from developing countries may be barely familiar with computers or tablets being disadvantaged on its use. Recent behavioural and neuroimaging studies found immediate efficacy for Calcularis®, a Swiss mathematical learning software, which improved children's subtraction and number line estimation after 24 sessions. There is a lack of evidence if shorter protocols could be equally effective. Method: We carried out a Randomised Controlled Trial to investigate if a brief protocol using this software could improve numerical cognition and eventually other related skills in children with Developmental Dyscalculia. Participants were 66 children aged 8 to 10 years, both genders, with operationalised diagnosis of Developmental Dyscalculia, enrolled in five Brazilian public schools. Children were randomly allocated in three groups: Control that was not trained, Non-Adaptive which performed a software demo version and Adaptive which completed the training. Students attended 20 training sessions, 20 minutes a day, 5 days per week, in small groups at schools. Neurocognitive assessment was carried out pre- and post- seven weeks interval in a double-blind manner. Results: Group vs Time interactions revealed that Adaptive group presented better post-training performance than pre-training in subtraction, word problems and oral number comparison. Enhancement was also observed for Adaptive group in phonological memory and shifting tasks, both had in common embodied stimuli and processing: numerals transcoding. Conclusion: The software improved either, trained (numerical cognition) and untrained (phonological memory and shifting) skills, and more importantly using a shorter protocol than the studies carried out in developed countries. The training programme boosted math's schooling achievement in children with Developmental Dyscalculia and group sessions seemed to be appropriate for a country with inequalities in education and resources.

P2.38: The role of the need for cognition in math anxious students' mathematic achievement
Presenter: Fraulein Retanal
Authors: Fraulein Retanal, Erin Maloney

Given the importance of creating strong foundations in terms of math abilities and math attitudes (Charette and Meng 1998; Duncan et al. 2007; Duncan 2011; Romano et al. 2010), it is important for future economic success that we take significant steps to improve math education within North America. In mathematics, attitudes, such as math anxiety, can play a significant role in how successful one will be. Researchers have long puzzled over the relation between math anxiety and math achievement. While it is clear that math anxiety is negatively related to math achievement, it is not completely clear why. Indeed, some researchers argue that math anxiety causes poor math performance by co-opting important working memory resources (e.g., Ashcraft & Kirk, 2001), while others content that high math-anxious individuals simply have lower numerical abilities (e.g., Maloney, 2016). Here, we propose the novel theory that math anxiety is, in part, related to lower math achievement due to higher-math-anxious students unwillingness to struggle with complex problems and reflect on their answers.

To test this hypothesis, participants (n=126) completed measures of math anxiety, general anxiety, math ability, the Need For Cognition scale (NFC) and the Cognitive Reflection Test (CRT). Need for cognition refers to an individual's tendency to engage in and enjoy activities that require thinking. While some individuals have relatively little motivation for cognitively complex tasks, others are high in NFC. The CRT is a task designed to measure a person's tendency to override an incorrect "intuitive" response and engage in further reflection to find a correct answer.

While there was a significant relation between math anxiety and math achievement, even after controlling for general anxiety and gender, ($\beta = .38$, $p < .001$), the strength of this relation decreased when NFC was added to the model ($\beta = -.31$, $p = .003$). While NFC does not completely explain the relation between math anxiety and math achievement, it does, nonetheless, explain a portion of this relation.

We next tested the theory that math anxiety would be related to performance on the CRT following the logic that, if higher-math-anxious individuals do not enjoy struggling through complex problems, then they may also be less reflective in their thinking. Indeed, even after controlling for general anxiety and gender, math anxiety significantly predicted performance on the CRT ($\beta = -.56$, $p < .001$). Critically, this relation held even after controlling for participants' math ability ($\beta = -.43$, $p < .001$). The fact that the relation between math anxiety and performance on the CRT remains after controlling for math ability is important as it has been argued that the CTR is mathematical in nature (Thomson & Oppenheimer; 2016).

In conclusion, we provide evidence that math anxiety is associated with a lower need for cognition and with less reflective thinking. We further suggest that this reluctance to struggle through complex problems and reflect on answers may explain, in part, the relation between math anxiety and math achievement.

P2.39: Math Vocabulary and Fraction Mapping Skills
Presenter: Hafsa Hasan
Authors: Hafsa Hasan, Anna Pogrebniak, Heather Douglas, Chang Xu, Jo-Anne LeFevre

What is a numerator? Chances are, if you can answer this question you understand fractions better than a friend who can't answer the question. Math-specific language supports children's early math learning (Purpura & Reid, 2016; Toll & Van Nuit, 2014) and educators stress that math vocabulary is an important tool for student learning (e.g., Rubenstein & Thompson, 2000). Presumably, understanding words like numerator may support fraction learning. However, few studies have focused on the role of math-specific language in fraction learning. The goal of this study was to explore how math vocabulary supports early fraction skills by comparing children who are learning formal fraction notation (e.g., ¾) with students who are more experienced in fraction notation. One hundred and thirty children (68 boys) from grade 4 (n=65) and grade 6 (n=65) were recruited from three rural Canadian schools. Students completed a test battery that included measures of working memory (i.e., digit forward, digit backward and spatial span), basic number skills (i.e., digit comparison and order judgment), vocabulary (i.e., general receptive vocabulary, and math vocabulary), and fraction mapping skills. Fraction mapping skills involved matching fraction pictures (e.g.,), numbers (e.g., 2/3) and words (e.g., two-thirds). Results showed that for both groups of students, math vocabulary accounted for variance in mapping skills above and beyond the influence of working memory, basic number skills and general vocabulary. Interestingly, for students in grade 6, math vocabulary fully accounted for the relation between general vocabulary and fraction mapping. In contrast, for students in grade 4, general vocabulary and math vocabulary together contributed to fraction mapping skills. These findings indicate that math vocabulary supports fraction notation (e.g., ¾) knowledge differently as students become more experienced with formal fraction notation.

P2.40: Quantity and Quality of Gestures are Related to Performance on an Embodied Geometric Estimation Task
Presenter: Hannah Smith
Authors: Hannah Smith, Avery Harrison, Erin Ottmar, Ivon Arroyo

Gestures are a form of embodiment of mathematical knowledge (Alibali & Nathan, 2012) and variation in gesture use reflects differences in mathematics knowledge. For instance, the use of dynamic (e.g., tracing the perimeter of a triangle) as opposed to static (e.g., pointing to the perimeter) gestures are associated with higher accuracy on a geometric proof task (Walkington et. al., 2015). We propose that both quantity and quality of gestures may be associated with language during a geometric estimation task . Specifically, we examine whether the type (dynamic or static) and the number of gestures are differentially associated with accuracy and precision of language used in a problem solving explanation.

We recruited 29 undergraduate students to complete a series of estimation tasks where they measured the length, height, or diameter of spheres, cylinders, cubes, and prisms using either an unmarked 6- or 12-inch dowel. Afterwards, participants explained how they arrived at their answer for each task. The sessions were videotaped and later coded for the frequency and type of gestures. We also coded the correctness and precision of language used in the verbal explanation.

Participants who provided correct reasoning in their answer explanations used more gestures and higher proportion of dynamic gestures compared to participants who provided incorrect reasoning, $ps < .047$. The frequency of gesture use did not differ between participants who used precise versus imprecise language during their explanations. However, participants who used imprecise language produced a higher proportion of dynamic gestures than those who used precise language, $p < .001$, suggesting that the dynamic gestures may support and complement explanations that had little verbal detail.

We also conducted this study with elementary students and are currently analyzing the data. Additional findings exploring the association between gesture and speech in elementary students, and developmental differences will be presented.

(P) P2.41: Cross-cultural differences in children's mathematical development: investigating the home numeracy environment
Presenter: Heather Lyle
Authors: Heather Lyle, Judith Wylie, Kinga Morsanyi

Asian children attain higher standards in mathematical development, often at an earlier age, than those of other cultures. This is of great interest to psychologists and educationalists alike. The implications of this research for policy makers is growing; educating children well enables them to contribute to the evolving demands of society, its well-being and prosperity. In addition, these children are often taught maths in their second language, shining a spotlight on the role of home numeracy activities as one potential explanation for the cross-cultural differences. Recent research has begun to demarcate areas of these home numeracy activities (HNA) and to examine not only the content but the frequency of parental engagement with HNA. This study seeks to add to the conversation on the nature and role of the home numeracy environment on children aged 3-6 years focusing on two schools, one in Northern Ireland, and one in China, which have had a staff exchange programme running for several years. Using parental questionnaires we will examine the relationship between parental maths values and the time given to numeracy-related activities undertaken at home. Parents will also be asked to complete a maths anxiety questionnaire. Information about children's maths abilities on school entry will be obtained from teachers, and parents will be asked to complete a questionnaire about their children's ordering ability. Path analysis will be used to explore the relationship between variables. We hypothesise that types of activities undertaken will confirm the findings of previous research, but that maths anxiety levels will be lower amongst Asian parents. We predict that the types of activities carried out in Chinese homes will more closely mirror teaching styles in the Chinese school than those in Irish homes and schools, and as such, will provide new insights into the intriguing question of cross-cultural differences in maths.

(P) P2.42: Modality preferred network in visual and auditory magnitude processing predict arithmetic performance
Presenter: Hui Zhao
Authors: Hui Zhao, Jianing Lu, Hailian Hu, Jiaxin Yang

Magnitude processing was considered the basis underlying math ability. The visual and auditory inputs are two major modality to learn the semantics of numeric symbol. Whether there is individual difference in the modality preference of learning and whether those possible individual preference would affect the learning and its neural correlates are remained unclear. The current study try to address the question by investigate the brain network during visual and auditory number comparison task and their correlation with arithmetic performance.

Subject: 28 (16male) primary school students participated the study, mean age 9.0 yrs (7.8-10.5). Written informed consent was obtained from all participants.Participants were asked to compare the magnitude of numbers either visually or auditorily presented. Participants also performed timed Addition, subtraction, multiplication and division tasks within 1 minute for each.

● Approach for statistical analysis

1. By parametric analysis, we would find the brain regions sensitive to magnitude distance in visual and auditory number comparison tasks.

2. Taking the distance sensitive region in IPS as seed, we are going to reveal the functional network of visual and auditory comparison task with gPPI analysis, and compare the networks of the two conditions.
3. 3.In order to look into the relationship of network involved in visual and auditory task with arithmetic performance, we would correlate the singnal changes across timeseries in two fMRI tasks with arithmetic performance. Machine learning approach would be taken to confirm the prediction of modality preference to arithmetic performance.

We assumed that there is individual difference and brain network difference between visual and auditory number comparison. The individual difference of brain network in visual and auditory task would predict arithmetic performance.

P2.43: Cross-linguistic effects on adults' number line estimation skills
Presenter: Iro Xenidou-Dervou

Authors: Iro Xenidou-Dervou, Camilla Gilmore, Julia Bahnmueller, Lieven Verschaffel, Koen Luwel, Jessica Heenman, Ernest C. D. M. van Lieshout

Cross-linguistic research with children has demonstrated that language – specifically, the way numbers are named – can influence the way we process numbers. In languages such as Dutch or German, two-digit numbers above twenty are reversed: The unit is named first, followed by the decade (e.g., 92 is in Dutch "tweeënnegentig" or <two and ninety>). This is known as the "inversion property" and it has been shown to negatively affect children's numeracy and overload their Working Memory (WM). The present study's aim was to examine the effect of number naming in adults' number line processing.

We conducted an eye-tracking experiment with Dutch- (n = 40) and English-speaking adults (n = 28) asking them to estimate the position of two-digit numbers on a 0-100 number line under the following conditions: 1) Oral - Normal (e.g. the Dutch heard "tweeënnegentig", the English "ninety-two"), 2) Oral – Artificial (e.g. Dutch heard "negentig en twee", English "two and ninety"), 3) Symbolic (target in Arabic notation), and 4) Nonsymbolic (dots). These conditions were presented with and without extra WM load. We also included a condition where the normal number-names were presented in a slow-motion manner (Oral – Delayed) to capture snap-shots of the cognitive steps.

We found the expected inversion effects in the Oral-Delayed condition: Dutch adults' estimation speed was negatively affected, and they demonstrated mistaken fixations on the inverted number area (e.g., looking at 29 instead of 92). However, the language groups did not differ in the Oral-Normal condition. Contrary to the English, the Dutch were as accurate in the unfamiliar Artificial condition as in the very familiar Normal condition. Both groups' performance dropped with WM load. Even though we intuitively expect that number names are fully automatised by adulthood, our findings suggest that language and WM can affect basic number line processing even in adulthood.

P2.44: The Ratio Processing System Supports Non-Symbolic Ratio Arithmetic
Presenter: Isabella Starling Alves
Authors: Isabella Starling Alves, Edward Hubbard

We have previously suggested that fractions knowledge builds on a basic ability to perceive non-symbolic ratios — the ratio processing system (RPS) — that supports non-symbolic ratio comparisons. However, it remains unclear whether the RPS also supports non-symbolic ratio arithmetic. To test this question, we conducted a series of experiments investigating non-symbolic ratio arithmetic (additions and subtractions). In Experiment 1, 34 undergraduates (20.12 +/- 1.29 y.o.) were presented with a non-symbolic ratio, then a second non-symbolic ratio yielding a non-symbolic ratio addition or subtraction, followed by five answer choices. Participants selected the correct result most often, and nearby ratios less frequently, with classical distance effects for both tasks. These findings suggest that the RPS can perform non-symbolic arithmetic. However, it is possible that participants were converting the nonsymbolic ratio to the symbolic notation, and performing exact arithmetic. To rule out this possibility, we replicated Experiment 1 with added time pressure. In Experiment 2, 26 undergraduates (20.17 +/- 0.40 y.o.) performed the same task as Experiment 1, but time pressure was added by presenting the operands for only 1.3s each. Distance effects were again observed, but performance was less accurate than Experiment 1. In Experiment 3, 24 undergraduates (19.79 +/- 1.10 y.o.) performed the same task as Experiment 1, but time pressure was increased by presenting the operands for only 1.3s and the response alternatives for a maximum of 2s. Distance effects were again observed but the distribution was flatter than in Experiments 1 and 2. Finally, Experiment 4 tested whether adults who have limited formal instruction with fractions could also perform non-symbolic ratio arithmetic. 22 semi-illiterate Brazilian adults completed the same tasks as in Experiment 1. They showed classic distance effects closely mirroring the findings of Experiment 1. These experiments provide evidence that the RPS performs non-symbolic arithmetic.

P2.45: Fractions, Decimals, Percentages: Rational Numbers In Cognitive Arithmetic
Presenter: Jacob Bornheimer
Authors: Jacob Bornheimer

Although the cognition of integers has been frequently studied, the same cannot be said for the cognition of proportions. Accordingly, we studied mixed rational-whole multiplication to extend current models of arithmetic. We hypothesized that different formats of proportions (fractions, decimals, percentages) will be processed differently.

Participants solved problems of the form ‘x of y’ where x is a proportion and y is a multi-digit whole number. In Experiment 1, participants (n = 9) described their strategy use. Nine different strategies were described and each participant described a minimum of five different strategies. In Experiment 2, participants (n = 36) solved problems in each of three formats: fractions, decimals, and percentages; latency, error data, and eye-movements were recorded. Participants also described their solution strategies.

Rational number format did not significantly affect response time or errors, but increasing the size of the operands did. Interestingly, the problem size effect was different across formats. Different strategies were used depending on presentation format. The results suggest that format may be an indirect factor, alongside appropriate strategy selection. Future work should focus on replicating these results, gaining better understanding of procedures for proportional problem solving, as well as investigating alternative means of studying proportion, such as estimation.

Keywords: proportional arithmetic, rational numbers, mixed rational-whole multiplication, fractions, decimals, percentages

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P2.46: Monotonic responses to numerosity in early visual cortex are eccentricity dependent
Presenter: Jacob Paul
Authors: Jacob Paul, Tuomas ten Cate, Ben Harvey

Humans and many animals have neurons tuned to specific numerosities. These neurons respond selectively, decreasing their response amplitude with distance from their preferred numerosity. It remains unclear how such tuned responses are derived from visual images. Computational models suggest an initial monotonic stage where response amplitude increases with numerosity. Here we utilize ultra-high-field (7T) fMRI and population receptive field (pRF) modeling to characterize the location and nature of these responses. We acquired data from five subjects (all male, aged 25-39 years, one left-handed). Visual stimuli were black circles whose numerosity changed between one and seven, with 20 as a baseline. Different stimulus configurations were used to account for relationships between numerosity and luminance, edge density and item size. Subjects maintained attention by indicating when white circles were shown instead of black (10% of trials). We estimated a GLM model that increased response amplitude proportionally to log(numerosity). A standard drifting bar procedure identified visual field map borders, and pRF modeling quantified the visual field position preference of each voxel. The monotonic response model closely matched responses in early visual areas (V1-V4), progressively decreasing into extrastriate cortex. Model fit depended critically on each voxel’s visual field position preference. Responses were also affected by stimulus configuration; arrays featuring different dot sizes or a smaller, more densely filled area were less well described by a monotonic response. However, numerosity explains responses better than other covarying low-level stimulus features. Our findings indicate monotonic responses to numerosity are are already established by V1 and inherited by subsequent processing stages. Critically, these monotonic responses depend on the eccentricity preference of each voxel. These results suggest canonical neural computations in early visual cortex (such as divisive normalization or surround-suppression) could provide a simple, biologically plausible mechanism linking low-level response properties of early visual cortex with higher-level numerosity perception.

P2.47: Fraction Card Games for Connecting Area Models and Symbols
Presenter: Jacob R. Butts
Authors: Jacob R. Butts, Michelle A. Hurst, Susan C. Levine

When learning about proportion, children often encounter non-symbolic area models depicting part-whole information (e.g., partially-filled rectangles). When these models are divided into discrete units and children are asked to make proportional judgments, they often use erroneous whole-number strategies (Boyer et al., 2008). However, practice thinking about proportion with models that are not divided can help prevent these errors on subsequent divided models (Hurst & Cordes, 2019). It remains unclear how these undivided and divided models impact symbolic fraction learning. Here, we propose an experiment investigating this question, which can have both theoretical and educational implications about how children approach and learn from different fraction representations.

Children (N=195) play a card game (modeled after “War”), where they compare two symbolic fractions by creating corresponding non-symbolic area models. Children are randomly assigned to conditions that vary only in the model's presentation: (1) Discrete: the models are pre-divided into units (the denominator) and the child is told how many to color, (2) Continuous: the models are not subdivided into units, but instead the experimenter shows the child how much to color for each fraction, (3) Continuous-to-Discrete: the experimenter divides the models into units in front of the child and tells the child how many to color. Children are tested at pre- and post-test using a battery of tasks testing symbolic fractions, non-symbolic fractions, and symbolic-to-non-symbolic mapping.

We will use regressions with pre-test score (covariate), grade (between-subject), and condition (dummy coded between-subject) predicting accuracy on post-test measures. We hypothesize: (1) children in the Continuous-to-Discrete condition will outperform children in the Continuous condition on symbolic-to-non-symbolic mapping, (2) children in the Continuous-to-Discrete condition will outperform both other conditions on symbolic tasks, and (3) children in the Continuous and Continuous-to-Discrete conditions will outperform children in the Discrete condition on non-symbolic tasks.

P2.48: Maternal Gender Biases in Early Exposure to Mathematics

Presenter: Jamie Patronick
Authors: Jamie Patronick, Leanne Elliott, Melissa Libertus

Gender differences in achievement, confidence, and interest in mathematics have been documented as early as the spring of kindergarten. Previous studies found that parents' stereotype-aligning attitudes about math are related to the amount of math-related learning opportunities children receive (LeFevre et al., 2009) and that preschool-aged boys receive significantly more number-specific input from their mothers than girls (Chang, Sandhofer & Brown, 2011). The goal of the current study was to measure whether mothers' attitudes about the importance of math differ based on their child's gender and further analyze gender differences in the amount of maternal math talk. Mothers (N=134) completed questionnaires about the importance of math and literacy and participated in a 10-minute free-play session with their 4-year-old children (67 girls). Children also completed the Test of Early Mathematics Ability-Third Edition (TEMA-3; Ginsburg & Baroody, 2003), a standardized math assessment for children between 3 and 8 years of age. Free-play sessions were transcribed and coded for math-related speech, including talk about number, quantity, and spatial relations. We found a significant interaction between mothers' ratings of the importance of math vs literacy and children's gender, ($F(1, 132) = 5.98$, $p = .016$, which was due to lower importance ratings of math compared to literacy for mothers of girls. Additionally, mothers of girls used fewer words to describe shapes ($p=.05$). Girls and boys did not differ significantly on the TEMA-3 ($p=.60$). These findings suggest that there are differences in how mothers of girls and boys rate the importance of math and some differences in the amount of math-related talk mothers use with their girls and boys at this age, even though differences in math ability have not yet emerged.

P2.49: Algebraic vs. arithmetic conceptions of 'x' when solving missing-operand problems.

Presenter: Jeffrey Bye
Authors: Jeffrey Bye, Rina Harsch, Sashank Varma

Understanding the concept of variable is fundamental to algebraic thinking and higher-level mathematics such as calculus. Algebraic representations like the variable 'x' are typically introduced in the context of linear equations in one variable ('missing-operand' problems, e.g., $x + 3 = 5$). Students can solve these equations via bottom-up pattern-matching (the arithmetic strategy) by retrieving the corresponding arithmetic fact (e.g., $2 + 3 = 5$), or via top-down symbol-manipulation (the algebraic strategy) by applying procedures to 'isolate' the variable by 'moving' constants (e.g., subtracting 3 from both sides), which ultimately requires retrieving a different fact (e.g., $5 – 3 = 2$). In order for students to succeed in algebra and beyond, they must be able to flexibly choose between multiple strategies. Prior research has revealed how people retrieve arithmetic facts, understand equality and missing operands, and apply algebraic rules to solve for x. Our ongoing study is novel in focusing on how flexibly people move between the arithmetic and algebraic strategies. Undergraduates first complete an arithmetic task to measure the speed with which they retrieve facts like $2 + 3 = 5$ and $5 – 3 = 2$. They then complete blocks of missing-operand problems like $x + 3 = 5$. These are interleaved with blocks of a priming task manipulated between-subjects, with half containing multistep arithmetic problems (e.g., $-10/[4 – 2]$), and half containing operationally-equivalent algebraic problems (e.g., $4x = 2x – 10$). We 'decode' which strategy a participant chooses by whether their speed on each missing-operand problem is better predicted by their speed on retrieving the fact corresponding to the arithmetic vs. algebraic strategy. We predict that the priming task will shift the strategy participants choose, and secondarily that independent of priming, participants with higher mathematical achievement will be more likely to choose the bottom-up arithmetic strategy.

