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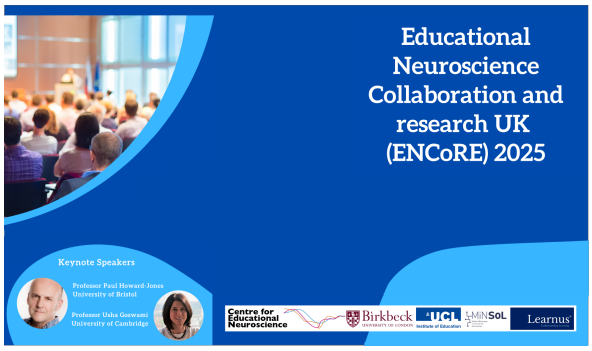

Table of Contents by Topic

Author index

Abstracts

Predicting mathematics self-efficacy and anxiety in further education students: the importance of individual psychological variables and perceptions of past and present teachers

Masha Apostolidu, Thomas Hunt

Background: In the UK, Further Education (FE) serves as a vital pathway for students aged 16 and over to pursue academic, vocational, and technical qualifications. Many FE students must retake GCSE mathematics after not achieving a grade 4 or higher, a requirement for numerous educational and employment opportunities. This cohort often struggles with high mathematics anxiety (MA) and low mathematics self-efficacy (MSE), both of which are critical psychological factors influencing mathematics performance. While prior research highlights the role of student self-beliefs and teacher perceptions in shaping MA and MSE, limited attention has been given to FE students in England, particularly regarding the influence of past and present teacher perceptions.
Methods: This exploratory correlational study examined the relationships between FE students' maths self-beliefs (self-concept, self-regulation, mindset, and utility value), perceptions of past and present teacher characteristics, and their impact on MA and MSE. The sample comprised 152 adult learners aged 18+ enrolled in FE mathematics courses in England, recruited from direct contact with 20 FE colleges in England. Two hierarchical regression models were employed: one predicting MSE and the other predicting MA. Control variables included trait anxiety, test anxiety, gender, and special educational needs (SEN).
Results: Mindset, self-concept, and self-regulation significantly predicted MSE, while MA was negatively associated with these factors. Perceptions of past and present teacher fairness and positive teaching correlated with MSE but were not significant predictors. Current teacher fairness significantly predicted MA, aligning with prior studies, while past teacher perceptions had limited influence. Mindset uniquely influenced MA, contrasting with literature suggesting broader effects of self-beliefs.
Conclusion: This study underscores the importance of supportive teacher-student relationships and self-regulatory behaviours in addressing MA and improving MSE among FE students. While self-regulatory behaviours and task relevance emerged as key predictors of MSE, the expected influence of mindset was less pronounced in this context. Teacher characteristics, particularly perceptions of fairness and support, were crucial in mitigating MA.
Implications: Future research could focus on larger samples and longitudinal designs to better understand how teacher-student dynamics evolve and influence outcomes over time. Such studies could provide deeper insights into how changes in teacher behaviour or student perceptions across an academic year influence self-efficacy and anxiety. Investigating interventions, such as professional development programs for educators, could also offer practical solutions for improving teacher-student interactions. Overall, this research is an important step toward understanding and addressing the unique barriers that FE adult learners face in mathematics.

Finger-based numerical representations in the sensorimotor cortex in children and adults — Evidence from fNIRS

Christina Artemenko

Background: Most children use their fingers when learning to count and calculate. These sensorimotor experiences are assumed to lead to embodied finger-based representations of numbers. For instance, the subbase-5 effect reflects increased difficulty in arithmetic problems that cross the subbase-5 boundary and thus require calculations to move from one to the other hand (e.g., 4 + 3 vs. 6 + 1). On the neural level, associations were assumed to originate from overlapping neural representations of fingers and numbers.
Methods: In a series of functional near-infrared (fNIRS) studies, we investigated the subbase-5 effect in mental arithmetic and its neural correlates in children (Artemenko et al., 2022) and adults (https://aspredicted.org/q9mm3.pdf). In children, a finger-based training was employed and followed up with fNIRS measurements during single-digit addition targeting at the subbase-5 effect in trained children compared to a control group. In adults, fNIRS was measured during two-digit addition and subtraction targeting the subbase-5 effect as well as the carry/borrow effects. Importantly, the arithmetic tasks were administered without the use of fingers.
Results: First, we found that finger-based training in children during the first year of school leads to the subbase-5 effect with neural activation in the sensorimotor cortex, associated with finger implicit movements. This indicates embodied finger-based numerical representations after training. Second, we failed to replicate the subbase-5 effect in adults on a behavioral level, with a reverse subbase-5 effect in addition and no subbase-5 effect in subtraction. On a neural level, however, traces of the subbase-5 effect were found in the sensorimotor cortex. This suggests that finger-related numerical representations might still persist until adulthood but might be less robust than expected.
Conclusion & implications: Together, these results suggest that finger-based numerical representations might be transient during the explicit use of fingers for initial arithmetic, with only slight traces in adulthood. The questionable replicability of the effect in adults might suggest that finger-related representations are more relevant to single-digit than multi-digit arithmetic. Nevertheless, the results of this research point at the effectiveness of embodied arithmetic learning in children.