P2.50: Experience with a dynamic algebra notation system predicts high-school students' algebra performance.

Presenter: Jenny Yun-Chen Chan
Authors: Jenny Yun-Chen Chan, Taylyn Hulse, Katharine Sawrey, Erin Ottmar

Algebra is a foundation for higher mathematics, yet many students struggle with algebra notation (National Research Council, 2001). The abstract and symbolic nature of algebra contributes to the difficulty students encounter during learning (Kieran, 1992). Students can explore algebraic symbols as tangible objects using Graspable Math (GM), a web-based tool that allows students to dynamically transform expressions from one state to another (e.g., from 2x+3+5x-4 to 7x-1). GM completes mathematically valid transformations (e.g., combining 2x and 5x) and provides error feedback by preventing mathematically invalid transformations (e.g., combining 3 and 5x). Experience with GM is associated with better algebra performance in middle-school students (Ottmar et al., 2015), however, it is unclear which aspects of students' behavior within GM are related to their algebra performance. Using a pretest-intervention-posttest paradigm, we assessed 38 ninth-graders on algebra performance at pretest, provided three 20-minute sessions on transforming expressions in GM, and assessed students' algebra performance at posttest. Within GM, we recorded the average duration, attempted errors (i.e., invalid transformation), and number of actions taken per problem. A linear regression model revealed that, as anticipated, students' pretest score predicted their posttest score (β=.40). Next, three regression models were conducted to explore whether (1) problem duration, (2) error rate, or (3) the number of actions independently predicts posttest scores beyond pretest scores. The first model revealed that duration, but not pretest score, predicted students' posttest score (β=-.33). Similarly, error rate, but not pretest score, predicted posttest score (β=-.37). The third model revealed that pretest score, but not the number of actions, predicted students' posttest score (β=.32). The findings suggest that aspects of behavior in GM may be differentially related to students' algebraic skills. Furthermore, students' experience with GM may have unique influences on their algebraic skills and these influences may be independent of their prior knowledge.

P2.51: Word Problems: How Performance Varies with ADHD Traits and Math Anxiety
Presenter: Jesse Nietmann
Authors: Jesse Nietmann, Sabrina Di Lonardo, Jo-Anne LeFevre

ADHD and math anxiety have both been linked to math difficulties in children and adults. However, few studies have looked at how math performance is affected in individuals with both conditions. In the present research, we examined the relationship between ADHD traits, math anxiety, and word problem-solving in adults. Undergraduates (N = 359) completed an online survey that included measures of ADHD symptomology (i.e., Adult ADHD Symptom Rating Scale) and math anxiety (i.e., Abbreviated Math Anxiety Scale). Participants also completed 48 multiplication and division word problems. In addition to completing the mathematics portion of each word problem, participants were given a multiple-choice comprehension question about the situation presented in the problem. Participants who reported more ADHD traits were more likely to report higher math anxiety. With respect to word problem comprehension, individuals who reported more ADHD traits and those who reported higher math anxiety had lower performance on the comprehension measure. In contrast, only individuals who reported higher math anxiety had lower performance on the math portion of the word problems. These results suggest that the relations between ADHD traits, math anxiety, and math performance are complex. While only math anxiety influenced multiplication and division performance, both ADHD traits and math anxiety negatively affected comprehension of the word problem. In life, problems will arise that require both situational comprehension and mathematical knowledge (e.g., student loans, vacation planning, home renovations). Thus, it is important to understand how ADHD traits and math anxiety may interfere with our ability to successfully address these situations. The present findings warrant further investigation into the cognitive mechanisms underlying ADHD and math anxiety.

P2.52: Rote versus Rule: Revisiting the Role of Language in Mathematical Thinking
Presenter: Jike Qin
Authors: Jike Qin, John Opfer

Language is often depicted as the sine qua non of mathematical thinking, a view buttressed by findings of language-of-training effects among bilinguals. These findings, however, have been limited to studies of arithmetic. Nothing is known about the potential influence of language on the ability to learn rules about the relations among variables (e.g., algebra). To test whether arithmetic and algebraic thinking differ, three studies has been done. In Study 1 and 2, Chinese-English bilinguals were trained to solve arithmetic and algebra problems in either Chinese or English and then tested on new and old problems in both languages. For arithmetic problems, solution times were always longer for English than Chinese; in both languages, solution times dropped during training; after training, solution times continued to drop for old problems, but returned to pre-training levels for new problems. In contrast, for algebra problems, solution times did not differ across language; solution times dropped during training; after training, gains in speed were preserved for both old and new problems. In Study 3, English monolinguals were trained solve arithmetic and algebra problems in either Chinese or English and then tested on new and old problems in both languages. Over the 3-day sessions, they learned to solve algebra problems in Chinese but never learned to solve arithmetic problems in Chinese. These findings suggest that the contribution of language to mathematical thinking may be limited to the areas of mathematics that are learned by rote and not by rule.

P2.53: An investigation into children's mathematics attitudes and their arithmetic fluency: How do teachers and parents play a role in their development?
Presenter: Jill Price
Authors: Jill Price, Katherine Robinson

The acquisition of mathematics skills in elementary school has an important role in future academic and professional success. These skills depend not only on cognitive abilities but also on emotional factors. Mathematics anxiety (MA) is defined as feelings of tension that "interfere with the manipulation of numbers and the solving of mathematics problems in a wide variety of ordinary life and academic situations" (Richardson & Suinn, 1972). Once formed, MA is difficult to change and can persist well into adulthood. This is concerning as MA is negatively correlated with math performance (MP). Aside from MA, little research explores the impact of mathematics attitudes on arithmetic fluency; especially in elementary school children. To fill this gap, the current study investigated the role of Grades 2, 4, and 6 children's MA as well as gender equality, confidence, motivation, and perceived usefulness of mathematics in their arithmetic fluency. The current study also examined the role that teachers and parents play in the development of children's mathematics attitudes and arithmetic fluency. Lastly, the current study uniquely explored three emotion regulation interventions (i.e., relaxation breathing, expressive drawing, and cognitive reappraisal) and their ability to improve children's mathematics attitudes and arithmetic fluency. Results showed children with higher MA had lower arithmetic fluency compared to children with lower MA. However, children's MA was not the only mathematics attitude to impact their MP. Children with higher gender equality, confidence, motivation, and perceived usefulness of mathematics also had higher arithmetic fluency compared to children with lower gender equality, confidence, motivation, and perceived usefulness of mathematics. Results also showed that teachers' MA was related to their students' arithmetic fluency but not their students' MA while parents' MA was related to their children's MA but not their children's arithmetic fluency. Lastly, short-term emotion regulation interventions were not effective at improving children's mathematics attitudes or arithmetic fluency. Children in the relaxation breathing, expressive drawing, and cognitive reappraisal conditions did not have lower MA or higher arithmetic fluency compared to children in the control condition. Overall, studying children's mathematics attitudes is important because deficits with MP in elementary school can have long-term implications for both learning and cognitive development.

P2.54: Cross-Language Differences in Remembering and Identifying Fractions
Presenter: Jimin Park
Authors: Jimin Park, Soo-hyun Im, Sashank Varma

Languages name fractions differently, and this may cause their speakers to understand and process them differently. In English, the numerator is named before the denominator, e.g., 3/7 is named "three sevenths", whereas in Korean, the opposite is true, e.g. 3/7 is named as "chil(7) bun ul sam(3)" which translates as "of seven parts, three". Building on prior studies (e.g., Paik & Mix, 2003), the current study tested the hypothesis that English and Korean speakers prioritize the fraction component that their language names first. It used two novel tasks. In the fraction span task, participants viewed and recalled sequences of four fractions. In one condition, the denominator of the previous fraction was the same as the numerator of the next fraction (e.g., 5/2, 2/9, 9/4, 4/7), whereas in the other condition, the opposite was true (e.g., 4/7, 9/4, 2/9, 5/2). As predicted, there was a crossover interaction, with English speakers making fewer errors in the first condition and Korean speakers fewer in the second. In the fraction identification task, participants saw a fraction, a blank screen for 1 second, and another fraction, and judged whether the two fractions were the same or different. The prediction was that English speakers would respond faster when the fractions differed in their numerators and Korean speakers would respond faster when the fractions differed in their denominators. This prediction was not supported: there was no crossover interaction. The findings from these two tasks suggest that cross-language differences in fraction processing may be present only when people must verbally code fractions to perform the task. A follow-up experiment is testing this hypothesis. Specifically, it includes a version of the fraction identification task that parametrically increases the delay between the two fractions. The expectation is that the predicted crossover interaction will emerge only at longer delays.

P2.55: The Effects of Technology on Problems-solving Skills for Low-achieving Students
Presenter: Jiyeon Park
Authors: Jiyeon Park,

Technology has shown the positive effects on students' learning in mathematics because it could provide (a) adapted and individualized learning, (b) immediate corrective feedback, (c) systematically sequenced curricula, and (d) virtual manipulatives (Swanson, Orosco, & Lussier, 2014). However, the evidence regarding technology is still being gathered, and research findings have not always shown positive outcomes for the application of technology in mathematical problem solving for low-achieving students (Kroesbergen & Van Luit, 2003). These mixed research outcomes call for more investigation on the impact of technology on problem-solving. The purpose of this study is to systematically review the available literature that has examined interventions using technology on problem-solving for low-achieving students. The following questions guided the study: (a) To what extent do technology-based interventions contribute to the performance of low-achieving students in their problem-solving? (b) What features of technology affects problem-solving skills?

Initially, 405 studies were identified using a keyword search, and 13 articles were finally selected using predetermined criteria including ten group-design studies and three single- case design studies. The results showed overall effectiveness of technology-based interventions, with an average effect size of 0.61 in group-design studies and 92 % of non-overlapping data (PND) in single-case design studies. Also, the technology-mediated approach was more beneficial on elementary students rather than secondary learners. The more time the intervention was delivered, the more improvement students showed. The interventions program developer (e.g., commercial product, researcher-developed program) does not make any significant differences, but the condition of comparison groups was a significant factor. Computer interventions were more effective when compared to business-as-usual or no-treatment groups, but the experimental groups did not perform higher than the comparison groups receiving alternative treatments. Also, no single instructional features (e.g., cognitive/metacognitive strategies, individualization, interaction, visualization, and motivational incentives) of computer programs were found to be significantly effective.

(P) P2.56: Effects of transcranial electrical stimulation on arithmetic learning and neural plasticity
Presenter: Jochen A. Mosbacher
Authors: Jochen A. Mosbacher, Stefan Halverscheid, Kolja Pustelnik, Roland H. Grabner

Arithmetic abilities are among the most important school-taught skills and lay the basis for higher mathematical competencies. However, for many students, their acquisition and application is challenging. Hence, interest in methods supporting arithmetic learning is growing. One method to foster learning is transcranial electrical stimulation (tES), in which small electric currents are applied to the brain during learning. Earlier, we compared the effects of different tES protocols on arithmetic learning in order to find the best protocol to support the acquisition of new procedural (procedural-tES) and fact knowledge (fact-tES). This upcoming study will further elucidate the potential of these tES protocols to enhance arithmetic learning in a multi-session training and investigate the accompanying structural and functional changes in the brain.

Over the course of 6 sessions, two groups of participants will practice novel arithmetic procedures (sessions 1-6) and build up knowledge about new arithmetic facts (sessions 4-6). The first session (accompanied by MRI) will serve as baseline. In the following sessions, one group (N=25) will receive procedural-tES during sessions 2-3 and fact-tES during sessions 4-6, the other group (N=25) will receive sham stimulation. One day as well as six months after the training, post-tests will take place. These include procedural and fact problems and will again be accompanied by MRI.

The effects of tES on learning processes will be analyzed by mixed-design ANOVAs with the factors group (active tES vs. sham) and session (training sessions plus post-tests) on accuracies and response latencies, separately for procedural and fact problems. MRI data will be analyzed using SPM12 and compared between baseline and post-test assessments to investigate tES related functional and structural changes.

P2.57: Confidence counts: Relationships between math dispositions and fractions knowledge.
Presenter: John Binzak
Authors: John Binzak, Percival Matthews, Edward Hubbard

Learning about fractions involves a development of cognitive abilities and affective dispositions, which frame how individuals engage with the content. Therefore, it is important to understand how affective dispositions toward math content relate to individual differences in fraction knowledge. Previous studies have examined how affect relates to math performance and achievement broadly. Here we tested how positive and negative affective constructs relate to performance on various fractions tasks.

Forty undergraduates completed a battery of fractions tasks and a questionnaire assessing their disposition toward mathematics. The survey measured how strongly participants identified with statements describing their interest, confidence, perceived utility, and attainment value for math broadly and fractions specifically. The survey also included measures of self-reported math anxiety during learning and evaluation contexts. Fractions knowledge was assessed using number line estimation (NLE), a paper-and-pencil fractions knowledge assessment (FKA), and fractions magnitude comparison tasks with symbolic, nonsymbolic, and mixed pair conditions. We then tested whether individual differences in math dispositions predicted variability in performance on the three tasks.

Interest, confidence, and math anxiety in learning contexts showed significant zero-order correlations with FKA performance, but measures of utility value, attainment value, and math evaluation anxiety were not related to FKA performance. Regression analysis confirmed a positive relationship between confidence and FKA scores but math interest and learning anxiety were no longer related to FKA scores when controlling for differences in confidence. Confidence in fractions specifically, but not in math broadly, was significantly related to better number line estimations. No significant relationships were observed between math dispositions and magnitude comparison performance; however, this may be partially explained by a ceiling effect on the task. The development of affective dispositions towards math and how they relate to fractions ability should be examined further in younger populations though longitudinal and training intervention studies.

P2.58: Effects of combined attention and math interventions in at-risk pre-kindergarten children are moderated by working memory

Presenter: Marcia Barnes
Authors: Marcia Barnes, Alice Klein, Greg Roberts, Anna-Mari Fall, Bruce McCandliss

Math difficulties often co-occur with weaknesses in cognitive abilities that are important for learning. Interventions that address both cognitive and math difficulties might increase response to intervention for children with or at risk for math learning disabilities (MLD). We report on a study of pre-kindergarten children at risk for MLD that tested for whom combined cognitive and math interventions might be most effective.

518 4-5 year old children at high risk for MLD were randomized to one of three conditions: 1) an intensive 24-week math intervention (4 days per week/15 minutes per session) combined with a low dose of adaptive computerized training in vigilance and executive attention (16 8-minute sessions 1 day per week); 2) the same math intervention without attention training; or 3) a business as usual control. Math outcomes were the Child Math Assessment and the TEMA-3. Moderator variables were ANS acuity, visual-spatial working memory (WM), phonological awareness and nonverbal IQ.

As reported elsewhere (Barnes et al., 2016), there was no added value of the combined intervention for math. The novel findings in the current report have to do with moderation of intervention effects. Each moderator variable was tested controlling for all other moderators. The combined intervention produced a significant positive effect on the TEMA-3 for children with low WM compared to children with similarly low WM in the other groups.

Specific intervention components –those that are mathematical (e.g., Fuchs et al., 2014) and those that are cognitive as in this study –may support learning in children with MLD with low cognitive resources. Findings are discussed with reference to the role of general cognitive skills in mathematical learning and performance. We also discuss how experimental studies might be designed to further investigate the effects of combined cognitive and academic interventions for children with MLD.

P2.59: Gain Scenarios Promote Attention to Number, Instead of Proportion, During Proportional Reasoning Tasks

Presenter: Karina Hamamouche
Authors: Karina Hamamouche, Sara Cordes

Children prioritize numerical information over relational information in proportion tasks. This whole number bias results in children indicating that a spinner with 2/3 red pieces is less likely to land on red than a spinner with 4/10 red pieces, because 4 pieces are more than 2. Decision-making research, however, shows adults prioritize proportional information, in gain scenarios (Bartels, 2006). We investigated whether gain versus loss framing may differentially impact children's attention to number in a proportional reasoning task.

Four- to nine-year olds ($n = 168$, $M_{age} = 6.11$) judged which of two spinners was most likely to land on red. Children learned if the spinner landed on red they would win a sticker and if it landed on blue, nothing would happen (gain condition) or if the spinner landed on red, nothing would happen, but if it landed on blue, they would lose a sticker (loss condition). We manipulated whether the relative number of red pieces in each spinner was consistent with proportional information (more red pieces in the spinner in proportionally greater spinner) or misleading (fewer red pieces in proportionally greater spinner). Results replicated previous findings that children relied on numerical information at the expense of proportion, (consistent: $M = 72.6\%$; misleading: $M = 58.8\%$; $t(167) = 4.506$, $p < .001$). Although there were no significant condition differences when judging continuous spinners, $t(166) = .201$, $p = .84$, analyses revealed a marginal Condition x Numerical information interaction ($F(1, 164) = 3.52$, $p = .06$), such that children in both age groups showed a greater reliance upon number in the Gain condition than the Loss condition. In contrast to research with adults, our findings reveal that gain framing may promote attention to number or alternatively, loss framing may heighten attention to the most relevant feature of the task – namely proportion.

P2.60: Understanding of arithmetic concepts: Does problem format matter?
Presenter: Katherine M Robinson
Authors: Katherine M Robinson

Conceptual understanding of arithmetic is critical in the development of arithmetic knowledge and skills (NMAP, 2008). This understanding can take years to develop and understanding varies across concepts. A growing number of studies have investigated conceptual understanding but most studies tend to examine one or a small number of concepts at a time (Robinson, Price, and Demyen, 2018). In some studies, children understand arithmetic concepts even before formal schooling while in other studies, even after several years of schooling, children still struggle. For example, Klein and Bisanz (2000) found that 4-year-olds demonstrated understanding of the arithmetic concept (the answer to a + b – b problems is always a as the the b terms are both added and subtracted) on 41% of problems. Robinson, Dubé, and Beatch (2017) found that Grade 3 to 5 students (9- to 11-year olds) demonstrated understanding of inversion on 41% of the problems as well. This lack of developmental change may reflect problem format as the first study used concrete problems (XX + XXX – XXX) while the latter used symbolic problems (2 + 3 – 3). Sherman and Bisanz (2009) found that children demonstrate conceptual understanding that is 2 to 3 times greater when problems are in concrete versus symbolic format. In the current study, 38 Grade 1, 30 Grade 2, and 30 Grade 3 students solved both symbolic and concrete problems assessing six arithmetic concepts. Overall understanding of the six concepts was greater on the concrete (57%) than the symbolic (38%) problems. However, on identity (e.g., 4 – 0) and negation (e.g., 4 – 4) problems, understanding did not differ across problem format. On inversion, associativity (e.g., 2 + 4 – 3), commutativity (e.g., 2 + 4 = 4 + ?), and equivalence (e.g., 2 + 4 + 3 = 2 + ?) problems, understanding was more than double on concrete versus symbolic problems. Conceptual understanding increased across development, particularly between Grades 1 and 2, and understanding on symbolic problems increased at a faster rate across development than on concrete problems. These results, overall, support and extend the findings of Sherman and Bisanz and also highlight that results and conclusions about children's understanding of arithmetic concepts are highly dependent on which concepts are being assessed.

P2.61: Exploring Differential Relations Between Spatial Abilities and Domains of Mathematics in Grade 2
Presenter: Katherine Winters
Authors: Katherine Winters, Michelle Drefs, Maria Ramirez

The past decade has seen increased emphasis on spatial ability within math education and growing research interest, fuelled by findings highlighting the importance of spatial ability for success in STEM careers and evidence suggesting that spatial abilities are malleable. Previous studies suggest that while there is significant overlap in their underlying processes, spatial ability and math are dissociable. Less attention has been given to investigating the relationships between subcomponents of spatial ability and performance in domains of mathematics, which is needed to translate research into meaningful educational applications.

The current study offers a first step in addressing this gap by recognizing spatial ability and mathematics as multi-componential and exploring whether object-based (visualization and mental rotation) and environment-based (perspective taking) spatial abilities differentially predict domains of mathematics (i.e., arithmetic, measurement, geometry, and word problem solving).

This cross-sectional, correlational study uses latent variables to measure three components of spatial ability and explores the unique variance explained in the math outcomes, after taking into account visual-spatial working memory (VSWM) and inhibitory control. As well, given mounting evidence suggesting that the spatial-math connection can be attributed, at least in part, to domain-specific skills, number line estimation is included as a potential mediator.Participants will include approximately 140 children (7-8 years) enrolled in grade 2 in Calgary, Alberta. Data collection begins in February 2019 and runs until June.

Planned Analyses: A series of multiple regression analyses will measure the direct and indirect effects of spatial abilities, VSWM, inhibitory control, and number line estimation on the math outcomes, controlling for age and gender. Path coefficients will be calculated using overlapping regression equations and a modified causal steps approach, followed by the Preacher and Hayes bootstrapping technique, will assess mediation significance. Secondary analyses will explore differential effects.

P2.62: Does the relationship between visual spatial skills and mathematical ability persist or change during primary school?
Presenter: Laura Outhwaite
Authors: Laura Outhwaite

Previous research shows visual-spatial skills are a robust predictor of mathematical achievement (Costa et al., 2018). In a longitudinal sample of 12,099 children aged 5-7 years, visual-spatial ability significantly accounted for over 15% of the variance in concurrent and later mathematical achievement (Gilligan et al., 2017). Cross-sectional research with 316 children found this visual-spatial mathematical relationship was concurrently stable between 4-11 years (Hawes et al., 2019). The current study aims to replicate and extend these findings by examining whether the visual-spatial mathematical relationship observed at the start of school (Gilligan et al., 2017) persists or changes at school completion in the same population sample. This has implications for the design of age-specific mathematical interventions. Based on current evidence, this study predicts visual-spatial skills, measured at age 5 and 7 will longitudinally predict mathematical achievement at age 11.

Data from the National Pupil Database (NPD), which includes mathematical SATs outcomes, a national standardised assessment at age 11, will be matched to cognitive data from wave 3 (age 5) and wave 4 (age 7) of the Millennium Cohort Study (MCS). The MCS is a longitudinal population-based study of children born in the UK between 2000 and 2002. The Pattern Construction subscale of the BAS-II will measure visual-spatial ability. Control variables will include, prior mathematical ability, language subscales from BAS-II, SES, ethnicity, gender, and age.

Correlation analyses will identify associations between variables and inform the subsequent general linear regression models. The regression models will examine visual-spatial skills measured at 5 and 7 as a predictor of mathematical achievement at age 11 accounting for the control variables. MCS weighted scores, to account for the stratified, clustered design, attrition, and non-response will be used. This statistical approach is consistent with Gilligan et al. (2017), affording meaningful comparison between the two studies.

P2.63: Cognitive Markers of High and Low Mathematical Performance in Preschool Children
Presenter: Merel Bakker
Authors: Merel Bakker, Joke Torbeyns, Lieven Verschaffel, Bert De Smedt

Several studies have examined the contribution of cognitive factors to the acquisition of mathematical abilities. This study aimed to characterize preschoolers who have difficulty with early mathematical abilities and preschoolers who excel in early mathematical abilities in terms of such cognitive markers. Three mathematical ability groups (low, average, high) were created based on their persistent total score on a mathematical test battery spanning two years of preschool. Our main goal was to characterize these groups in terms of (a) their domain-specific mathematical abilities and (b) the following domain-general predictors: language ability, spatial ability, and verbal and non-verbal working memory.

Children were tested at three time points (T), i.e. the end of Kindergarten Year 2 (T1), at the beginning (T2) and end (T3) of Kindergarten Year 3. They completed eight mathematical tasks (i.e., verbal counting, nonverbal calculation, object counting, numeral recognition, number order, symbolic comparison, nonsymbolic comparison, dot enumeration) at T1 and T3, whereas at T2 they completed measures of language, spatial ability, and verbal and non-verbal working memory.

There were significant group differences for all tasks. In general, the low-achieving group performed significantly worse compared to average achievers, who in turn performed significantly lower than the high achievers. Logistic regression analyses showed that language ability and non-verbal working memory were the strongest predictors of group membership.

The present study provided a detailed characterization of high, average and low early mathematics achievers in terms of their domain-specific and domain-general cognitive abilities. The results show that we can already detect substantial and consistent individual differences across a range of mathematical as well as domain-general cognitive abilities before the start of formal mathematics education. Furthermore, our data indicate that the same cognitive factors are important predictors for whether children show low or high mathematical ability.

P2.64: Assessing the Influence of Task-Context on the Neural Coding of Quantities
Presenter: Michael Slipenkyj
Authors: Michael Slipenkyj, Ian Lyons, Daniel Ansari

A fundamental question in numerical cognition concerns the relation between symbolic and analog (non-symbolic) quantities. Recent research demonstrated that quantities represented in these two formats correspond to qualitatively different patterns of neural activity (e.g., Lyons & Beilock, 2018). However, a related question concerns whether neural processing of quantities is sensitive to computational context. To this end, we tested whether prior results obtained using a delayed match-to-sample (DMS) task generalized to a different task context emphasizing relative quantity – namely, a delayed magnitude-comparison (DMC) task. In the DMC task-context, only two brain regions showed a significant univariate effect of quantity (in contrast to 19 for the DMS task-context). Consistent with previous work with the DMS task-context, representational similarity analysis of neural activity patterns in the DMC task-context revealed no evidence for similar patterns of neural encoding between analog and symbolic quantities. Also consistent with previous work, analog DMC similarity patterns were well-predicted by numerical ratio, but those of symbolic quantities were not. In contrast to previous work, however, symbolic DMC patterns were not predicted by lexical frequency. To summarize, an overall, a lack of similarity between symbolic and analog formats appears to be a robust finding, indicating a persistent dissociation between the two formats. For analog quantities, though univariate results appeared to be sensitive to task-context, similarity-based results were consistent and independent of task context. Symbolic quantities, on the other hand, showed strong sensitivity to context regardless of analysis approach. Explanations for what may have influenced symbolic numbers sensitivity to context (sample size, task design, etc.) are discussed.

P2.65: Fraction reduction is cued by division but not by multiplication
Presenter: Shawn Tan
Authors: Shawn Tan, Jo-Anne LeFevre

When working with fractions, reducing a fraction such as 5/15 involves obtaining a common factor for both the numerator and the denominator, and dividing the numerator and denominator by the common factor to obtain a simple fraction 1/3. In the context of fraction multiplication and division, Reducing fractions is not necessary to solve a problem. Fraction multiplication requires participants to multiply numerators and denominators, while fraction division requires solvers to first invert the second fraction before multiplying the numerators and the denominators. Selecting and applying the reduction step is not required, yet reducing numerator-denominator pairs, has the benefit of making problems easier to perform basic arithmetic operations. In this study, we examine how often solvers reduce fractions when presented with fraction multiplication and division problems, and the characteristics of problems that might facilitate successful application of fraction reduction.

59 participants were asked to solve fraction arithmetic problems. Written protocols were collected to determine whether problems were reduced. If participants asked whether their solutions should be reduced, they were told that “it was up to them”. We report accuracy and frequencies of responses for same and different denominator fraction multiplication and division problems are reported

Accuracy was higher for different denominator multiplication problems than for division and same denominator multiplication problems. There were a greater proportion of correct reduced responses for division problems than multiplication problems. Conversely, there were a greater proportion of correct non-reduced responses for multiplication problems then division problems. This finding suggests that division problems cued the reduction step. The reduction step was cued less frequently for fraction multiplication problems even though all problems could be reduced.

Our results show that in fraction arithmetic, the required operation cues solvers to select and apply a step, even though this step is not necessary to generate the solution. We suggest that selection of this step appears to be linked to the cognitive resources required for performing the operation. Fraction multiplication can be solved by multiplying numerators and denominators to generate a correct response. Dividing fractions requires solvers to apply steps in a correct sequence. During fraction division, the second fraction is inverted, followed by multiplying numerators and denominators. Fraction reduction appears to have a role in reducing the cognitive load on memory resources for fraction division. This finding has implication for strategy selection in the domain of algebra, where solvers knowledge of selecting and applying the appropriate procedures can provide some insight into why adults have difficulty when working with algebra problems.

P2.66: Form perception predicts septinary addition achievement
Presenter: Shijia Fang
Authors: Shijia Fang, Xinlin Zhou,

Numerous studies have investigated the cognitive mechanism underlying arithmetic learning. However, the findings remain inconsistent. Several types of cognitive abilities were found to be significantly correlated with arithmetic learning, including digit magnitude processing, digit span, approximate number system (ANS) acuity, processing speed and verbal working memory. Previous studies have shown that the form perception can fully account for the significant association between ANS acuity and arithmetic fluency. The current study hypothesized that form perception is one of the critical factors to support arithmetic learning.

Forty undergraduate students (female: 20, mean age=20.42, SD=1.35) took part in a five-day septinary addition learning program. They learnt the septinary addition (e.g., 3+6=12) for 30 minutes per day. Before and after the learning, they were administered with general cognitive ability tests, including non-verbal matrix reasoning, numerosity comparison, mental rotation and figure matching.

After controlling for intelligence measured with non-verbal matric reasoning, the association between form perception and the septianry addition and the association between ANS acuity and the septinary addition both became closer with the times of learning. Only form perception and ANS acuity can finally predict septinary addition achievement. Moreover, the ANS acuity’s prediction can be accounted for by the form perception’s prediction.

The current study showed that form perception could independently predict septinary addition achievement. The result suggests that form perception could support arithmetic learning. This finding is not only an exploration of the cognitive mechanism of arithmetic learning, but also provides theoretical basis for mathematical education.

P2.67: Children's Math Abilities and the Relation to Risky Decision Making: A Study Proposal

Presenter: Shirley Duong
Authors: Shirley Duong, Melissa Libertus

Recent work suggests that number processing skills support adults' decision making under risk [e.g., 1]. Fuzzy-trace theory (FTT) posits that gist processing is the key to advantageous decision making [2], and higher math skills in adults predict better decision making if it relies on gist representations. What remains unknown is whether math abilities are a supporting mechanism of decision making in young children. The proposed study aims to examine: (1) the relation between children's math abilities, the ability to extract the gist from numerical information, and risky choice behavior; and (2) the mediating role of gist extraction in the relation between math skills and decision making. It is hypothesized that higher math abilities will predict better gist extraction and that gist extraction will mediate the relation between math skills and risky choice. Risk preferences and gist extraction will be assessed with the Cups Task [3], in which children evaluate risky and riskless options to obtain prizes. Math abilities will be measured with standardized assessments and tasks tapping into non-symbolic and symbolic number processing, counting, arithmetic, and probability comprehension. The proposed study will contribute to a better understanding of the oft-cited link between math abilities and life outcomes.

P3.68: Cross-notation symbolic number comparison with single- and double-digit numbers
Presenter: Irina Surducan
Authors: Irina Surducan, Camilla Gilmore, Iro Xenidou-Dervou

Numerical skills predict academic success and civic engagement, among many other aspects of life, and the ability to compare symbolic numbers is strongly related to numerical skills across the lifespan. When comparing numerical symbols, the numerical distance effect (NDE) is obtained – reaction times are slower for pairs of numbers that are numerically closer than for pairs of numbers that are further apart. Traditionally, the NDE is thought to reflect access to the magnitude representation of numerical symbols. Single-digit numbers presented in Arabic notation are compared faster and more accurately than number words and their corresponding distance effects are of equivalent strength, but less is known about how the magnitude of double-digit numbers is accessed in various notations. The current study examined whether number symbols activate magnitude representations in a notation- and size-dependent fashion. We specifically asked whether the size and notation of numbers affect the NDE. Fifty participants, aged 18.4 – 37.7 years, completed a pre-registered cross-notation number comparison experiment in which the size (single-digit or double-digit) and the notation (Arabic, number word or mixed) of the symbols were varied while keeping the comparison ratio constant between conditions. We showed that, for all notations, the size of the numbers affected the numerical distance effect: in all cases, it was stronger for single-digit numerals than for double-digit numerals. This suggests that, regardless of notation, access to the magnitude representation appears to be more efficient for single-digit numbers. We discuss the results in terms of the Triple Code Model of numerical cognition.

P3.69: Re-inverting inversion: Natural offloading in number transcoding?
Presenter: Julia Bahnmueller
Authors: Julia Bahnmueller, Selina Galefski, Korbinian Moeller, Hans-Christoph Nuerk, Christina Artemenko

Number word inversion (e.g., “42” in German is verbalized as “zweiundvierzig“, which literally translates to “two and forty”) is associated with worse performance in different numerical tasks including transcoding. Some children but also adults try to regain correspondence between the order of number words and Arabic digits by inverting the order in which they write down tens and units of multi-digit numbers. In particular, matching the number word “zweiundvierzig”, the unit digit “2” may be written down first followed by the decade digit “4” placed to the left of the unit digit. To the best of our knowledge, there is no study addressing the prevalence of as well as cognitive characteristics and potential benefits associated with this strategy. To pursue these points, we assessed transcoding direction of two-digit numbers, working memory capacity (verbal working memory and central executive) as well as arithmetic performance of German-speaking adults (n = 896). About 2% of participants consistently wrote down the unit digit before the decade digit. Another 5% were inconsistent regarding writing order. Interestingly, we observed that the group writing down units before decades (consistently or inconsistently) had lower verbal working memory capacity as well as lower central executive abilities compared to the group writing down decades before units. However, no evidence for a between-group difference was observed for arithmetic performance. Because groups differed in working memory capacity but not arithmetic performance, these data might indicate that regaining correspondence by adjusting the writing order of tens and units may serve as an offloading strategy for transcoding multi-digit numbers in a language with inverted number words. Further research is needed to more directly evaluate the potential of this strategy especially in children acquiring multi-digit number knowledge.

P3.70: Improving numeracy in children with Down Syndrome through computer-based cognitive training
Presenter: Marco Zorzi
Authors: Marco Zorzi, Francesco Sella, Sara Onnivello, Silvia Lanfranchi

Numerical and arithmetic skills are severely limited in individuals with Down Syndrome (DS), whose proficiency can be even lower than that expected on the basis of mental age. DS individuals show difficulties even in basic number skills such as counting (e.g. Nye et al., 2001) and numerosity discrimination (e.g. Sella et al., 2013). We assessed the possibility to train basic number skills through play with an adaptive computer game, “The Number Race” (Wilson et al., 2006), The game is aimed at enhancing number sense, cementing the links between representations of number, conceptualizing and automatizing arithmetic, and maximizing motivation. A group of 40 children with DS (age 7-14 years) took part in the study. Half of the children was trained individually on basic numerical skills (experimental group) while the other half (control group) was trained on basic reading abilities (letter, syllable and small words reading). For both groups, training lasted ten weeks, with two weekly sessions of 20-30 minutes each. At pre and post-test

several aspects of basic numeracy were assessed such as numerical intelligence (lexical, semantic and pre-syntactic representation of numbers), counting, the ability to map numbers on a number line, the ability to compare quantities and digits. Moreover, letter detection, syllable, word and nonword reading were assessed to verify the effectiveness of the control training. Finally, general intelligence was assessed. Preliminary results show that, compared to the control group, the experimental group had a greater improvement in several aspects of numerical intelligence, such as lexical, semantic and pre-syntactic representation of numbers, as well as in counting. All these gains appear to remain stable after three months from the intervention. We conclude that computer-based training can strengthen basic number skills in DS, which in turn is expected to improve the educational outcome in mathematical learning.

P3.71: Spatial biases induced by mental arithmetic and the impact of task difficulty

Presenter: Maria Glaser
Authors: Maria Glaser, André Knops

While plenty of research suggests that numbers are represented spatially, some recent studies extended this to mental arithmetic by showing that addition/subtraction problems shift attention to the right/left. Two experiments investigate 1) how these attentional shifts during the calculation phase develop over time by manipulating the delay between the arithmetic problem presentation and the spatial attention measurement (Exp 1 & 2) and how arithmetic task difficulty modulates these effects by varying the carry/noncarry-property of the arithmetic problems (Exp 2). In both experiments, spatial attention was measured via a temporal order judgment task (TOJ) where participants needed to decide which of two lateralized stimuli was presented first. The baseline consisted solely of the TOJ task and in the arithmetic task participants were first presented with the two-digit arithmetic problem via headphones and performed the TOJ task after the delay (250, 750 & 1500 ms) before responding to the arithmetic task. Operation and delay were varied within subjects (Exp 1 & 2) and the carry/noncarry property was varied between subjects (Exp 2). We found attentional shifts to the left/right for subtraction/addition problems compared to the baseline suggesting that visuospatial attention mechanisms are recruited during mental (symbolic) calculation. While Exp 1 showed no significant interaction between operation and delay, Exp 2 hinted at a decrease of the attentional shift over time, but mainly for noncarry problems. We assume that two-digit carry-problems involve additional processes that either mask or don't allow for an operation on the spatial magnitude representation that induces attentional shifts.

P3.72: Involving Parents in Children's Learning and Perceptions of Math Through Board Games

Presenter: Martin Buschkuehl Brandon Smith
Authors: Martin Buschkuehl & Brandon Smith

Learning not only happens inside but also outside of the classroom. To promote the latter learning situation, we invited predominantly low-income families to a family math night event in which families were introduced to three educational math board games. Following the event, families received the games and were asked to continue playing them at home as a family over the course of four weeks. Before and after the game play period, children's and caregivers' appreciation and attitude towards math were assessed. Preliminary data analyses from 39 families revealed that families played an average of 13 times. An average game play session lasted about 45 minutes and families indicated to having liked their experience (1.8 on a 1-5 scale with 1 = really liked it). Playing the board games also resulted in more incremental mindsets in the children, indicating that they were more inclined to think that their basic qualities such as their math abilities can be developed through effort and hard work and do not represent fixed traits. No changes in math anxiety and motivational aspects focusing on the expectancy of success and value for mathematics were observed. Data collection is ongoing; however, our preliminary results suggest that families are open and able to integrate math activities in their daily lives, which might ultimately lead to positive downstream effects in educational contexts.

P3.73: Arithmetic learning in children – an fMRI training study

Presenter: Merel Declercq
Authors: Merel Declercq, Bert De Smedt,

The development of arithmetic competencies is characterized by a shift from procedural strategies to fact retrieval. Previous fMRI studies focusing on this strategy shift in children, discovered that the intraparietal sulcus is active during procedural strategies, while for fact retrieval, the angular gyrus shows increased activation. The present study extends this body of work by conducting an fMRI study in which strategy use was experimentally manipulated by providing a training and by comparing the brain activity for trained and untrained items. This approach has been applied in adults, but has not been used in children so far. Participants were 40 typically developing 10-year-olds, of which 26 (13 girls) remained after elimination due to excessive motion and mistakes during acquisition of the fMRI data. All participants completed a 6-day training program at home, training 10 "double-digit x single-digit" multiplications. Two sets of 10 items were created, matched for the double-digit and single-digit operand, as well as the solution, and balanced between subjects. Training was followed by an fMRI session, with three experimental conditions (10 trained items of the training, 10 equally difficult untrained items, and 10 single-digit multiplications) and one control condition matched for visual and motor activity. All children completed 6 runs, each of which contained the 4 conditions. The analysis of the behavioral training data revealed a significant decrease in reaction time ($F(2.698, 64.745) = 159.273$, $p < .001$), while accuracy significantly increased during training ($F(5,120) = 11.279$, $p < .001$), independent of which set was trained. These data indicate that the training has worked. For the fMRI data, all preprocessing steps are finished and we are currently analyzing the trained versus untrained and the untrained versus trained contrasts. By the time the conference starts, all analyses will be ready to present on the poster.

P3.74: Is Bilingualism really a plus? Investigating addition mechanisms in children using fNIRS and eye-tracking
Presenter: Mona Anchan
Authors: Mona Anchan,

In a 2017 national math assessment of 4th-grade children in Alabama, 86% of bilingual children scored below proficiency compared to 49% of monolingual children. To develop effective interventions to close this gap, it is crucial to understand how mathematical processing in bilinguals differs from monolinguals, both at the behavioral and neural levels. Due to competing languages, it is plausible that bilinguals represent and process math knowledge differently than monolinguals. We hypothesize that bilingual children who speak Spanish at home will process arithmetic slower than their English-speaking monolingual peers due to increased cognitive load. They will also respond less quickly and make more errors due to increased attentional demand. This cross-sequential study seeks to investigate arithmetic processing, specifically addition, in school children of ages 8-12 in grades 3-6 over a period of three years. There is extensive research on the different mechanisms involved in processing single-digit (simple) and double-digit (complex) arithmetic problems with monolingual children. However, the differences between doing arithmetic in one's native language and a second language have not been scrutinized extensively. To fill this gap, monolingual and bilingual children will be tested on an arithmetic task twice every year (March, October). Functional Near-Infrared Spectroscopy will provide spatial and temporal understanding of brain processes involved, while eye-tracking will provide behavioral insights about executive functions and attentional processes. Unlike other arithmetic studies where participants respond by clicking buttons, we employ a novel paradigm that allows subjects to respond verbally to arithmetic questions as they would in the classroom. This enhances the task validity making our results relevant for classroom practice. This study aims to: (1) compare single-digit addition versus double-digit addition in English and Spanish in bilingual and monolingual children during development; (2) correlate mathematical performance of bilingual and monolingual children to active brain areas and neural processes.

P3.74: One-year follow-up on a classroom-based mindfulness program for math anxiety
Presenter: Nadine Yildiz
Authors: Nadine Yildiz, Darcy Hallett

Previous research has provided evidence that a 12-week, teacher-implemented, classroom-based Mindfulness program improved the math performance of grade 4 and 5 students, with 5th grade students also demonstrating a reduction in math anxiety, over an active control and a business-as-usual (BAU) control. The aim of the present study was to determine a) if the pattern of improvement continues to be evident one-year later; and 2) if the groups differed in emotion regulation. Mindfulness is hypothesized by some to help anxiety by increasing emotion regulation, so it is our expectation that the intervention group will demonstrate elevated emotional regulation compared to controls.

On year after completion of a classroom-based Mindfulness program, a relaxation program (the active control) or a BAU control condition, grade 5 and 6 students (from the 96 former grade 4 and 5 students who completed the study) were tested on the same battery of measures from pre-test and post-test to assess the long-term outcome of their participation. Measures included the Woodcock-Johnson III – Math Fluency subtest as a measure of procedural math ability, the Chelsea Diagnostic Mathematics Test – Number Operations as a measure of conceptual ability, Math Anxiety Rating Scale – Elementary as a measure of math anxiety, Spence's Children's Anxiety Scale as a measure of general anxiety, and the Child and Adolescent Mindfulness Measure a measure of Mindfulness. Additionally, to further begin assessing the mechanisms behind the differences previously found between groups, emotion regulation was assessed using the Emotion Regulation Questionnaire for Children and Adolescents.

Data collection is currently ongoing. Based on our previous results, we expect to find some differences in our intervention group in terms of calculation ability, math anxiety, and emotion regulation compared to our active control and BAU control.

P3.76: Non-Symbolic Addition in an Artificial Algebra
Presenter: Nicola Morton

Authors: Nicola Morton, Anna Wilson, Rory Collins, Simon Kemp, Randolph Grace

In a non-symbolic artificial algebra, participants learn by feedback to respond to arithmetic relations between non-symbolic stimulus magnitudes (e.g. difference or ratio of stimulus brightness or length; Grace et al., 2018). Here we tested if participants could learn to add magnitudes consistent with the axioms of a commutative algebraic group. Feedback was provided based on a linear mapping between the sum of the stimulus magnitudes and location along a horizontal response bar. For two stimulus modalities (line length and brightness), we found that responses were commutative (i.e., a + b = b + a) and associative (i.e., a + (b + c) = (a + b) + c), that there was an identity element (i.e., a + 0 = a), and that elements had an inverse (i.e., a + (-a) = 0). Results showed that without explicit instruction, participants learned to add stimulus magnitudes according to a commutative (Abelian) algebraic group. Given how rapidly participants learned to respond accurately in our task, results suggest that the perceptual system represents and operates on stimulus magnitudes in a manner consistent with an algebraic group. The hypothesis that algebraic structure is embedded in how organisms perceive the world has the potential to explain behaviour such as spatial navigation that appears to require arithmetic computation, and may provide insight into how human brains encode mathematical thought.

P3.77: The development of symbolic magnitude understanding in early childhood
Presenter: Nicole Scalise
Authors: Nicole Scalise, Geetha Ramani

With the goal of providing equitable early childhood education for all children, researchers have worked to identify the mathematical skills that are most important for supporting later math achievement. In particular, young children's knowledge of numerical magnitudes, like knowing that seven is more than three, is thought to play an important role in their mathematical development. The present study aims to investigate the development of symbolic magnitude understanding of preschool children from low-income households, who typically lag behind their middle-income peers on symbolic numerical tasks.

Data from 135 Head Start preschoolers (ages 3-5 years old) will be collected in two phases, 3-4 months apart. To date, the first phase of data collection has been completed. Children's cardinality knowledge, symbolic magnitude knowledge, and executive functioning (EF) skills were assessed during the first phase, and their symbolic addition skills will be assessed during the second phase. These data will be used to test a conceptual model of preschoolers' symbolic magnitude knowledge: symbolic magnitude predicted by cardinality and predictive of addition skills, with EF skills predicting each numerical skill.

Measured variable path analysis (MVPA) will be used to test the hypothesized structural relations from the conceptual model. MVPA tests the complete model simultaneously, as opposed to conducting a multi-step mediation test with linear regression. Mplus will be used to fit the model, and standard model-fit indices provided will be reported (e.g., SRMR; RMSEA; CFI). The magnitude and significance of each parameter estimate will also be interpreted to determine whether there is support for the proposed structural relations. Results from the current study will be used to inform the design of comprehensive early numeracy interventions, providing teachers, parents, and researchers with insight into key skills to focus on.

P3.78: Mathemarmite: a video game to train children count
Presenter: Pedro Cardoso-Leite
Authors: Pedro Cardoso-Leite, Brice Clocher, Aurelien Defossez, Michel Fayol, Rory Flemming, Dominic Mussack, Paul Schrater

Numerous studies show that early mathematical abilities determine to a significant extent subsequent educational achievement in mathematics. Differences in these abilities exist prior to entering school, persist over decades and are at least in part determined by socio-economic status. It appears then, that interventions targeting the improvement of early mathematical abilities might be beneficial in terms of the long-term return on training-investment and reduce the impact of social inequalities on education.

Many interventions have already been devised and yielded promising results. However, they are rarely developed to production quality and scalable. It is worth noting here that our digital landscape has radically changed over the past decade and that most children today have access to mobile devices. Hence, developing early mathematical interventions in the form of video games might hold the key to improve mathematical abilities at a large scale and at a low cost.

We developed Mathemarmite (http://mathemarmite.lu/)—a freely accessible video game that offers young children an opportunity to hone their counting abilities in a cosy, timeless and friendly environment where they follow recipes and mix ingredients in the right quantities to cast spells and discover a variety of monstrous transformations that they can immortalize in their Monster Photobook.

Mathemarmite, however, is not only a game—it is also a research project that involves experts in game design, mathematical abilities and machine learning. As people play the game, data is gathered to personalize in real time the individual's learning experience but is also processed extensively offline to improve our understanding of mathematical cognition. Knowledge gained with the data collected in this game will be used to improve the game and hopefully learning in subsequent iterations.

P3.79: Exploring the Symbolic Math Processing in Immersion and Non-Immersion Students
Presenter: Renée Whittaker
Authors: Renée Whittaker, Chang Xu, Heather Douglas, Jo-Anne LeFevre, Helena Osana, Jill Turner, Anne Lafay, Sheri-Lynn Skwarchuk

Knowledge of symbolic representations of number is foundational for the development of mathematical competence. Previous research has shown an educational delay in both linguistic and early numeracy skills for second language learners compared to children who learn math in their home language (Kleemans et al., 2011). The Pathways Model supports the notion that language ability in addition to quantitative and working memory contribute to early mathematical success (LeFevre et al., 2010). The goal of the present study was to examine whether immersion learners would show similar pathways to symbolic math learning as non-immersion learners. Participants included 182 grade 2 students (Mage= 7.8 years): 108 students were enrolled in French immersion programs and were learning math in French (their second language) and 74 were enrolled in non-immersion programs and were learning math in English (their home language). Students were assessed on their language skills in their home language (i.e., general receptive vocabulary), quantitative skills (i.e., subitizing and digit comparisons), and working memory (i.e., digit forward span, digit backward span and visuospatial span). French immersion students were assessed on language skills in their instructional language. Students were also assessed on their symbolic math skills including mathematical orthography that captures knowledge of rules and conventions of written math text and arithmetic fluency. Results show that for both immersion and non-immersion students, quantitative skill and working memory both uniquely predicted arithmetic fluency. However, for immersion students, the general vocabulary (in both languages) also uniquely predicted arithmetic fluency, whereas for non-immersion students, general vocabulary did not uniquely predict it. Furthermore, for French immersion students, quantitative skill uniquely predicted mathematical orthography, whereas for non-immersions students, working memory predicted it. These results suggest differences in symbolic math processing between immersion and non-immersion students.

P3.80: Testing the Specificity and Extent to which State-Level Math Anxiety Explains the Link between Trait-Level Math Anxiety and Online Math Performance
Presenter: Richard Daker
Authors: Richard Daker, Ian Lyons

Higher trait-level math anxiety has been consistently shown to predict poor math performance. A common assumption in the literature is that high anxiety about math at the trait-level triggers a state-level anxiety response specifically when encountering math-related stimuli, and that this state-level anxiety response leads to in-the-moment decrements in math-performance. Surprisingly, however, to date this set of assumptions has only been indirectly tested. To do so, we measured trait-level math and general anxiety several days before participants came into the lab. Participants then completed challenging arithmetic tasks and difficulty-matched word-verification tasks. Crucially, just prior to starting each task, participants were told whether they would be completing the math or the word task. Shortly after being told which task was next, participants rated their state-level anxiety ("On a scale of 1-7, how anxious are you feeling right now?"). In this way, we tested whether state-level anxiety elicited by an impending math task indeed explained (mediated) the relation between trait-level math anxiety and performance on that math task. Moreover, by controlling for general trait anxiety, anxiety ratings prior to the word task, and word performance, we isolated effects specific to math. Results showed that state-level math anxiety significantly mediated the relation between trait-level math anxiety and online math performance (ACME = -.099, 95% CI [-.21, -.02]), thus lending direct empirical support to a key assumption in the literature. Interestingly, however, we observed only a partial mediation effect, with the indirect path via state-level math anxiety accounting for only about 20% of the trait-level math anxiety → math performance relation (%C = .209). Possible alternative mechanisms to explain the remaining 80% of the link between trait-level math-anxiety and online math-performance are discussed.

(P) P3.81: Fraction Education Based on Cognitive Neuroscience Theory And 4A-Instructional Model Intermediated by A Lesson Study
Presenter: Rogéria Toledo
Authors: Rogéria Toledo, Cintia Santos, Arthur Powell, Maria Alice Souza, Roberto Abreu-Mendoza, Miriam Rosenberg-Lee

Historically, fractions have proven to be a significant bottleneck in the mathematics curriculum. Yet, emerging research from education and cognitive neuroscience points to the utility of building accurate representations of fraction magnitude for supporting students understanding of fractions. The present study examines the instructional strategies developed by teachers participating in a professional development course aimed at integrating educational and neuroscience research about fraction learning and evaluates changes in the teachers' understanding of fractions, using a pre/post-test design.

The course will be offered in a master's program in Science and Mathematics Teaching in Brazil that will occur between February and June 2019. This course will implement the Japanese Lesson Study approach with these three stages: (1) lesson planning, (2) execution of the lesson, and (3) reflection on the lesson (Wrober & Souza, 2018). In order to develop teachers' concept of fractions, they will read and discuss relevant research from mathematics education and cognitive neuroscience. The 4A-Instructional Model, (Powell 2018), will guide the development of instructional activities by emphasizing four types of actions—actual, virtual, written, and general—to develop students' understanding of non-symbolic and symbolic magnitudes of fractions. To evaluate teachers' conception of fractions, specifically, how they understand fraction magnitude, we will apply a fraction comparison task before and after the course. Crucially, we will assess whether teachers are processing fractions componentially (i.e. with reference to numerators or denominators) or holistically (with reference to their magnitude of the fractions).

This study combines qualitative and quantitative analyses, to track changes in teachers understanding of fractions. We expect that mathematics teachers will develop activities to teach fractions that consider the results of cognitive neuroscience research. Moreover, we expect that their fraction comparison performance will improve, showing evidence of processing the magnitude of fractions, rather than interference from components.

P3.82: Representing numerical information across different formats in the adult brain

Presenter: Ruizhe Liu
Authors: Ruizhe Liu, Griffin Koch, Marc Coutanche, Julie Fiez, Melissa Libertus

Previous human brain imaging studies suggest that several brain regions are involved in representing numerical information: left temporal cortex supports the verbal representation of numbers (e.g., Andin, Fransson, Rönnberg, & Rudner, 2015); the intraparietal cortex represents semantic information (e.g., Piazza, Pinel, Le Bihan, & Dehaene, 2007); and a sub-region in the inferior temporal cortex represents the visual form of Arabic numerals (e.g., Daitch et al., 2016). Moreover, a few studies suggest that a precentral region is involved in representing hand-sign numbers (e.g., Kaufmann, et al., 2008). However, to date, the neural mechanisms underlying the four types of numerical information have not been directly compared in the same participants. While undergoing functional magnetic resonance imaging, ten adults (mean age = 21.5 years) completed a Number Comparison Task and a Phonological Comparison Task, which allowed us to identify brain regions associated with semantic and phonological representations of numerical information. All stimuli were presented in either an Arabic or Hand-sign format, which allowed us to identify brain regions associated with the visual and manual representations. Preliminary analyses suggest that the Number Comparison Task yielded stronger signal change in right posterior parietal and bilateral ventral temporal cortex, while the Phonological Comparison Task yielded stronger signal change in left lateral and medial frontal cortex. Hand-sign numerals yielded greater activation across multiple regions in bilateral posterior parietal cortex, occipital cortex, and ventral temporal cortex, while Arabic numerals did not reveal greater activation than hand-signs in any brain region. Overall, our preliminary findings support partially distinct networks for the semantic and phonological representation of symbolic numbers. The separation between the manual and visual code of symbolic numbers in the brain remains less clear.

P3.83: Using Mathematics Applications As Digital Home Intervention Tool

Presenter: Sabrina Shajeen Alam
Authors: Sabrina Shajeen Alam, Adam K. Dubé,

One of the key hurdles in addressing mathematical learning disabilities (MLD) is the high cost and effort needed to create individualized instruction tailored to a child's specific mathematics deficit. Home numeracy practices might be an important means of improving students' knowledge and proficiency with basic mathematics concepts. Further, children's mathematics development may also be supported by application-based learning activities at home (e.g., math apps on tablets; Berkowitz et al., 2015). However, there is no research to date on the effectiveness of these practices as a home intervention tool for children with MLD. The present study investigates whether using digital devices can improve mathematics understanding for children struggling with mathematics. Method. The study consists of 2 tests (pre- and post-test) and a digital home numeracy practice (DHNP) intervention program using math apps. Children with MLD from grades 1 through 3 (n = 50) will be randomly assigned to play either a magnitude representation (MR) focused math app (e.g., comparing two numerals; 2 vs 6) or a non-MR focused math app (e.g., addition, counting) in their home. Key-Math 3 diagnostic assessment (Connolly, 2007) and numeracy screener (Nosworthy et al., 2013) tools will be used to measure their mathematics performance before and after the intervention. Statistical analysis and outcome.

Performance between the MR and non-MR focused group across the intervention will be measured and compared using mixed model Analysis of Variance (ANOVA). Results from the study will inform whether digital practices impact mathematics learning and whether MR-focused activities improve children's basic mathematics understanding.

P3.84: Approximate Number System Acuity in Girls with Turner Syndrome: A Model for Pathways to MLD

Presenter: Sarah Lukowski
Authors: Sarah Lukowski, Emily Padrutt, Michele Mazzocco

Turner Syndrome is a sporadic monosomy disorder that results from either complete or partial loss of one of two X chromosomes in females. Girls with Turner Syndrome (TS) have a higher incidence of math learning disabilities (MLDs) compared to the general population. Unlike most MLD trajectories, math achievement levels in girls with TS increase from early elementary to middle school, implicating compensatory processes. As such, understanding the nature of these mathematics difficulties and the skills with which girls with TS might overcome these difficulties may offer critical insights into pathways to—and alternative interventions for—MLDs. Although earlier research has characterized mathematics profiles of girls and women with TS, the approximate number system of young girls with TS has not, to our knowledge, been examined. The present study reports on nineteen 4- to 8-year-old girls with TS and nineteen individually age- and grade-matched girls without TS also matched for verbal knowledge and expressive vocabulary. Matching was confirmed by paired-sample t-tests (all p-values >0.26). Consistent with the broader literature, the girls with TS showed significantly poorer performance on a math ability assessment (Test of Early Math Ability), $t = 2.33$, $p = 0.03$, but not on an untimed math achievement subtest (Woodcock Johnson Applied Problems subtest), $t = 1.19$, $p = 0.15$, relative to girls without TS. Importantly, on an approximate number system task, girls with TS showed significantly less accurate performance on average (mean difference = 10.5%, $t = 3.97$, $p = 0.001$), and a significantly higher Weber fraction (mean difference = 0.40, $t = 3.13$, $p = 0.001$). We address possible strategies that girls with TS may adopt to overcome early number skills deficits to reach relatively unimpaired math achievement compared to their peers.

P3.85: Variables that Influence the Algebra Performance of University Students

Presenter: Sarah Powell
Authors: Sarah Powell,

Proficiency with algebra is difficult for students, even students at the college level. We administered an assessment of algebra to 362 university students in the United States. Students also completed measures of rational numbers, mathematics fact fluency, mathematics anxiety, reading fluency, and spelling accuracy. A dominance analysis revealed that of the five academic-related variables, rational numbers performance dominated all other variables, accounting for over 33% of the variance in algebra performance. As per general dominance results, the average difference in fit between all subsets of models of equal size, which did versus did not include rational numbers performance, was more than four times greater than the next closest independent variable (mathematics fluency, with an average difference in fit of 0.075). In this way, rational numbers performance was the single most important variable (among the variables considered in our analysis) for influencing algebra performance. This suggests that, for college students to succeed with algebra, rational numbers knowledge is more important than mathematics fact fluency, mathematics anxiety, reading fluency, or spelling accuracy.

Clearly, strong understanding of and procedural proficiency with rational numbers is necessary for strong performance in algebra. Likely the first exposure to rational numbers for most students comes through the learning of fractions in the elementary grades. Prior research demonstrates the importance of fractions knowledge on algebra performance at middle school (Booth & Newton, 2012) and high school (Siegler et al., 2012). Our results provide corroborating evidence, while extending those studies by focusing on the college level and by relying on an analytic method that submits rational numbers performance to a more stringent test. Mathematics instruction during the elementary and secondary levels must secure students' understanding of and procedural competence with fractions, two aspects of fractions performance tapped in this study's outcome measure. Rational number knowledge, as operationalized in the present study, also involves knowledge of decimals, percentages, proportions, and ratios (Britt & Irwin, 2008; DeWolf et al., 2016), reflecting the need for quality instruction in these areas to establish deep knowledge of rational numbers and pave the way for success with algebra. In terms of post-secondary developmental mathematics, our results again suggest course content focus on important concepts and procedures related to rational numbers before or while providing instruction focused on algebra concepts and procedures. To focus exclusively on algebra, without developing foundational knowledge of rational numbers, does students a disservice.

As colleges look to restructure developmental mathematics sequences and as elementary and secondary schools seek to better prepare students for meeting college and career benchmarks of algebraic proficiency, results indicate that instruction related to rational numbers is essential across grade levels for students to develop a deep algebra understanding.

P3.86: Representation and processing of exponential expressions
Presenter: Sashank Varma
Authors: Sashank Varma, Jeffrey Bye

Small natural numbers (0-9) are understood by reference to continuous magnitude representations. By contrast, more complex numbers can be understood by reference to structured representations, e.g., people can separately represent and process the numerator and denominator of a fraction. We investigated whether people can understand exponential expressions (e.g., 2^4) using structured representations to separately process their base and exponent components (e.g., 2 and 4, respectively) using magnitude representations of small natural numbers. In a study employing a 2x2x3 within-subjects design, 38 undergraduates compared pairs of exponential expressions. The Form factor specified whether expressions differed in their bases (polynomial, e.g., 4^2 vs. 7^2) or exponents (exponential, 2^4 vs. 2^7). The Context factor specified whether polynomial and exponential comparisons were blocked or intermixed. The Magnitude factor defined the relation between differentiating components (base or exponent) as being far (e.g., 5^2 vs. 5^9), near-small (e.g., 5^3 vs. 5^4), or near-large (e.g., 5^7 vs. 5^8) – relevant for testing distance and size effects. An analysis of reaction times revealed a main effect of Context, with intermixed comparisons slower than blocked comparisons ($p < .001$). This suggests that when the differentiating component must be identified on a trial-by-trial basis, processing slows. There was no effect of Form ($p = .223$). Critically, there was a main effect of Magnitude ($p < .001$), with Helmert contrasts indicating both distance and size effects ($ps < 0.001$). This suggests that the differentiating components of exponential representations are compared using magnitude representations of small natural numbers. In summary, people can capitalize on the structure of exponential expressions and separately process their base and exponent components. Ongoing research is investigating the role of magnitude representations, rules, and heuristics when comparing ‘heterogeneous’ exponential expressions (e.g., 4^8 vs. 9^5).

P3.87: Cognitive Support for Learning Fractions by Analogy
Presenter: Shuyuan Yu
Authors: Shuyuan Yu, Clarissa Thompson, Pooja Sidney, Dan Kim, John Opfer

Analogy to familiar numbers can help children project the magnitudes of novel numbers. With highlighted structural similarities of integers and fractional magnitudes in number lines, children can use their pre-existing knowledge of integer magnitude to bootstrap an understanding of fractions. In experiment 1, thirty 10-year-olds identified or placed an integer or fraction on a number line. Estimates of integers were as much as 2x more accurate than estimates of fractions. Therefore, we hypothesized that comparing fractions to integer scales might improve representations of fractions as much as 2x.
In experiment 2, fifty-two 10-year-olds were randomly assigned to an integer condition, where they were trained to estimate positions of fractions and integers on aligned number lines, and a control condition with no analogical bases and alignments. Aligning target problems with analogical sources greatly increased accuracy of estimates. In the delayed post-test, children in the integer condition outperformed children in the control condition, but not as much as 2x, indicating that children might need more cognitive supports to fully benefit from the analogy.
In experiment 3, sixty-four 10-year-olds learned to estimate fractions with analogical sources of integers. At post-test, children solved number-line problems either with (Cue condition) or without (No Cue condition) visually-aligned cues to facilitate source retrieval. Children in the Cue condition improved their estimates from pretest to post-test as much as 2x, suggesting that children’s understanding of fractional magnitudes came from the comparison to integers. Further, visually-aligned cues activated inert knowledge at post-test.
Together, the three experiments suggest that familiar sources, alignment, and source retrieval cues are helpful cognitive support for learning fractions by analogy.

P3.88: Evaluating the neural correlates of fraction arithmetic: an fMRI study
Presenter: Silke M. Bieck
Authors: Silke M. Bieck, Elise Klein, Thomas Dresler, Johannes Bloechle, Julia Bahnmueller, Robert S. Siegler, Korbinian Moeller

Fractions are difficult to understand for schoolchildren but also adults. While recently there has been increasing research examine fraction processing; only little is known about the neural correlates underlying fraction arithmetic. First behavioral findings indicated an association between whole number arithmetic and fraction arithmetic. Therefore, this study aims at identifying the neural underpinnings of fraction arithmetic and their commonalities with and differences from whole number arithmetic and the conceptual understanding of fractions on the neural level. This way, we want to gain new insights into why fraction arithmetic is particularly difficult.

We will collect fMRI data of participants solving fraction arithmetic problems, executing all four basic arithmetical operations, as well as a fraction magnitude comparison task to assess conceptual fraction knowledge. Additionally, participants will complete whole number addition and multiplication to assess calculation processing and arithmetic fact retrieval. Finally, an n-back paradigm will be employed to control for working memory processes.

To evaluate similarities and differences in activation at the whole-brain-level between (i) conceptual and procedural fraction processing and (ii) fraction arithmetic and whole number arithmetic, we plan a conjunction analysis between (i) fraction arithmetic and fraction magnitude comparison and (ii) fraction arithmetic and whole number arithmetic as well as the respective direct comparisons. By adding working memory measures as covariate, we will be able to explore similarities and differences in brain activation corrected for this process. To evaluate fMRI signal changes in functional regions of interest (ROIs), the fraction magnitude comparison task will serve as functional localizer for fraction arithmetic. In the same vein, whole number addition and multiplication will serve as localizer tasks for fraction arithmetic. Differences in the BOLD response might additionally help to disentangle conceptual from procedural fraction processing as well as fraction arithmetic from whole number arithmetic.

P3.89: Number sense in children with cerebral palsy

Presenter: Silvia Cristina De Freitas Feldberg
Authors: Silvia Cristina De Freitas Feldberg, Claudia Berlim Mello, Flavia Heloísa Santos, Orlando Amodeo Bueno

As for a better understanding of the causes of problems in the learning of mathematics usually reported in scholar children, as well as neuropsychological basis of numerical cognition; we carried out an exploratory case-control cross-sectional study to investigate numerical skills in children and adolescents with congenital lesions. Methods: Participants were 50 scholars, aged 7 to 15 years, of both sexes (28 boys), 31 controls and 19 diagnosed with cerebral palsy. Among those with cerebral palsy, nine had hemiplegic (5 right-sided and 4 left-sided, respectively) and ten diplegic (lower limbs) types. The assessment included the ZAREKI-R (a battery of numerical cognition subtests, oriented for the diagnosis of developmental dyscalculia), a computerized number sense task for comparison of non-symbolic magnitudes and neuropsychological tests for the assessment of executive functions, including working memory. Inferential analyses were used in the comparison of groups. Results: Participants with cerebral palsy performed worse than controls in several subtests of the ZAREKI-R, as well as in the number sense and working memory tasks. Conclusions: Numerical skills were impaired in children with cerebral palsy, regardless the type, resulting in a profile dyscalculia due to congenital lesion. Besides, in the domain of executive functions, their difficulties were more associated with working memory deficits than to inhibitory or flexibility problems. This cognitive profile explains, at least in part, the difficulties of children with cerebral palsy in the learning of mathematics.

P3.90: Componential Vs. Holistic Processing Of Fractions: A Cross-Language Difference Of Fraction Reading Order In English And Korean

Presenter: Soo-Hyun Im
Authors: Soo-Hyun Im, Jimin Park, Sashank Varma

A fraction consists of two parts, a denominator and a numerator. Two views of fraction understanding have been tested using various fraction comparison tasks (Bonato et al., 2007; Meert et al., 2009). The componential view proposes that people process fractions in a piecemeal manner, for example comparing just their denominators, and then their numerators. The holistic view proposes that people process fractions by integrating their numerators and denominators and comparing the resulting fraction magnitudes. The current study evaluated these two views in a new way by capitalizing on cross-language differences in fraction reading order. Korean names fractions by listing the denominator first and then the numerator, whereas English names the components in the reverse order. It utilized fraction comparison tasks. The fraction was presented in one of three ways—denominator-first, numerator-first, or simultaneous—and participants compared it against 3/5. The componential view predicts that English speakers should be advantaged in the numerator-first condition whereas Korean speakers should be advantaged in the denominator-first condition. The holistic view predicts no such crossover interaction. We initially recruited 28 English-speaking and 22 Korean-speaking college students at a US university. Each participant completed all three conditions of the fraction comparison tasks. The preliminary results showed that there was no crossover interaction between native language (English vs. Korean) and presentation order (numerator-first vs. denominator-first). In fact, there was only a main effect of presentation order, with both groups performing better in the denominator-first condition than the numerator-first condition. Although strong conclusions cannot be drawn from a predicted null result, the failure to find a crossover interaction is more consistent with the holistic view than the componential view. In addition, the advantage of the denominator-first condition over the numerator-first condition is consistent with the important role the denominator plays in part-whole relationships and the magnitudes of fractions.

P3.91: Nonsymbolic Number Processing in Children With Hearing Loss
Presenter: Stacee Santos
Authors: Stacee Santos, Hiram Brownell, Marie Coppola, Sara Cordes

Children with hearing loss (CHL) reportedly perform worse than their hearing peers on assessments of symbolic math abilities, such as standardized tests (e.g., Pagliaro & Kritzer, 2013; Traxler, 2000). Less attention, however, has been given to nonsymbolic number abilities in CHL, particularly the Approximate Number System (ANS). Recently, Bull et al. (2017) found that when controlling for inhibition and working memory, 5-12 year old CHL still displayed lower ANS acuity compared to the hearing controls. However it is unclear how early in development these differences in ANS acuity emerge and why.

Three – to six -year-old children (N = 60, 15 with hearing loss using amplification and listening and spoken language) completed tasks assessing ANS acuity (Panamath), verbal number knowledge, and their receptive understanding of the word "more." Parents completed a child vocabulary measure. Aligning with findings with older children, CHL had lower ANS acuity, in addition to lower number knowledge, understanding of "more", and parent-reported vocabulary relative to their hearing peers (p's <.05). Interestingly, the results showed that vocabulary was an important predictor of ANS acuity and a child's understanding of "more" fully mediates children's performance on ANS acuity tasks. This suggests that this seemingly nonverbal number system is linked to language. Further, consistent with previous research, number knowledge was an important predictor of ANS acuity in the hearing control group, but not for CHL. Additionally, hearing age for CHL (age of amplification – age at test) was positively correlated with all study variables, in a similar pattern to children without hearing loss, demonstrating that access to language advances the early development of numerical concepts.

P3.92: The brain correlates of numerical order processing and their relationship to arithmetic performance in children: a functional MRI study
Presenter: Stephan E. Vogel
Authors: Stephan E. Vogel, Gerrit Sommerauer, Karl-Heinz Grass, Roland H. Grabner

The past years have seen a growing interest to better understand the cognitive development of basic numerical abilities and their relationship to mathematical performance. Recent empirical findings have highlighted that symbolic numerical order (i.e., knowledge about the relative rank or position of numerals) constitutes a significant predictor for arithmetic abilities over and above the processing of numerical magnitudes (i.e., the quantity of a numeral). Despite these advances, it is unknown which brain regions mediate this significant association in children and whether numerical order is a significant predictor on the level of the brain. To address this question, a total of 30 children from elementary school (mean age: 8.63 years; range: 7-10 years) were asked to complete a numerical order task (are the numbers going up? e.g., 1-2-3) and a numerical magnitude task (which is the larger number? e.g., 5-7) inside a functional magnetic resonance imaging (fMRI) scanner. Arithmetic performance was assessed with a timed paper-pencil test outside the scanner. As in previous work, the behavioural results demonstrated significant correlations between numerical order, numerical magnitude and arithmetic fluency. The association between numerical magnitude processing and arithmetic was fully mediated by numerical order. On the level of the brain, a significant association between numerical order processing and arithmetic performance was observed in the intraparietal sulcus (IPS) and the middle temporal cortex. No such association was found for numerical magnitude processing. These findings provide novel evidence for the unique and important role of numerical order processing in typically developing children.

P3.93: Influences of Stimulus Complexity on Infant Number Discrimination: Shapes vs. Faces
Presenter: Taylor Williams
Authors: Taylor Williams, Alex Silver, Klaus Libertus, Melissa Libertus

From birth, humans have access to the object-file system that allows for exact representation of small quantities (Feigenson et al., 2004). To date, research on infants' earliest math skills has focused on their abilities to track numbers of simple objects (e.g., circles). However, infants rarely encounter simple shapes in their daily environments. Rather, infants are more likely to observe complex stimuli and particularly prefer to look at complex social stimuli such as faces or face-like patterns (Valenza et al., 1996). Here, we aim to combine these lines of research by examining infants' number discrimination ability with simple ovals vs. complex face stimuli. Sixty-five infants (mean age = 6.57 months, range: 5.5-7.5 months; 49% female), participated in a preferential looking paradigm presenting two image streams on a computer screen. One stream repeated a constant number stimulus, while the other stream alternated between displaying one or two stimuli. If infants are able to discriminate between one and two stimuli, we expect them to look significantly longer towards the changing stream. Replicating previous work (Feigenson et al., 2002), we found that infants preferred to look to the changing stream when both streams displayed simple ovals (p=.04). Critically, when infants were shown faces as stimuli (color- and size-matched to the ovals), they did not show a significant preference for either stream of images (p=.56). These findings suggest that when presented with facial stimuli, infants are unable to or no longer interested in detecting numerical changes. Future work needs to disentangle whether these limits apply to other complex stimuli that are non-social (e.g., images of houses) and discrimination of larger quantities.

P3.94: From The Eye Of Children With Mathematics Learning Disability: Do They Perceive Arithmetic Word Problems Differently?
Presenter: Terry Tin-Yau Wong
Authors: Terry Tin-Yau Wong, Eason Sai-Kit Yip

Children with mathematics learning disability (MLD) are known to have difficulties in word problem-solving. Further investigation is needed to reveal the stage(s) of problem-solving in which children with MLD are deficient. The current study aimed at identifying their deficit in the problem representation stage of arithmetic word problem solving, with the use of a novel problem types identification measure.

Second-graders (n = 1957) were recruited from local primary schools for mathematics achievement screening tests at two time points. MLD group (n = 66) and control group (n = 139) were invited for an individual assessment on problem type identification, general and math-related cognitive abilities.

Results from the mixed-design ANCOVA showed that MLD group was significantly outperformed by the control group in overall problem type identification, after controlling the effect of cognitive correlates, reading achievement, and arithmetic performance. An interaction between problem type and group was found, and further analysis recognized that the group difference was significant for three out of the four problem types, namely change (increase and decrease) and compare.

The study confirmed the difficulties in problem representation of arithmetic word problems experienced by students with MLD and provided evidence to the need to introduce schema instructions in mathematics lesson.

P3.95: Knowing how and what to count: Children's conceptual counting mistakes are uniquely related to early numeracy
Presenter: Theresa Elise Wege
Authors: Theresa Elise Wege, Bert De Smedt, Camilla Gilmore, Matthew Inglis

All counting and numerical operations rely on units. A unit can be counted, added to a set and used to compare the numerosities of two sets.

Young children often have misconceptions about the unit a number refers to, and which units can be counted. These are slowly overcome as children grow older. A very prevalent misconception in young children is that numbers and counting always refer to spatio-temporally independent objects. This causes them to struggle with the quantification of more conceptual units. An example of such a conceptual mistake would be if a child counted each of the blue and red cookies when asked: "How many different colours are there?"

We aimed to investigate how these specific conceptual mistakes are related to children's early numeracy development. Our design disentangled conceptual mistakes from simple counting errors, linguistic difficulties and spatial intelligence. We tested 64 children (aged 4-5 years). Children's numeracy skills were assessed using the PENS-B and participants completed a 21-item version of Raven's CPM and an 8-item conceptual counting task. Our conceptual counting task involved counting a single array of objects based on different units. We assessed each child's linguistic understanding, and scored conceptual mistakes separately from counting mistakes based on pre-registered scoring rules.

We found that the frequency of children's conceptual mistakes was strongly correlated with their numeracy performance, while the number of simple counting mistakes (i.e., miscounting the correct unit) was not. Furthermore, the frequency of children's conceptual mistakes shared a significant amount of unique variance with numeracy performance, even after accounting for age, Raven's and simple counting mistakes.

We conclude that children's early understanding of conceptual units is a numerical ability distinct from simple counting errors, and that it cannot be accounted for by verbal or spatial abilities.

P3.96: Early numerical skills and school trajectory
Presenter: Victor Koleszar
Authors: Victor Koleszar, Ignacio Cervieri, Alejandro Maiche

Figuring out which abilities underlie mathematical knowledge seems to be fundamental to understand how to improve learning through the design of the curriculum at school, and the possibility of identifying those children who may have difficulties and develop teaching strategies for them. How we process different magnitudes and the distinct manner of number or quantity presentations (and the relationship between them) have been shown to be very relevant to early learning and development of numbers and mathematical concepts (either presented as symbolic or non-symbolic). In 2013, our investigation group carried out an intervention to strengthen the quantity estimation capacities and evaluated the effect on math performance, and general cognitive skills related to working memory, attention and language. We present and discuss the results of that research in relation to the subsequent performance and trajectory of 300 of that children in school from 6 years to

K-11. Results show that symbolic number recognition seem to be important at first years and can be useful to identify some difficulties. In addition, throughout the school trajectory, estimate quantities and order numbers skills explain much of the variance of our data sample in multiple linear regression models, even controlling by working memory and age.

P3.97: How is finger counting related to addition learning in first graders?
Presenter: Vitor Geraldi Haase
Authors: Vitor Geraldi Haase, Fernanda Rocha de Freitas, Andressa Moreira Antunes, Helga Krinzinger

Finger-based numerical representations/ counting are important in early arithmetic. Children with math learning difficulties are delayed and persist for more time in using fingers. We investigated the association between finger-based strategies and addition accuracy in 1st-graders and its underlying cognitive mechanisms.

174 children participated at beginning of 1st grade. 43 children were excluded because of autism (2), intellectual disability (2), age over 8 years (1), dropout (2). 36 children were unable to perform very simple single-digit additions. Final sample comprised 131 children (mean age= 76.02 months, sd= 4.18, 44.9% female). 12 horizontally presented addition problems with results below 10 were responded as fast and as accurately as possible. Strategies were coded as counting, montring, minimal movements, covert counting, and no finger-based strategy. Children were assessed for intelligence, finger gnosias, ANS accuracy (w), phonological and spatial working memory (WM). Data on addition accuracy and finger counting were submitted to hierarchical cluster analysis.

Four clusters emerged (G1: n=15, G2: n=73, G3: n=34 e G4: n=9). Addition accuracy increased linearly and significantly across groups. Frequency of finger use differed significantly across groups, being lower in kids with poor addition performance (G1), increasing in kids with intermediate ability (G2, G3), and decreasing in addition knowers (G4). Association between finger-based strategies and addition was unrelated to intelligence, ANS accuracy (w), finger gnosias, and phonological WM. Group differences were observed in spatial WM, with better performance associated with addition accuracy and lower use of fingers in the addition knowers.

Results suggest a quadratic relation between finger-based strategies and addition mastery in beginning 1st-graders. Spatial WM was the most salient cognitive correlate. Finger-counting may scaffold early addition performance, being gradually replaced by memory-requiring strategies.

P3.98: The number-weight illusion
Presenter: Wolf Schwarz
Authors: Wolf Schwarz, Dennis Reike

When objects are manually lifted to compare their weight then smaller objects are judged to be heavier than larger objects of the same physical weights: the classical size-weight illusion (Gregory, 2004). It is also well-established that increasing numerical magnitude is strongly associated with increasing physical size: the number-size congruency effect (e.g., Besner & Coltheart, 1979; Henik & Tzelgov, 1982). The present study investigates the question suggested by combining these two classical effects: if smaller numbers are associated with smaller size, and objects of smaller size appear heavier, then are numbered objects (balls) of equal weight and size also judged as heavier when they carry smaller numbers? We present two experiments testing this hypothesis for weight comparisons of numbered (1 to 9) balls of equal size and weight, and report results which largely conform to an interpretation in terms of a new "number-weight illusion".

P3.99: Perceptions of the Magnitude of Mathematical Language Terms in Preschoolers and Adults
Presenter: Yemimah King
Authors: Yemimah King, Caroline Hornburg, David Purpura

Children's math language knowledge is a strong predictor of their early numeracy skills (Purpura & Logan, 2015; Toll & Van Luit, 2014). However, little is known about how perceptions of quantitative math language terms, including expressive knowledge--the ability to successfully express thoughts about quantities--are related to math skills. This study will investigate how preschoolers and adults describe and match magnitudes to quantitative math language terms (e.g., "few" refers to a small number of things or 3-5 items) and how these perceptions are related to math skills. Additionally, it will provide insight on developmental differences in how children and adults perceive the magnitude of math language terms which is important because adults must understand how young children think in order to successfully teach developmentally appropriate activities (Sarama & Clements, 2009). Hypotheses include: H1) Adults will have more precise descriptions/estimates of math language terms than children and H2) Precision for both adults and children will be related to their math skills. One hundred preschoolers (3-5 years old) and 100 adults (college students) will participate. All participants will complete four author-developed tasks to assess perceptions of nine math language terms where they will verbally define terms, show quantities with blocks, estimate magnitude on a number line, and select dot set pictures representing each term. Preschoolers will have the option to select quantities from 0-10 and adults from 0-100. Individual precision of estimates will be measured as consistent representations for each term across tasks. Participants will also complete numeracy and language assessments. T-tests and regression analyses will be used to test H1 and H2, respectively. It is expected that children will give terms less precise descriptions than adults. It is also expected that, controlling for general language, participants with more precise descriptions of quantitative math language terms will have higher numeracy scores.

P3.100: Different roles of number-quantity processing in the development of children's arithmetic skills
Presenter: Yiyun Zhang
Authors: Yiyun Zhang,

Numerous studies have devoted to the role of number-quantity processing in arithmetic skills, but results are mixed. The authors hypothesized that the role of number-quantity processing as children develop arithmetic skills differs depending on the number tasks and age of the child. 1006 children from first to fourth grade were recruited to perform several mathematics and general cognitive tasks. Hierarchical regressions showed that numerosity-digit mapping was only an independent predictor of arithmetic computation in lower grades and numerosity acuity was only an independent predictor of arithmetic computation in higher grades. These findings suggest that number-quantity processing diverges as arithmetic skills develop in children.

P3.101: Where and under what conditions do spatial and numerical cognition converge and diverge in the brain? An fMRI meta-analysis.
Presenter: Zachary Hawes
Authors: Zachary Hawes, H. Moriah Sokolowski, Chuka Bosah Ononye, Daniel Ansari

While it has been well-established that basic spatial processes (e.g., comparing line lengths) are related to basic numerical processes (e.g., comparing Arabic digits), it is not yet known whether spatial skills proper (e.g., mental rotation) relate to numerical and mathematical processing in the brain. To address this gap in the literature, we report the results of a meta-analysis of brain regions associated with neural activity in three key aspects of mathematical thinking: basic symbolic number processing, mental arithmetic, and mental rotation (a widely used measure of spatial ability). We targeted these three cognitive processes because they provided opportunities to test theoretically informed predictions as to when, why, and where we should expect to see common and distinct neural activity.

Activation Likelihood Estimation (ALE) was used to construct quantitative meta-analytic maps synthesizing results from 86 neuroimaging papers (~ 30 studies/cognitive process). Conjunction and contrasts analyses were then performed on these maps to identify common and distinct brain regions associated with each cognitive construct.

All three cognitive processes were found to activate bilateral parietal regions in and around the intraparietal sulcus (IPS); a finding consistent with shared processing accounts. Numerical and arithmetic processing were associated with overlap in the left angular gyrus, whereas mental rotation and arithmetic both showed activity in the middle frontal gyri. These patterns suggest regions of cortex potentially more specialized for symbolic number representation and domain-general mental manipulation, respectively. Additionally, arithmetic was associated with unique activity throughout the fronto-parietal network and mental rotation was associated with unique activity in the right superior parietal lobe.

This study presents the first theoretically-informed meta-analysis on relations between spatial and numerical abilities. Taken together, these findings contribute new insights into the neurocognitive mechanisms supporting spatial and numerical thought specifically, and mathematical thought more generally.

Poster Session 4 Abstracts:

P4.102: The contributions of cognitive, numeracy, and motivational factors for middle childhood math performance

Presenter: Allison Liu
Authors: Allison Liu, Sarah Karamarkovich, Teomara Rutherford

Mathematical skills are important for academic and everyday success, but the majority of children do not reach grade-level proficiency (National Assessment of Educational Progress, 2017). Prior studies have shown the importance of cognitive, numeracy, and motivational factors that influence math success, especially within the context of early childhood (e.g., Fisher, 2013; Geary, 2013; LeFevre et al., 2010; Raghubar, Barnes, & Hecht, 2010). Fewer studies have examined these relations during middle childhood. This age may be a particularly important period as one where both self-regulation skills and identity develop more fully (Eccles, 1999). In the current study, we investigated the factors that contribute to math skill growth in 1,428 3rd-5th grade students, recruited from 52 low-performing elementary schools in Southern California as part of a larger study testing a supplemental math software. We measured whether four cognitive factors (working memory, inhibitory control, cognitive shifting, spatial ability), three numeracy factors (symbolic number precision, non-symbolic number precision, automatic number processing), and two motivational factors (math expectancy, math values) predicted performance on the mathematics section of the California Standards Test (CST), controlling for students' prior CST performance, gender, grade, language status, SES, and race/ethnicity. A multilevel regression, nested by teacher, revealed working memory, cognitive shifting, mental rotation, symbolic and non-symbolic number precision, and math expectancy positively predicted post math performance. Further, there was evidence that these factors contribute differently depending on the type of math assessed. Our findings suggest that cognitive, numeracy, and motivational factors all play a significant role, with cognitive and numeracy factors showing the highest relative contributions to math performance in middle childhood.

(P) P4.103: Individual and developmental differences in the neurocognitive integration of number notations and their relation to math competence

Presenter: Darren Yeo
Authors: Darren Yeo, Gavin Price

Understanding that different number notations – sets (•••), number words (/three/), and Arabic numerals ("3") – represent the same number is important for math competence. It is proposed that learning the associations between notations may engage overlapping neuronal populations (mapping account). Although some studies observed such neurocognitive integration for set-numeral associations in adults, other studies did not, suggesting that the representations of different notations may become less integrated with experience and skill acquisition as symbols become used more flexibly (estrangement account). Critically, individual and developmental differences in how notations are integrated and their relation to math competence are unknown. We test the hypotheses that the mapping and estrangement accounts may both be valid, but in different age groups, and that the extent of integration may relate to math competency differently with age. In a target sample of 40 adults and 40 kindergarteners, participants will decide whether set-word, set-numeral and word-numeral pairs presented sequentially have the same meaning while being scanned using functional magnetic resonance imaging. We will first isolate regions that are selectively engaged by all three notations. For each participant and within each region-of-interest, neural activation patterns elicited by the same number in different notations will be correlated with one another (e.g., ••• with /three/, /three/ with "3") to index cross-notation representational similarity (CN-RS). We then fit them with models representing full or partial integration. We predict (1) greater full CN-RS in kindergarteners than in adults, (2) positive relation between full CN-RS and math competence in kindergartners, but a negative relation in adults, and (3) integration involving number words (partial CN-RS) remains high in adults and is a critical mechanism for math competence regardless of age. The predicted outcomes will support an inverted-U developmental trajectory of notational integration and provide insights into how numeral knowledge can be supported in later grades.

P4.104: Reverse distance effects do not exist

Presenter: Eli Zaleznik
Authors: Eli Zaleznik, Olivia Comeau, Joonkoo Park

Cognitive processes underlying number ordering have received much attention, due to the apparent relationship between ordering and arithmetic ability. Order judgment often results in the reverse distance effect (RDE) where small distances between numbers lead to faster responses unlike the opposite in magnitude judgment. The existence of RDEs has led to the idea that number ordering is done using a serial search for the next ordered number in a sequence and may be related to arithmetic competence. However, there is

reason to question the validity of RDEs as they appear only consistently in consecutive sequences. In two experiments, we directly test the "search" hypothesis, and through that, for the existence of the RDE.

In the ordinal judgement (OJ) task, three single digit numbers were presented simultaneously, and participants judged whether they were ascending. Each trial contained consecutive sets (3, 4, 5), small range sets (2, 3, 5), or large range sets (1, 4, 8). In the sequencing task, participants saw four numbers presented sequentially. The first three numbers were consecutive (e.g., 11, 12, 13). The last, target number was the next number in the sequence (14), one greater (15), four more than (18), or four less than (10) the expected number. Participants responded with a button press to indicate whether the target number followed the sequence.

In the OJ task, excepting the single case of ordered consecutive sets, participants responded faster to sets with larger distance than with smaller distance. In the sequencing task, participants responded faster when the target number was further from the expected than when the target was closer to the expected.

The absence of RDEs suggest that number ordering does not hinge on the process of responding to the next nearest number, except in the special case of highly familiar consecutive sets.

P4.105: Learning Under Pressure: Impacts Of Stereotype Threat Vs. Incentives On Conceptual Math Learning

Presenter: Emily Lyons
Authors: Emily Lyons, Lindsey Richland

While most prior research on pressure and math achievement has focused exclusively on testing situations, many students also feel a great deal of pressure during everyday math instruction. Additionally, children of color, who now represent the plurality of students in US public schools (NCES, 2017), report sometimes worrying that their academic abilities will be judged based on negative stereotypes during everyday math instruction (Larnell, Boston& Bragelman, 2014).

We investigate how heightened pressure during cognitively challenging mathematics instruction impacts early adolescents' immediate learning, retention and interest. In a series of 3 classroom-based experiments, we compared impacts of two different but sometimes co-occurring sources of pressure that many students experience in the mathematics classroom: stereotype threat and incentives. While both sources of pressure can increase anxiety, they differ in the extent to which identity is implicated and threatened.

In all experiments, procedures were implemented in 3 sessions over a 2- week period using a pretest, lesson and immediate posttest, delayed posttest design. Students viewed a videotaped conceptual math lesson on individual computers in their everyday math classrooms. This methodology maximizes ecological validity while also allowing for controlled stimuli. Students were randomly assigned to condition within classroom and stereotype threat (experiment 1), incentives (Experiment 2), or both (Experiment 3) were manipulated via video before learning.

Study 1: 135 5th grade students of color (83% African American, 17% LatinX; 71 girls) were randomly assigned to a stereotype threat or Control learning condition. When race was made salient prior to instruction (Stereotype Threat Condition), students retained less learning over time (βstandardized=-0.26, p =0.03) and reported less interest in the lesson ((βstandardized=-0.31, p =0.04).

Study 2: 178 diverse 5th grade students (33% African American, 27%White, 26% LatinX, 13% Biracial; 88 girls) were randomly assigned to the incentivized performance pressure or control condition. Unlike stereotype threat, incentives did not harm learning or interest overall (all ps >0.5) , although impacts of incentives interacted with student gender.

Study 3: In a 2x2 research design, 212 students of color were assigned to experience either or both stereotype threat and incentivized performance pressure while learning. Students who experienced both sources of pressure retained the least learning (Figure 1), suggesting that pressure from incentives may exacerbate the detrimental effects of stereotype threat.

Findings from these studies indicate that the role of pressure in shaping academic achievement extends beyond impacts on test performance to also shape initial knowledge acquisition, particularly when identity is threatened. Impacts of pressure while learning may be particularly far-reaching, as learning is built on a foundation of prior knowledge. These findings underscore the importance of working to guard against pressure in learning as well as testing contexts.

P4.106: Symbols are special: An fMRI adaptation study of symbolic, nonsymbolic and non-numerical magnitude processing in the human brain

Presenter: H Moriah Sokolowski
Authors: H Moriah Sokolowski, Zachary Hawes, Lien Peters, Daniel Ansari

It is a commonly held view that the uniquely human ability to think about numbers symbolically (e.g. '3' or 'three') is linked to an evolutionarily ancient system used to process nonsymbolic quantities (e.g. 'ooo') in the human adult brain.

Forty-five adults participated in the current preregistered study (https://osf.io/2549a/), in which an fMRI adaptation paradigm was used to isolate the semantic representations of symbols, quantities, and physical size.

Results indicated that the neural correlates supporting symbolic abstraction are entirely distinct from those that support nonsymbolic magnitude processing at both the univariate and multivariate level. At the univariate level, symbolic number processing was associated with activation in the left angular gyrus, whereas the processing of nonsymbolic magnitudes (both quantity and physical size), related to activation in the right intraparietal sulcus. At the multivariate level, normalized patterns of activation for symbolic number processing exhibited a dissimilar pattern of activation compared to nonsymbolic magnitude processing in both the left and right parietal lobes. However, the patterns of activation associated with quantity and physical size exhibited a large amount of representational similarity.

These findings challenge the longstanding believe that the culturally acquired ability to conceptualize symbolic numbers is rooted in an evolutionarily ancient system that supports nonsymbolic magnitude processing. Moreover, these data reveal that the evolutionarily ancient system used to process nonsymbolic numbers may actually be a general magnitude processing system used to process nonsymbolic numerical and non-numerical magnitudes. These findings highlight the need for the field of numerical cognition to shift away from exploring how symbols are linked to analog nonsymbolic representations, and toward more complex questions related to the neural consequences of learning symbolic abstraction.

P4.107: Mathematics Anxiety, Achievement, and Teacher Influences in a Developing Nation
Presenter: Elayne Teska
Authors: Elayne Teska, Emily Lyons, Lindsey Richland

Mathematical proficiency is a global area of concern, and improving the efficacy of mathematics education is key to increasing nations' successful participation in the global economy. In this presentation, we draw attention to a factor that is under-considered in the global discourse on mathematics education, mathematics anxiety, which is linked to reduced mathematics achievement, with the strongest relative effects seen in the highest-performing youth (OECD, 2013).

The current study examines mathematics anxiety in the highly diverse, developing nation of Belize. We report on relationships between teachers' and students' mathematics anxiety and achievement. Belize offered a unique case to explore these relationships as it is a developing country with lower than average mathematics achievement.

We collected data on mathematics anxiety and achievement from 7,443 4th and 7th graders in Belize. We also collected data on their teachers' mathematical content knowledge, pedagogical content knowledge, mathematics anxiety and self-efficacy.

In a series of regression analyses, we examined relations between student and teachers' mathematics achievement, anxiety, and attitudes. Regression analyses show that student's mathematics achievement is predicted by student mathematics anxiety ($B=-0.07, p<.001$), student self-efficacy ($B=.29, p<.001$), and teacher mathematics score ($B=.08, p<.01$). Student mathematics anxiety is predicted by teacher mathematics anxiety ($B=.05, p<.05$), student self-efficacy ($B=-0.18, p<.001$), and student mathematics score ($B=-0.07, p<.001$). Female students' mathematics anxiety was higher than male students' anxiety ($B=-.20, p<.03$).

Overall, these results provide new insights into how teachers' knowledge of mathematics, and their attitudes toward the subject, affect students' mathematics learning in a developing nation, even amidst the other many structural barriers to learning in the developing country. The cross-sectional data also show that gender differences in attitudes toward mathematics widen over time, with implications for mathematics performance, suggesting that girls are gaining negative attitudes toward mathematics from sources other than their own early mathematics achievement.

P4.108: Impact of Association, Interference, and Priming on Math Story Problems
Presenter: Jill Turner
Authors: Jill Turner, Sabrina Di Lonardo, Jo-Anne LeFevre

Word problems are difficult for many students because comprehension of math and story content must occur simultaneously. In Experiment 1, we attempted to replicate and extend the work of Mattarella-Micke and Beilock (2011). Undergraduates (N = 205) completed 48 multiplication and division story problems online where a protagonist was associated with or dissociated from a set of objects. The story problems consisted of either a highly interfering element ("5" for 3 x 2) or less interfering element ("4" for 3 x 2). We failed to replicate the findings - association and interference did not influence word problem performance. In Experiment 2, interfering numbers were replaced with addition and subtraction questions. These operations were included to test priming effects on multiplication and division performance, and to determine if association or dissociation interacted with priming. Undergraduates (N = 346) completed 64 story problems. When the object was dissociated with the protagonist, participants had higher error rates for addition problems than subtraction problems and higher error rates for division problems than multiplication problems. Furthermore, when multiplication and division problems were primed with an addition problem, performance did not differ across the two operations. However, when these problems were primed with a subtraction problem, participants had higher error rates for division problems than multiplication problems. Thus, performance on story problems is influenced by more than just math knowledge and taps into differences in general cognitive capacity. These findings warrant further investigation into the non-mathematical influences on story problem performance.

P4.109: Math anxiety changes in response to math learning, task, and difficulty
Presenter: Kelly Trezise
Authors: Kelly Trezise, Robert Reeve, Ruohan Xia, Lindsey Richland

Mathematics anxiety (MA) is a significant issue for math educations: impairing problem solving and increasing avoidance. However, few studies have examined the MA that students experience in classrooms. Over two studies, we explored whether MA varies with math task, difficulty, and learning. In Study 1, we examined 140 Australian 13-year-olds' MA experienced during two tasks: a problem solving task, where students solved five types of linear equations, and a math judgment task, where students made judgments about the equivalence of an unknown in two equations. Students' MA was higher for the judgment task than the problem-solving task ($t(137)=5.01$, $p<.001$, Cohen's $d=.427$), and for both tasks, MA was higher for more difficult problems ($F(2.50, 341.79)=91.91$, $p<.001$, $\eta^2p=.40$; $F(1, 137)=30.85$, $p<.001$, $\eta^2p=.18$). In Study 2, we examined MA in 73 11-year-olds' attending an elementary school in the US. Students completed a video lesson on proportional reasoning. During the lesson, students received instruction for two problem solving strategies (Least Common Multiple, and Division), then asked to apply these new strategies to a new problem, followed by a higher order thinking section. Students also completed a pretest, and two posttest assessments: immediately after the lesson, and one week after the lesson. Students reported their MA during each test, and during the lesson. MA varied between the tests ($F(2, 132)=13.77$, $p< .001$, $\eta^2p=.172$); MA was lower at delayed posttest, compared to pretest and immediate posttest. There was also significant variation of MA within the lesson ($F(2.95, 183.14)=34.05$, $p<.001$, $\eta^2p=.35$). MA increased during instruction, and peaked when students applied the two strategies to a new problem and during Higher Order Thinking. Together the two studies demonstrate students' MA can fluctuate in response to educational content. The findings suggest that research is required to understanding the learning and performance implications of these fluctuations in anxiety.

P4.110: Do School Psychologists Believe They Know Enough Mathematics?
Presenter: Kelsey Gould
Authors: Kelsey Gould, Michelle Drefs

The role of a school psychologist has expanded whereby they are now expected to be competent in providing instructional support for various academic subjects, including mathematics (NASP, 2016; see also Ysseldyke et al., 2006). In relation to mathematics support, such a position suggests that school psychologists possess a certain degree of mathematical competency and mathematical self-efficacy to excel in their role. This poster explores school psychologists' mathematical understanding and beliefs as it relates to their mathematical and instructional knowledge. Practicing ($n = 23$) and in-training ($n = 98$) school psychologists from across North America completed a brief beliefs survey followed by a Mathematical Knowledge for Teaching questionnaire (MKT; Hill, 2010) to measure their content knowledge as it relates to number and operations. Pearson correlations were conducted to determine the relationship between school psychologists' beliefs and MKT. Results suggest that school psychologists perceive themselves as having a high level of mathematical knowledge for their role, with a reported mean of 3.99 on a 5 point Likert scale (where 1= I have no knowledge and 5 = I am an expert) and perceived knowledge of mathematics accounted for 8.94% of the variability in MKT scores. Compared to mathematical knowledge, school psychologists reported having less understanding of teaching practices ($M = 2.73$) where perceived knowledge of teaching practices accounted for 7.2% of the variability in MKT scores. Overall, these finding suggests that school psychologists' self-efficacy as it relates to instructional approaches may be a limiting factor in their ability to provide effective mathematical supports.

(P) P4.111: The role of the base-10 system in processing magnitudes using the number line estimation task
Presenter: Kelsey J. Mackay
Authors: Kelsey J. Mackay, Lieven Verschaffel, Wim Van Dooren, Filip Germeys, Koen Luwel

Many theories make a distinction between the cognitive understanding of natural and rational numbers (Moss & Case, 1999; Ni & Zhou, 2005; Siegler, 2016). However, within rational numbers, a distinction can be made between fractions and decimals. Research has found that decimals are more easily processed than fractions (Iuculano & Butterworth 2011; Resnick et al., 2018) which could be due to the fact that decimals are presented in a base-10 system, while (most) fractions are not. We will investigate if the presence of the base-10 system can be a fruitful way to further understand the cognitive processing of numbers (i.e., rational vs. natural; fractions vs. decimals). We will therefore conduct a 2x2 within-subjects design by manipulating number type (natural vs. rational) and base system (base-10 vs. non-base-10). This manipulation leads to four conditions: (a) a natural number base-10 condition (e.g., 250 on a 0-1000 number line), (b) a natural number non-base-10 condition (e.g., 1 on a 0-4 number line), (c) a rational number base-10 condition (e.g., 0.25 on a 0-1 number line), and (d) a rational number non-base-10 condition (e.g., 1/4 on a 0-1 number line). Sixty children (aged 10-12), sixty adolescents (aged 14-16), and sixty adults (over 18 years old) will complete each condition on the computer, while their eye movements are recorded. Our analysis will examine developmental differences in performance (i.e., accuracy and RT) and also examine developmental differences in the processing of numbers (i.e., eye movements). We will analyze the first fixation on the number line, the number of returns to the target number, and the total fixation duration on the different quartiles of the number line. We hypothesize that decimals are more similar to natural numbers compared to fractions, because both natural numbers and decimals are presented in a base-10 system, whereas fractions are not.

(P) P4.112: The effect of formal math instruction on research findings: A cross-educational study

Presenter: Kiran Vanbinst
Authors: Kiran Vanbinst, Lien Peters, Daniel Ansari, Bert De Smedt

The current study aims to investigate to what extent differences in classroom instruction (i.e., emphasis on arithmetic fact retrieval) moderate findings from developmental research on the cognitive determinants of arithmetic ability. The study is preregistered on the Open Science Framework (https://osf.io/4bkp9/), and comprises a cross-educational research design in two groups of children (Belgian and Canadian) with striking differences in their mathematical curricula. Comparing these groups allows us to compare the strength of the association between symbolic numerical magnitude processing and arithmetic fact retrieval in (Canadian) children who are allowed to use counting to solve arithmetic problems, with the strength of this association in (Belgian) children who are prohibited to count and instructed to retrieve arithmetic facts from an early age on. These differences in instruction may moderate the association between symbolic numerical magnitude processing and arithmetic fact retrieval (see e.g., Schneider et al., 2017). Belgian data were collected in February-April 2018 in 50 first and 50 second graders. In February-April 2019, 50 Canadian first and 50 Canadian second graders will be tested with the same testing battery, which comprises measures of arithmetic performance and strategy assessments.

We will perform ANOVAs with Grade (1 vs. 2) and Country (Canada vs. Belgium) as between-subject variables. We will also compare correlations between groups to investigate whether the strength of the association between arithmetic and symbolic numerical magnitude processing is dependent on the educational system. We expect, based on previous literature (Vanbinst et al., 2015, 2017), that children's arithmetic ability will be correlated with their symbolic numerical magnitude processing skills, and with the use of more advanced strategies (note that the definition of an advanced strategy might be education-dependent).

P4.113: Number accuracy and arithmetic in two children with mathematics learning disabilities after a computerized number line intervention

Presenter: Laetitia Marcon
Authors: Laetitia Marcon, Marie-Christel Helloin, Helena Patricia Osana, Anne Lafay

Individuals with Mathematics Learning Disabilities (MLD) often have difficulties in accurately estimating the position of numbers on a number line; such deficits may thus explain why they find arithmetic so challenging. The aim of the present study was to investigate the number accuracy and arithmetic skill of children with MLD after participating in an intensive and individualized number line intervention.

A simple phase change across subjects and outcomes design was used. Two children (9 and 15 years old) practiced estimation and calculation, with corrective feedback, on the digital number line software DéCaLigne during three 30-minute sessions per week for four weeks. Performance was assessed four times: one month prior to and immediately before the intervention, after the intervention to measure immediate performance, and one month later to measure maintenance. The children were assessed on their number accuracy (i.e., placing numbers on a number line) and performance on addition and subtraction computations with the number line (i.e., learning) and without (i.e., mental computation as transfer).

Both children significantly improved their number accuracy and their arithmetic performance, both with and without the number line, between the second baseline and the immediate learning assessment after the invention. They also maintained their number accuracy and their arithmetic performance one month later.

The results support a relationship between estimation and calculation using a number line and arithmetic skill. As such, the number line intervention offers hope to clinicians and teachers, but replications are essential to characterize it as an evidence-based practice.

P4.114: Inducing a mathematical formula buffers against overgeneralization
Presenter: Lauren N. Sprague
Authors: Lauren N. Sprague, Nicole R. Hallinen, Kristen P. Blair, Nora S. Newcombe

A common misstep in mathematical problem solving is to overgeneralize learned procedures to inappropriate contexts. While adapting learned steps to solve new types of problems is a mark of flexibility and expertise, to do so erroneously indicates weak conceptual knowledge of the procedure. Previous work has suggested benefits of induction-based learning over direct procedural instruction, but has not examined whether these instructional methods differentially prepare students to generalize solutions. In two experiments, we investigated whether searching for an algebraic formula before receiving direct instruction facilitates generalization. Guided by evidence that sketching aids in problem solving, Experiment 2 tested our prediction that sketching during the learning period would supplement the positive transfer effects of both instructional methods.

Undergraduates completed a three-block learning phase, followed by a transfer task. In Learning Block 1, we familiarized participants with a perimeter growth pattern problem. During Block 2, subjects were randomly assigned to either induce a formula applicable to the problem, or to learn a formula through direct instruction. In Block 3, both groups were told the formula and practiced applying it. Experiment 2 included two additional conditions: subjects either viewed images of the growth pattern, or were instructed to sketch patterns during Blocks 1 and 2.

The transfer task included three problems that appeared similar to the familiarized problem, but differed in underlying structure and could not be solved using the original formula. Our primary dependent measure was overgeneralization of the formula on these problems. In addition, we qualitatively measured participants' explicit knowledge of the formula's structure.

In both experiments, we find that searching buffers against negative transfer, leading to less overgeneralization for participants who first searched for a formula as compared to those who only received direct instruction. This effect holds for students who searched for, but did not effectively find a formula. Asking students to sketch alleviated some of the negative effects of tell-and-practice, but sketching did not augment the effect of the induction process.

Even when learners do not formulate algebraic procedures themselves, searching seems to be a productive way to help them connect a formula to its referent and avoid making overgeneralization errors.

P4.115: Gender differences in math and spatial anxiety and self-concept in early elementary school
Presenter: Lindsey Hildebrand
Authors: Lindsey Hildebrand, Sara Cordes

Despite little evidence of inherent gender differences in math abilities (Spelke, 2005), gender differences in math motivation and attitudes are visible as early as elementary school (Devine, Fawcett, Szűcs, & Dowker, 2012; Duncan et al., 2007). Moreover, these differences in math motivation and attitudes, especially math anxiety, have been found to relate to lower participation and performance in science, technology, engineering, and math (STEM) activities (Foley et al., 2017). Some have looked to inherent differences in cognition to explain gender differences. However, recent work has highlighted another strong contributor to gender differences in math anxiety in adults– differences in spatial ability (Ferguson, Maloney, Fugelsang, & Risko, 2015) and spatial anxiety (Sokolowski, Hawes, & Lyons, 2019). Not surprisingly, skills in these two domains are intimately related: spatial skills relate to performance in mathematics both concurrently and predictively (Cheng & Mix, 2014; Newcombe, 2010). Further, both math and spatial skills are robust predictors of success in STEM achievement (Wai et al., 2009). In the present study, we explore how math and spatial anxiety and self-concept are related in school-aged children and whether gender differences observed in later adolescence and adulthood are visible at these ages.

First through fourth grade children ($N=72$; 36 male) were given measures of math and spatial anxiety and self-concept (adapted from Ramirez, Gunderson, Levine, & Beilock, 2012, 2013). Gender differences were observed for both anxiety (Math: $t(70)=2.22$, $p = .03$; Space: $t(70)=3.47$, $p = .001$) and self-concept (Math: $t(70)=-4.64$, $p < .001$; Space: $t(70)=-3.90$, $p < .001$) with girls reporting higher anxiety and lower self-concept in both domains. Further, all four measures were significantly related to one another ($ps<.01$). These findings are the first to reveal that gender differences in math and spatial anxieties and self-concept are early emerging, robust, and related.

P4.116: Bias towards fraction components and math achievement in low-income college students
Presenter: Linsah Coulanges
Authors: Linsah Coulanges, Melanie Pincus, Suja Patel, Davendra Beni, Deborah Walker-McCall, Miriam Rosenberg-Lee

Up to 79% of low-income students are unprepared for university level mathematics (Goldberger

2007). To address this gap, many colleges and universities have instituted intensive summer programs with instruction in math and other disciplines, such as Rutgers University- Newark's Academic Scholar's Institute (ASI). This study sought to assess the effectiveness of this program in improving math achievement and to characterize this population's fraction knowledge, a key predictor of future performance in algebra and higher mathematics (Seigler, 2012). Mathematics knowledge was assessed using the Math Fluency and Calculations subtests of the Woodcock-Johnson III. In the fraction comparison task, we contrasted trials where individual components were consistent (3/5 vs. 5/6) or inconsistent (7/9 vs. 4/5) with actual fraction magnitude. We also computed a measure of participants "bias" by assessing how well their responses could be predicted by selecting the larger numerator or denominator, rather than fraction magnitude. Performance on Calculations scores improved significantly ($p<0.001$) following the 5-week ASI program (n=34), while there were no changes in Calculations the control sample of Rutgers students (n=38) that completed the assessments five weeks apart ($p>.5$). Before the program, accuracy on the fractions task positively correlated with Calculation scores (r=.386, p=.032). However, the bias measure had a stronger relationship, with greater use of componential strategies relating to poor math performance (r=-.598, p=.004). Almost a third of participants had bias levels above 80%. While initial fraction performance did not predict gains on the standardized math measures, fraction bias remained a significant predictor of math skills after the program (r=-.479, p=.006), again stronger than the correlation with overall accuracy (r=.114, p=.542). Our results indicate that short-term mathematics instruction can improve performance on standardized math measures for low-income students and suggest that reliance on componential strategies may persist in this population, making it a promising target for intervention.

P4.117: How Chilean Children's and Parents' Beliefs about Who Does Math Influence Math Learning
Presenter: M. Francisca Del Rio
Authors: M. Francisca Del Rio, Maria Ines Superreguy, Katherine Strasser, Carolina Iturra, Ismael Gallardo

Early mathematical skills are critical for later career success in science, technology, engineering, and mathematics (Uttal et al., 2013). Building early and positive beliefs about mathematics can have cascading effects for STEM skill development (Watts et al., 2014). Gender stereotypes about mathematics may contribute to gender differences in attitudes, participation, or performance in STEM fields (Gunderson et al., 2012).

This study investigated how Chilean gendered beliefs related to math – of mothers, fathers, and children – contribute to girls' and boys' math achievement from first to third grade. Participants were 266 (125 girls) children from 1st, 2nd, and 3rd grade and their parents, of both low and high socioeconomic status. Children completed both explicit and implicit measures of gender stereotypes and math self-concept, and two math achievement tests. Mothers and fathers completed the adult versions of the same instruments, along with measures of math anxiety.

Results showed that, on implicit measures of math gender stereotypes, boys and girls associated math with boys significantly more strongly than with girls. Both parents demonstrated the math = male stereotype on both implicit and explicit measures. Children's math achievement was explained by their explicit math self-concept, after controlling for grade and SES. Boys' (but not girls') explicit math self-concept was negatively explained by their mothers' math anxiety. Indeed, there was an indirect significant effect of mothers' math anxiety, via boys' explicit self-concept, on math achievement.

These results show that Chilean children begin to develop gender beliefs about "who does math" early, and these beliefs, as well as those of their parents, affect their math achievement.

P4.118: Fingers dexterity predicts early math skills development: Insight from 3D human motion analyses
Presenter: Maëlle Neveu
Authors: Maëlle Neveu, Line Vossius, Cédric Schwartz, Bénédicte Forthomme, Laurence Rousselle

Children's ability to use their fingers in numerical contexts is assumed to contribute to the development of basic mathematical skills (Fayol & Seron, 2005; Gunderson et al., 2015). Some authors pointed to finger gnosia as a good predictor of arithmetic abilities developed some years later (Fayol, Barrouillet, & Marinthe, 1998; Noël, 2005; Penner-Wilger & Anderson, 2008) while others highlighted the relationship between manual dexterity and early numerical and arithmetical abilities (Asakawa & Sugimura, 2009, 2011, 2014; Suggate, Stoeger & Fisher, 2017). At present, the contribution of the fine motor skills to early number development has been less investigated.

The aim of this study is to examine how manual dexterity contributes to early number and arithmetical processing using 3D human motion analyses, a technique providing fine-grained measures of finger dissociation and finger coordination –two components of manual dexterity. Thirty preschoolers aged between 3 and 5 years old were tested in finger dissociation and finger coordination tasks as well as in tasks assessing early numerical and arithmetic development (i.e. reciting of numbers words, counting, number words cardinal knowledge, calculating with picture support).

The multiple regression analyses showed the predictive value of finger dexterity for cardinality and arithmetic skills while controlling for age differences. This result outline the tight relationship between fine motor skills and early mathematical abilities and suggest that finger coordination could have decisive influences on the use of finger-based strategies in support to the development of numerical concepts and early arithmetic in young children.

(P) P4.119: Parent and Child Spontaneous Focus on Number and Mathematical Talk During Play Activities
Presenter: Mary Depascale
Authors: Mary Depascale, Richard Prather, Geetha Ramani

Parental mathematical talk relates to children's mathematical development. However, parents vary in the type and amount of math talk used with children, and differences in parent math talk relate to differences in children's math learning (Ramani, Rowe, Eason, & Leech, 2015). Few studies have explored the underlying causes of this variation.

Spontaneous Focus on Number (SFON) is the tendency to notice number in one's environment (Hannula & Lehtinen, 2005). There is some evidence that adults vary in their SFON tendency (Chan & Mazzocco, 2017). Variability in parents' SFON may account for some variability in math talk, as the tendency to notice number may influence the content of talk during parent-child interactions. No prior studies have examined parent SFON in relation to math talk.

The current study explores if parent SFON accounts for observed variability in parent math talk, if adult SFON relates to adult math ability, and how parent SFON relates to children's SFON and math knowledge.

Data are being collected from 78 4-, 5-, and 6-year-olds and their parents during one lab visit. Children and parents engage in a 15-minute play interaction with a book, toy cash register and foods, and balance scale. Children and parents then separately complete two measures of SFON (a picture description task and a matching task) and a measure of math knowledge.

Parent-child interactions will be transcribed and coded for math talk. Multiple linear regressions and correlations will be used for the analyses. We expect that SFON will predict math talk for both children and parents. Additionally, we expect SFON to relate to both parents' and children's math knowledge. Finally, in an exploratory analysis, we will examine whether parent and child SFON relate. Results will be discussed in terms of understanding a potential intergenerational transmission of SFON.

P4.120: Flexible Attention to Numerical and Spatial Magnitudes in Early Childhood
Presenter: Mary Fuhs
Authors: Mary Fuhs, Yiqiao Wang, Victoria Bartek, Elizabeth Gunderson

The Flexible Attention to Magnitudes (FAM) account proposed here argues that: 1) Flexibly shifting between both numerical magnitudes (number of items) and spatial magnitudes (e.g., surface area) is a unique challenge in early childhood, and 2) Children's FAM ability is predictive of their early math achievement above and beyond other known correlates, including executive functioning skills. We developed a novel measure for preschool-aged children that explicitly tests children's ability to shift flexibly between attending to numerical and spatial magnitude cues and tested its association with children's math achievement.

Participants ($N = 309$; 51.3% female; Mage = 4 years, 7 months; SDage = 4.35 months) were primarily from low-SES backgrounds. In the FAM task, children were first asked to compare spatial magnitudes of two object sets (stars), then were asked to compare numerical magnitudes of object sets, and finally were asked to switch back and forth between comparing spatial and numerical magnitudes. Numerical and spatial magnitudes were always incongruent. Other assessments included the Minnesota Executive Function Scale (MEFS; Carlson & Zelazo, 2014) and two Woodcock-Johnson IV Early Cognitive and Academic Development subscales, Picture Vocabulary and Number Sense (Schrank, Mather, & McGrew, 2014).

Supporting hypothesis 1, children's performance on the mixed FAM task trials, requiring shifting between attending to either spatial or numerical magnitude cues, was significantly worse than their performance on both the spatial magnitude only trials ($t(294) = 36.13$, $p < .001$) and the numerical magnitude only trials ($t(295) = 12.17$, $p < .001$). Supporting hypothesis 2, FAM ability was a significant predictor of children's math achievement ($\beta = .15$, $SE = .05$, $p = .002$), above and beyond age, family income, language, and executive functioning skills. Future work will investigate whether this ability is a specific predictor of later math learning.

P4.121: Neural correlates for the outcome of spaced versus massed learning in arithmetic
Presenter: Mengyi Li
Authors: Mengyi Li, Xinlin Zhou

There have been several neuroimaging studies focusing on the encoding stage to account for the advantage for spaced learning over massed learning, providing evidence of the deficient processing theory. Little research has been conducted to investigate the neural correlates for the outcome of spaced versus massed learning in arithmetic learning. Using functional MRI, the present study examined the hypothesis that the spaced learning could enhance the performance of the arithmetic test, and enhance the hippocampal activity after spaced learning. Sixteen participants learned 48 two-digit times one-digit multiplication problems in seven learning sessions. In each session, each problem was repeated four times, with half problems presented in spaced learning and the other half presented in massed learning. Participants calculated the arithmetic problems in three times of fMRI scanning (before the learning sessions, after the first learning session and after seven repeated learning sessions) and behavioral test (after each learning session). Spaced learning significantly improved participants' behavioral performance including reduced reaction time and error rate during the arithmetic test administered in and out of the scanner. ROI analysis found that compared to massed learning, spaced learning significantly increased the brain activity in right hippocampal during the 3rd fMRI. The spaced learning in arithmetic learning is better than massed learning possibly due to more time spent during spaced learning. The hippocampus is significant for arithmetic learning.

(P) P4.122: Exploring differences in domain-specific and domain-general abilities between mathematicians and non-mathematicians.

Presenter: Michaela A. Meier
Authors: Michaela A. Meier, Stephan E. Vogel, Roland H. Grabner

Which cognitive abilities are associated with mathematical expertise? While the cognitive foundations for mathematical abilities have been investigated in typical and atypical populations, our knowledge about cognitive abilities associated with mathematical expertise is still scarce. Studies have recently demonstrated that some domain-specific (e.g., exact number representation, estimation skills) as well as domain-general abilities (e.g., intelligence (IQ), working memory (WM) capacity) are differently related to mathematical and non-mathematical expertise. However, since these abilities have never been investigated in the same population, their unique contribution to mathematical expertise is currently unknown.

To fill this research gap, the present work aims to examine differences of domain-general and domain-specific abilities in a group of 40 mathematicians (separated into higher and lower expertise) and 40 non-mathematicians (matched for age, sex and education). The following domain-general and domain-specific components will be measured with behavioral tasks: IQ, WM, patterning abilities (ability to perceive and process patterns), numerical magnitude and order processing, approximation of numerosities (i.e., dot-arrays), arithmetic and mathematical abilities, as well as the capacity to memorize domain-specific material (e.g., twin primes). Behavioral data will be analyzed with a 2x2 analysis of variance with the variables Domain (mathematicians vs. non-mathematicians) and Expertise (higher vs. lower expertise). Based on the existing results described above, we expect significant differences in all domain-specific abilities between mathematicians and non-mathematicians. Furthermore, given the findings from other fields of expertise (e.g., chess), we predict mathematicians with higher expertise to demonstrate higher memory capacity for structured domain-specific material, compared to mathematicians with lower expertise. The present work will contribute to a better understanding of the cognitive mechanisms underlying high mathematical performance.

P4.123: Abacus training decreases the prevalence of developmental dyscalculia in China

Presenter: Yujie Lu
Authors: Yujie Lu, Mei Ma, Xinlin Zhou

Developmental dyscalculia (DD) is a specific mathematical learning disability, with the prevalence of about 3 ~ 7%. Previous DD intervention programmes usually targeted on numerosity, number, simple arithmetic or even general cognitive abilities. The current study investigated the effect of a long-term (2~3 years) abacus training course on the prevalence of DD.

All students in 12 classes of second or third grade in primary school took part in the investigation. The 6 training classes received abacus training (n = 245, 128 boys and 117 girls, mean age = 105.6±7.2 months), while the 6 control class (n = 234, 115 boys and 119 girls, mean age = 103.2±6.7 months) received regular mathematical instruction.

Participants' first-term math grades were collected as pre-treatment baseline. Eight cognitive tasks were administered to assess post-treatment achievements, covering mathematical abilities and cognitive abilities.

No group difference was found in the pre-treatment baseline. The prevalence of DD is 6.4% for controls. No children in training classes suffered from DD. After controlling for age, gender, grade and general cognitive abilities (nonverbal matrix reasoning), children in the training classes showed a higher score in arithmetic computation, and also demonstrated better acuity of approximate number system (ANS) and spatial short-term memory.

The long-term (2~3 years) abacus training decreases the prevalence of developmental dyscalculia, and promotes the development of arithmetic computation, ANS acuity and spatial short-term memory. All the findings suggest that abacus training could be applied into the current school education to solve DD problem and promote children's typical development in arithmetic.

(P) P4.124: One, Two, Three, What? Investigating the Distance Effect in Sequential Number Processing: A P300 Study
Presenter: Nathaniel Shannon
Authors: Nathaniel Shannon, Mona Anchan, Brian Rivera, Firat Soylu

During simple counting we are constantly updating and revising our mental representations in preparation for the next number. Relatedly, the P300 event related potential (ERP) component has been shown to be responsive to incongruities between a sequence (numbers, letters, etc.) and a final target. Specifically, increased response times and increased mean P300 amplitudes are produced when participants are presented with an incrementally increasing sequence of numbers with an incongruent ending when compared to a congruent ending (Polich, 1997, 2007). However, there is little work investigating how distance effects (the numerical distance from the congruent target) among incongruent number sequence endings may affect the mean P300 amplitude. This study will investigate this interaction by comparing behavioral and neural responses to congruent and incongruent sequence endings while monitoring the distance between the target and non-target endings. In the proposed study, 30 participants will be presented with a series three numbers, starting between 1 and 6, which will increase incrementally by 1. The fourth number will contain a congruent or incongruent target; each possible incongruent ending will also be presented to investigate distance effects. Participants will complete 12 blocks of 120 experimental trials (60 congruent, 60 incongruent) while EEG data is recorded. Participants will be asked to report the congruity of the final number of each sequence. An ANOVA (congruity x distance) will be performed to determine the individual and combined effects of congruity and numerical distance. We hypothesize that, as seen in previous research, responses to incongruent sequence endings will evoke higher mean P300 amplitudes and longer response times. It is also hypothesized, that numerical distance effects (Piazza et al., 2004, 2018) will lead to increased reaction times and increased mean peak P300 amplitudes for incongruent sequence endings close to the target when compared to further sequence endings.

P4.125: The relation between math-talk and math-gestures for parent-child dyads
Presenter: Raychel Gordon
Authors: Raychel Gordon, Meredith Rowe, Geetha Ramani

Research has shown that parents' math talk influences their children's mathematical development. However, little is known about the role of parents' mathematical gestures - a unique but related form of mathematical communication. The current study examined the relation between the parents' and children's math-related gestures and math-related talk while engaging in informal learning activities. Twenty-nine preschoolers ($M = 4.41$ years; range = 3.17 to 5.64 years) and their parents were recruited from a Head Start center.

Dyads were given three bags and instructed to play with each activity inside. The activities were a book, a puzzle, and a board game; each of these contained Arabic numerals and other math-related content. Each interaction was transcribed for both verbal and gestural communication.

Parents had an average of 9.125 ($SD = 9.13$) math-specific gestures, ranging from 0-37 instances. Parents produced on average 140.8 math-related utterances ($SD = 64.34$), with a range from 43-340 utterances. Children had an average of 6.0 ($SD = 5.28$) math-specific gestures, ranging from 0-19 instances. Children produced on average 93.83 math-related utterances ($SD = 47.49$), with a range from 18-207 utterances. Parent's math talk was significantly correlated with their use of math gestures, $r = .623$, $p < .001$. Children's math talk was also significantly correlated with their use of math gestures, $r = 0.512$, $p < .01$. However, there were no significant relation between children's math gestures and their parent's math gestures, $r = .20$, $p = .31$.

The overall proportion of math talk for parents was significantly related to children's proportion of math talk ($r = .45$, $p < .05$), suggesting that one person's use of math talk may have influenced the other. However, this relation does not hold for math-related gesture, suggesting that the mechanisms and motivations underlying math gestures may be separate from those of math talk.

(P) P4.126: Fingers come in handy: does finger use support learning a pseudo-number-word sequence?
Presenter: Roberta Barrocas
Authors: Roberta Barrocas, Stephanie Roesch, Korbinian Moeller

The "manumerical" cognition framework suggests that number magnitude representations are rooted in early sensorimotor experiences of finger counting. Although accumulating evidence demonstrates an association of fingers and numerical competencies, so far no study provided direct empirical evidence that finger use corroborates numerical learning. Therefore, this study will investigate whether finger use fosters the acquisition of a pseudo-number-word sequence to emulate children's experience of using their fingers when learning the actual number word sequence. This way, we seek to shed light on the role of fingers for the development of basic numerical skills. We expect that finger use will lead to more efficient learning and recall of the pseudo-number-word sequence.

Participants will be assigned to one of three learning groups. After hearing the sequence, they will have to recite the pseudo-number-words while either: i) moving their fingers sequentially, ii) gently pressing a foam ball (allowing for control of motor action influences), or iii) not employing any elaboration strategy. The number of list repetitions as well as number of position errors until correct sequence recall will be used as dependent variables at three different time points: i) while learning the list, ii) 20 minutes, and iii) one week after learning the list. To evaluate group differences in transferability to other numerical and arithmetic tasks, we will also assess participants' abilities to perform magnitude comparisons and calculation on the to-be-learned pseudo-number words after the training. Finally, verbal working memory and general cognitive ability will be measured as control variables.

Approach for statistical analysis

To test for specific effects of finger on learning the pseudo-number-word sequence, we will conduct MANCOVA with group as a between-participant factor, verbal working memory as well as general cognitive ability as covariates, and number of repetitions, position errors, comparison as well as arithmetic performance as dependent variables.

P4.128: Measuring Preschool Children's Affective Attitudes towards Mathematics

Presenter: Xiao Zhang
Authors: Xiao Zhang, Yawei Yang, Bi Ying Hu, Lixin Ren

Educators and researchers generally agree that mathematics learning should go beyond knowing and applying concepts and procedures and include developing students' disposition (e.g., attitude and self-efficacy) towards mathematics. Attitudes towards mathematics, broadly defined as a state of readiness that exerts a directive influence upon an individual's mathematics learning behavior, are the most studied aspect of mathematical disposition. Mathematical attitudes are associated with mathematics achievement in elementary, middle, and high school students. Yet, little research has been conducted on preschool-age children's attitudes towards mathematics, due mainly to the lack of appropriate instruments for measuring such attitudes among this age group. To fill this gap, this study aims to develop the Preschool Affective Attitudes towards Mathematics Scale (PAAMS; 9 items) and evaluate its psychometric properties in a cross-sectional sample of Chinese preschool children (N = 609). The children were interviewed individually on their affective attitudes towards mathematics activities with their parents, teachers, and classmates and were tested individually on their mathematics performance. Parents rated their children's interest in mathematics activities.

The results showed that a three-factor model that captured young children's affective attitudes towards mathematics activities with their parents, teachers, and classmates fitted the data best. The PAAMS demonstrated acceptable internal consistency reliabilities and satisfactory convergent correlations with parent-report child mathematics interest. Child-report mathematics affective attitudes were positively associated with mathematics performance. The results suggest that the PAAMS is a reliable and valid instrument for measuring preschool children's affective attitudes towards mathematics.

(P) P4.129: Effects of a non-symbolic fraction intervention on proportional reasoning

Presenter: Roberto A. Abreu-Mendoza
Authors: Roberto A. Abreu-Mendoza, Linsah Coulanges, Kendell Ali, Arthur B. Powell, Miriam Rosenberg-Lee

Children can more readily compare continuous proportions than the same quantities segmented into discrete elements, especially when proportional information conflicts with counting knowledge (e.g., 3/5 vs. 4/9). The current study aims to evaluate the effects of a non-symbolic fraction intervention on children's proportional reasoning of segmented proportions and to evaluate the role of inhibition on children's learning gains.

The Experimental group – second-graders participating in an after-school program –will receive a non-symbolic fraction intervention focusing on the proportional relations. A pre/post assessment will measure proportional reasoning by presenting children with two spinners (doughnut-shaped figures) and asking them to choose the spinner with the proportionally larger red area. The Spinner task will be presented in either a Continuous format, or divided into adjacent, Discrete, or non-adjacent Discrete Mixed segments. The number of segments will be consistent or misleading, and spinner size will also vary. To measure inhibitory control, we will use the Hearts and Flowers task. In the Hearts block, children will respond with the hand on the same side as the figure appears; in the Flowers block, the opposite hand; while in the Mixed block, they will see interleaved Hearts and Flowers. The Control group will only complete the pre/post assessment.

To measure the effect of the intervention on proportional reasoning, we will use a mixed repeated measures ANOVA on gain scores (post- minus pre-training scores) with factors Group, Format, Segments, and Size. We hypothesize that the Experimental group will show more significant gains than the Control group on trials where the number of segments is misleading and that children with greater inhibitory control (higher scores in the Mixed condition) will have greater improvements in proportional reasoning.

P4.130: Sex differences in early executive function components vary by measurement type
Presenter: Sammy Ahmed
Authors: Sammy Ahmed, Ying Wang, Dominic Kelly, Frederick Morrison

There is a growing body of research that suggests children's executive functions (EF) are particularly important for supporting emerging math skills. Many math related activities and tasks require children to actively process and manipulate information, maintain and shift their attention to aspects of a task, and apply reasoning based skills. Recent research on EF development has revealed small sex differences in early EF development, favoring females. However, the literature is largely mixed and discrepancies in the magnitude and significance of sex differences across sub-components, and measurement type have been documented. Thus, the current study examined early sex differences in EF across individually assessed cognitive tasks, teacher reports, and group-based EF assessments.

Participants were 195 kindergarteners (104 boys, 91 girls) that were assessed individually, using three cognitive tasks (Head-toes-knees-shoulders, Digit Span-Backwards, Pair Cancellation), and in a group context, using newly developed EF tasks that mimic classroom behaviors (Ahmed, & Morrison, 2018). Teacher-reported EF was measured using 19 items from the CBQ (Rothbart, 2001).

CFA revealed a one factor solution for individually-assessed tasks, and 3-factor solutions for group based and teacher reports ($\chi 2$ (197)=318.8, p=.000; CFI=.92; TLI=.91; RMSEA=.05). Further, we observed significant sex differences in all three group-based, and teacher reported EF components - all favoring girls. But for individually assessed measures, only significant sex differences emerged for response inhibition, not for attention or working memory.

These results highlight the need to consider measurement type when studying early sex differences in EF. It is possible that when assessed individually, in a controlled lab-based setting, sex differences are less likely to emerge than when assessed in a naturalistic setting in the presence of peers and distractors. Given EF's role in supporting early math skills, understanding the nature of early sex differences in EF development would have important implications for educational practice and instruction.

P4.131: Measuring the Quality of Parent-Child Interactions and the Relation to Preschool-Aged Children's Math Skills
Presenter: Shirley Duong
Authors: Shirley Duong, Sarah Pitulski, Heather Bachman, Elizabeth Votruba-Drzal, Melissa Libertus

Previous research has demonstrated that the frequency of math-related conversations that parents engage in with young children predicts children's math abilities. However, this approach does not consider the quality of parent-child interactions, such as the types of questions parents ask or the different roles that children and parents take in these interactions. The present study addresses this research gap by examining the links between the quality of parent-child interactions (34 dyads; mean child age = 4 years 6 months) in a 5-minute structured puzzle activity and children's concurrent math abilities. Quality is indexed by the frequency of the following three categories of behaviors: (1) domain-general parental scaffolding (praise and motivational preservation), (2) task-specific parental scaffolding (correction and explanation), and (3) parent and child elicitations (recruitment of interest, directiveness, and questioning). Moreover, the complexity of questioning is coded as either low-level (e.g., perceptually-based questions) or high-level (e.g., abstract questions). Children's math skills are measured with widely used assessments of number and spatial skills. Pearson correlations indicate that the frequency of parents' explanations is positively associated with children's approximate number system (ANS) acuity ($r = .47$, $p<.05$), spatial skills ($r = .36$, $p<.05$), and standardized math scores ($r = .48$, $p<.01$). Further, the frequency of parents' low-level questioning is negatively related to children's ANS acuity ($r = -.43$, $p<.05$), number skills ($r = -.41$, $p<.05$), and spatial skills ($r = -.42$, $p<.05$). No other correlations reached statistical significance. This investigation provides a novel examination of qualitative aspects of parent-child interactions and their associations with children's early math abilities, which has the potential to inform interventions aimed at promoting young children's math skills.

P4.132: Linguistic Influences on Number Line Estimation: Digit Identity and Inversion effects
Presenter: Sophie Savelkouls
Authors: Sophie Savelkouls, Katherine Williams, Hilary Barth

Despite the common assumption that number line estimation (NLE) performance is driven by the magnitude of the presented numeral, recent studies show that specific digits may also influence performance. Lai, Zax & Barth (2018) found that estimates for numerals on either side of a hundreds boundary (e.g. 299/302) were placed in very different locations despite having indistinguishable magnitudes on a 0-1000 number line. The present study asks whether this left digit effect (LDE) could in part be due to the order in which numerals are spoken. Although in English the leftmost digit is spoken first ("forty-one"), the inversion property of other languages (e.g., German, Dutch) means that the rightmost digit is spoken first ("eenenveertig" – one and forty in Dutch). Thus, we asked whether the order in which number words are spoken might influence the LDE.

Participants included English monolinguals (N = 20) and Dutch-English bilinguals (N = 40, half tested in English, half in Dutch). Using a standard 0-100 number line, participants estimated the location of 30 target numbers including 9 tens-boundary pairs (e.g. 39/41). Importantly, target numbers were read aloud by an experimenter, in either English or Dutch, to ensure that participants were basing estimates on the spoken language. The LDE was measured with difference scores (for each pair, estimate for larger target - estimate for smaller target).

Pre-registered analyses revealed a strong LDE in monolingual English speakers' estimates: participants systematically placed 39 farther to the left and 41 farther to the right ($p < .05$). However, no LDE was observed among Dutch-English bilingual participants tested in either language (p's >.09).

This finding is consistent with the idea that the order in which digits are spoken influences multi-digit number processing, suggesting linguistic influences on estimation abilities.

P4.133: Word-Problem Solving in English Language Learners
Presenter: Stephanie Hadden
Authors: Stephanie Hadden, Sarah Macintosh, Heather Douglas, Chang Xu, Jo-Anne LeFevre

Children learn mathematics through language. Language skills are implicated in arithmetic (Sowinski et al., 2015) and word-problem solving (Fuchs et al., 2006). With 1 in 5 Canadians speaking an immigrant language at home (Statistics Canada, 2016) it is important to distinguish the relations between math skills, the home language and the language of instruction. In this study, we compared symbolic math skills and word-problem solving skills amongst first language learners (L1; n=52) and English language learners (L2; n=26). Children (Mage = 8 years, 4 months) completed measures of symbolic math skills (number comparison, number ordering, and arithmetic fluency) and word-problem solving (Key Math). Both groups of students performed equally well on the symbolic math tasks. In contrast, English language learners performed significantly worse on the word-problem solving task than first language learners. Interestingly, an item-by-item analysis showed that performance was significantly different on the easiest questions: L2 students made more mistakes (76% accuracy) on the most basic questions compared to L1 students (>94% accuracy) on these same questions. A qualitative error analysis indicated that the L2 children made more comprehension-type errors than procedural errors. Although many students struggle solving word problem, these findings indicate that word problems are more challenging for L2 students than L1 students and these extra challenges are likely related to comprehension as opposed to calculation.

P4.134: Rules of Order: Evidence for a fundamental bias when processing the ordinality of numbers
Presenter: Sylvia Gattas
Authors: Sylvia Gattas, Ian Lyons

Research on how people process numerical order carries implications for our basic theoretical understanding of what a number means and our practical understanding of the foundations upon which more sophisticated mathematics are built. Previous work has consistently shown that one's sense of ordinality is linked to the count-list, leading to a general assumption that participants are strongly biased to see sequences of numbers that match the count-list (2-3-4, 5-6-7) as being in order.

One relatively unexamined consequence of the link between ordinality and the count-list is a to see all non-count-list sequences as not in order (even when they actually are: 1-3-5, 2-4-6). Here, we disentangled these factors using a novel paradigm that manipulated the rules for determining whether numerical sequences are 'in-order'. While we found strong biases to see ordered, non-count-list sequences as 'not-in-order' (single-digits: d=1.25, double-digits: d=1.50), we saw only weak biases to see count-list sequences as 'in-order' (single-digits: d=0.33, double-digits: d=0.19). Furthermore, the non-count-list bias provided a stronger and more consistent explanation for the reversal of the distance-effect (single-digits: d=0.42, double-digits: d=0.65), relative to the countlist bias (single-digits: d=0.28, double-digits: d=0.22). These data provide evidence that over-reliance on the count-list in guiding our sense of numerical order may restrict our broader sense of what it means for numbers to be ordered, which in turn provides a novel explanation for a common phenomenon in numerical cognition. More broadly, this work helps describe how people think about one of the foundational principles of mathematics - numerical order.

P4.135: Enhancing Multi-Digit Number Knowledge Through Number Board Games
Presenter: Winnie Wai Lan Chan
Authors: Winnie Wai Lan Chan, Terry Tin-Yau Wong

Young children start to make sense of multi-digit numbers well before they are taught formally in school. Although informal activities in daily life appear to play an important role, it seems that no intervention study has been taken to examine such possibility. Informal activities such as number board games have been found to be effective in enhancing basic number knowledge. In the present study, we aimed to examine whether such games would be useful in helping young children to understand multi-digit numbers. Ninety-one children studying in the lower kindergarten in Hong Kong played some board games for 30 minutes each day for six days. They were randomly divided into four groups. Three groups of children played number line board games (i.e., roll the dice and move one's token forward the number of spaces as rolled on the dice). The experimenters helped the children to map the numbers onto their magnitudes on the number line (mapping condition), or drew the children's attention to the ordinal sequence of the numbers (ordinal condition), or did both (mapping and ordinal condition). Another group of children played colour board games which had nothing to do with numbers (control condition). All children completed a multi-digit number comparison task before and after the games. Results showed a significant group difference in the post-test, after controlling for the pre-test performance. In particular, the mapping group performed significantly better than the ordinal group in the number comparison task after playing the games. These findings suggest that playing number board games, especially when the number-magnitude mapping is highlighted, can help young children to make sense of multi-digit numbers.

P4.136: Assessing Math Performance Errors in Young Girls: Considering Age, Race and elf-Efficacy When Designing Math Interventions

Presenter: Yvette Harris
Authors: Yvette Harris, Seyma Inan, George Woodbury, Seham Almutairi, Madison Cook, Karmiella Ferster, Reagan Brown, Da Yeon, Carolina Garcia

For the past several decades, researchers have turned their attention to analyzing the pattern of errors that children make on cognitive/ problem solving tasks (Makonye & Fakude, 2016). According to these investigators, error analysis (EA) serves two main purposes. One, EA allows researchers to determine the underlying cognitive skills that map on to error patterns, two, EA, provides guidance to teachers on interventions that match a student's unique error profile (Rittle-Johnson & Alibali, 1999). Expanding upon this work, with a focus on math performance, the goal of our study was to explore the relationship between age, race and self-efficacy and error patterns in a group of school age girls from diverse cultural and economic backgrounds.

Eleven African American (Mage= 9.36 years, SD = 1.63), 18 Caucasian (Mage= 9.11 years, SD = 2.06) and one Hispanic and one Asian (Mage= 9.5 years, SD = 0.71) were recruited from a tri-county area. Girls completed a math self-efficacy questionnaire, and the Aimsweb curriculum-based measure in Math Computation (M-COMP) and Math Problem-solving (M-CAP) evaluated their math performance.
Mann-Whitney U tests indicated that African American girls committed more factual errors ($U = 17.0$, $p < .001$) and more conceptual errors ($U = 45.5$, $p = 0.028$) than Caucasian girls on the M-COMP and M-CAP. No significant differences emerged for age, or self-efficacy and error patterns.

African American girls in particular experience challenges on math computation and math problem solving tasks in terms of factual and conceptual errors. Their pattern of performance suggests that they have not yet mastered math vocabulary, and either overgeneralize the use of concepts or have a very narrow definition of a given math concept. We offer suggestions on ways to develop targeted interventions for African American school age girls with a focus on math pedagogy, self-efficacy and modifying home environmental variables.

P4.137: Intelligence mediates the relationship between exact arithmetic and verbal working memory

Presenter: Zhang Tingyan
Authors: Zhang Tingyan, Wei Wei,

This study examined the role of verbal and spatial working memory in solving approximate arithmetic and exact arithmetic. Specifically, whether, and to what extent, intelligence could affect the relationship between verbal and spatial working memory and approximate arithmetic and exact arithmetic. A sample of 206 university students were administered tests of approximate arithmetic, exact arithmetic, two verbal working memory tasks (complex span task and digit span backwards task), two spatial working memory tasks (symmetry span task and Corsi span task) and two intelligence tasks (Raven's progressive matrices task and LPS reasoning scale). We used AMOS to analyze all the data. The results revealed high correlations between verbal working memory and two types of arithmetic ($r = 0.71$ for approximate arithmetic, $r = 0.59$ for exact arithmetic). In contrast, there was low correlations between spatial working memory and two types of arithmetic ($r = 0.10$ for approximate arithmetic, $r = 0.08$ for exact arithmetic). Furthermore, based on a mediation analysis, the relationship between verbal working memory and exact arithmetic was found to be entirely indirect via intelligence. However, intelligence had no effect on the correlation between verbal working memory and approximate arithmetic. These results suggested that the unique contribution of spatial working memory was smaller both in approximate arithmetic and exact arithmetic. However, verbal working memory was effective at predicting approximate arithmetic and exact arithmetic. More importantly, verbal working memory was also found to have an indirect effect, mediated by intelligence, on exact arithmetic.

Collaboration Pitches Abstracts:

C1: Opportunities to Learn via Big Data in a Numeracy Intelligent Tutor

Presenter: Rene Grimes, University of Texas, Austin
Authors: Rene Grimes

An underlying question in mathematics cognition is "How much time do students need to reach levels of proficiency on any given mathematical skill?' Class time may not be an adequate measure: spending more time does not guarantee students are actively engaged in the learning process. A better level of analysis may be the number of tasks students require to reach mastery. Having a baseline of approximate numbers of "opportunities to learn" students need, on average, to acquire specific skills, and which skills seem to be the most difficult or need the most practice, could help teachers establish and plan subsequent teaching. However, findings are mixed as to which types of tasks are most predictive of later math skills. Recent research suggests non-symbolic representations are important in early numeracy but symbolic representations are predictive of later math skills. Additionally, research of non-symbolic representations has narrowly focused on incorporating dots and dot arrays for comparison tasks; although, the use of number lines has received some attention as an important tool for developing conceptual understanding of fractions and ratios. Nonetheless, other non-symbolic representations are used in classrooms; for example, tally marks, bar models and number rods. One economically valid way to analyze the different types of non-symbolic representations, and symbolic representation, for instruction of number naming, counting, cardinality and ordinality is through the use of instructional computer applications containing these elements. Incorporating data mining and learning analytics methods evaluating the efficacy of existing numeracy software may make it easier to explore questions related to the differences in the types of numerical representation, as well as differences in specific mathematics tasks. One type of technology is particularly well suited for this type of analysis: intelligent tutoring systems (ITS). ITS are mastery based, highly adaptive, and include embedded formative assessment. I am currently conducting an exploratory study of the log-file data of several thousand users of an early numeracy ITS, as well as conducting a replication study of a dissertation on the efficacy of this ITS. Collaboration with researchers and educators using this ITS, in both laboratory and school settings, will add to the scant literature on how humans perceive and process different types of non-symbolic representations; the roles of continuous magnitude and the approximate number system; and processing of mathematics vocabulary and early numeracy tasks. I invite statisticians familiar with data mining and learning analytics methods, mathematics cognition researchers, and classroom teachers to join me in fun, but rigorous, empirical studies which will include analyzing big data sets of an early numeracy ITS program. In order to help us understand some of math cognition's most wicked problems, we need to investigate the roles of different non-symbolic representations as well as the number of and types of skills necessary to master early number sense skills. Collaborators interested in studying different age ranges of participants, various study settings, different populations, and speakers of both English and Spanish will expand our current understanding. Are you ready to learn?

C2: Mathemarmite: a video game to train children count

Presenter: Pedro Cardoso-Leite, University of Luxembourg
Authors: Pedro Cardoso-Leite, Brice Clocher, Aurelien Defossez, Michel Fayol, Rory Flemming, Dominic Mussack, Paul Schrater

Numerous studies show that early mathematical abilities determine to a significant extent subsequent educational achievement in mathematics. Differences in these abilities exist prior to entering school, persist over decades and are at least in part determined by socio-economic status. It appears then, that interventions targeting the improvement of early mathematical abilities might be beneficial in terms of the long-term return on training-investment and reduce the impact of social inequalities on education.

Many interventions have already been devised and yielded promising results. However, they are rarely developed to production quality and scalable. It is worth noting here that our digital landscape has radically changed over the past decade and that most children today have access to mobile devices. Hence, developing early mathematical interventions in the form of video games might hold the key to improve mathematical abilities at a large scale and at a low cost.

We developed Mathemarmite (http://mathemarmite.lu/)—a freely accessible video game that offers young children an opportunity to hone their counting abilities in a cosy, timeless and friendly environment where they follow recipes and mix ingredients in the right quantities to cast spells and discover a variety of monstrous transformations that they can immortalize in their Monster Photobook.

Mathemarmite, however, is not only a game—it is also a research project that involves experts in game design, mathematical abilities and machine learning. As people play the game, data is gathered to personalize in real time the individual's learning experience but is also processed extensively offline to improve our understanding of mathematical cognition. Knowledge gained with the data collected in this game will be used to improve the game and hopefully learning in subsequent iterations.

C3: Study of the causal role of the intraparietal sulcus in tasks that involve complex processing of magnitudes: space, number and time
Presenter: Sara Garcia Sanz, Universidad de la Sabana, Colombia
Authors: Sara Garcia Sanz, Diego Redolar Ripoll, Josep Maria, Serra Grabulosa

In recent years it has become evident that the parietal cortex is involved not only in the detection of numerosity, but in the quantification of environmental variables. The processing of time, space and number are very interrelated. There are no studies about the involvement of the intraparietal sulcus in tasks that involve a combination of these three aspects. On the other hand, non-invasive brain estimation techniques allow establishing causal relationships between brain regions and cognitive functions. With this project, we seek to establish the causal role of the IPS in performing tasks that involve the integration of temporary, spatial and numerical information. A TMS study will be carried out to elucidate the involvement of the IPS and other structures in the performance of comparison tasks whose execution implies the conversion between symbolic and non-symbolic magnitudes, as well as the integration of temporary, spatial and numerical information; such as flow, time and volume; and the ability to interconvert between them. We intend to develop an instrument that allows to measure the ability to handle quantitative information of the environment. It is about measuring the capabilities of conversion between symbolic and non-symbolic magnitude information; and integrating space, time and number. For example, by comparing a flow of water and the number of bottles that are filled.With the present collaboration pitch is intended to receive feedback about the design of tasks with a greater ecological value. If IPS is not only involved in numerosity but in the general processing of magnitude, this has important educational implications. In contexts where spatial orientation or the ability to compare magnitudes are skills that are highly developed, it can be a method to strengthen mathematical competence, But tests that have a greater ecological validity are required for assessing. And it is also needed a better knowledge of the neural bases of mathematical processing.

C4: Effects of attitudes, mindset, and anxiety on children's maths performance
Presenter: Dawn Short, Abertay University
Authors: Dawn Short, Janet McLean

Research shows children's numeracy attainment in Scotland is falling, with the academic attainment gap between children from wealthiest and poorest backgrounds expanding (Scottish Government, 2016). This is important as poor numeracy can lead to life-long negative effects (OECD, 2016; Schneider et al. 2017).

My study is a cohort sequential longitudinal design, beginning when children commence formal education (age 4.5 – 5 years), following 200 children for the first two years of school, and comparing performance over time. It investigates numeracy skills (Pearson, 2009) and uses numerical mapping tasks (Li et al. 2018), to investigate children's performance on symbolic and non-symbolic representation of number (Gilmore, 2014; Li et al. 2018). Children's and teachers/caregivers' maths anxiety and growth mindset are also assessed (Gunderson et al., 2013; Ramirez et al., 2013).
The study aims to identify periods in children's mathematical development where interventions to improve numeracy skills of at-risk children would be most beneficial. Previous research (eg. Jordan, Kaplan, Locuniak, & Ramineni, 2007; Jordan, Glutting, & Ramineni, 2010; OECD, 2016) demonstrates the educational trajectory of disadvantaged children is most affected by poor numeracy skills in the first years of school, but most research occurs in affluent populations. Therefore the authors wish to collaborate with others working with similar populations, to create larger data sets to inform this research area and enable development and testing of an effective intervention.

<u>Research Questions</u>
1. What is the relationship between children's numerical mapping ability and their performance on numeracy tasks through the first years of school?
2. Are female students more affected than male students by maths anxiety of their teachers, and if so, will a teacher awareness intervention reduce this transfer of maths anxiety?
3. Is there a relationship between growth mindset instruction in the first year of school and children's attitudes and performance on maths?

C5: Home Numeracy Experiences In Many Countries
Presenter: Jo-Anne LeFevre, Carleton University

Creating a global network of researchers to study Home Numeracy across the world.

C6: Working memory and math performance: the influences of SES and parenting practices

Presenter: Kerry Lee, The Education University of Hong Kong
Authors: Kerry Lee

Mathematics performance in early schooling is linked to both later success in adulthood and, indirectly, to future health outcomes. Compared to reading, we know relatively little about the early predictors of later mathematical success and how to help children who are falling behind. Research has shown that children's working memory capacity (WMC) is one of the best cognitive predictors of mathematical achievement. Defined as the amount of information that can be processed and remembered simultaneously, WMC typically explains 25% of variance in mathematics performance. In a previous study, we showed that this correlation is particularly high at the start of formal schooling and surpasses that of prior performance in mathematics (Lee & Bull, 2016). Surprisingly, despite robust individual differences in WMC at each grade, the rate at which WMC increased did not differ across individuals. This is an important finding and put the spotlight on the origins of individual differences in WMC.

The proposed study will examine whether some aspects of socioeconomic status (SES) are more closely associated with differences in WMC. It will also examine whether this relation is mediated by factors associated with SES (e.g., parenting practices, the kind of games to which children are exposed). Data will be collected from several sites worldwide because subjective perception of SES and its affordances will likely vary with different socio-cultural practices. Data collection just commenced in Hong Kong and will soon commence in Thailand. At each site, we will sample ~211 5-year-old children (stratified into low, medium, and high SES groups) and their main care-givers. Children will be administered a short battery of three working memory tasks. Their care-givers will be asked to complete a survey on SES parenting stress, parenting styles, and home affordances.

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