Information trade-offs in adolescents with Autism and spectrum of ADHD traits

Khadijah Asif, Teodora Gliga, Andrew Bayliss

Background: We process large amounts of information from different sources in our daily life, requiring a visual attention system that selectively processes relevant, and inhibits irrelevant information. A shift in attention from one source of information to another occurs when the effort needed to continue extracting information from the first source outweighs the relative benefit. Information seeking, and visual engagement are areas that have received some interest within autism research however largely conflicting results have emerged, and cooccurrences with ADHD are neglected.
Methods: In our paradigms visual attention is measured through two sources. The first is frontal theta oscillatory power which indexes information seeking, directed towards video repetitions and secondly, P1 component of an ERP indicating early sensory processing directed towards brief flashes of a distractor image interrupting the repeated videos.
In infants we have seen that modulation between the two measures (frontal theta activity and P1 amplitude) is predicted by individual differences scores on the ITSP which measures sensory seeking behaviors (Piccardi et al.,2021).
Predictions & Results: We expect similar trends of modulation in our sample of 40 adolescent (aged 13-17) where we use multidimensional trait measures of autistic and ADHD traits as well as measures of executive function. In adolescents we predict a similar trend of high engagement with the video followed by decline and subsequent increase in response to the distractor. Moreover, we expect to see adolescents with high ASD scores to exhibit the neural 'shift' (ie: when average theta power to video decreases and P1 ERP component to distractor image increases) with a sharper change and the opposite, a shallower change in adolescents with higher ADHD traits.
Conclusion: With our EEG paradigm, where information seeking and visual disengagement is indexed through changes in neural signal alone, we show that adolescents with higher autistic traits exhibit patterns of modulation that reflects lower sensory seeking behaviors and vice versa with ADHD traits presenting reflecting higher sensory seeking. We discuss how these fits in with our understanding of neurodiversity, where traits converge and diverge from each other.

Neuroeducational profiles of gifted children and adolescents: A Systematic Review

Derya Atalan Ergin (Cappadocia University), Gülendam Akgül (Ankara University)

Background: Giftedness refers to exceptional abilities in reasoning and learning within intellectual, creative, or artistic domains, typically with an IQ two standard deviations above the mean. Neuroimaging advancements have allowed researchers to explore distinctive brain patterns in structure, connectivity, and function that may underpin the enhanced cognitive abilities of gifted cildren and adolescents, aiming to apply these insights to optimize their educational experiences.
Methods: The objective of this systematic review is to synthesise the existing literature on the neurological profiles of gifted children and adolescents in relation to educational outcomes. A systematic electronic search will be conducted in accordance with PRISMA guidelines, utilising five databases: Web of Science, Scopus, PubMed, PsycINFO, and Medline. The keywords are "educational neuroscience", "neuroeducation", "neuroscience", "gifted", "giftedness", "talented", "high ability", "highly intelligent", "superior intelligence", "high intelligence", "high-IQ", "twice-exceptional", "exceptional students", "exceptional children". The review included papers published in English, empirical observational studies reporting quantitative data, and peer-reviewed studies. The studies were conducted with children and adolescents from the general population, aged between 5 and 18 years. All data pertaining to brain structure and the development of gifted children and young people will be extracted. For each included study, the following information will be extracted: type of publication, year of publication, journal name, subject category (e.g., psychology, social science, sociology), sample size, gender, mean age, age range, ethnicity, socio-economic status, country, number of participants, neuroimaging technique used in the study, research outcomes, and connections to educational practices of gifted children (Prospero ID number:628037)
Results: This registered study is currently in progress, and data collection and analysis are underway. The results are expected to provide significant insights into gifted education.
Conclusion: The results will be discussed in the context of the neurological differences between gifted and non-gifted children and adolescents, with a particular focus on their reflection in educational settings and outcomes for teachers working with gifted students.
Implications: The study identifies distinctive neurological patterns in gifted individuals, providing guidance for the implementation of bespoke educational strategies, including curriculum acceleration, enrichment programmes and personalised learning plans, which are designed to better meet their needs.

Teachers' attitude towards educational neuroscience in Türkiye

Derya Atalan Ergin (Cappadocia University), Gülendam Akgül (Ankara University), Evren Morgül (Roehampton University)

Background: The field of educational neuroscience seeks to comprehend the efficacy of educational approaches by integrating knowledge from multiple disciplines through the utilisation of various methodologies for the collection of biological and behavioural data. Teachers are the primary individuals responsible for facilitating learning in educational settings. Lessons that are designed with an educational neuroscience approach are of significant importance in enhancing the retention of information in students. In this study examined teachers' attitudes towards neuroscience and educational neuroscience.
Methods: In the study, interviews were conducted with teachers working in middle schools and teaching various subjects. A total of seven open-ended and semi-structured questions were posed to the teachers regarding neuroscience and educational neuroscience. After the transcription of the responses, the answers were analyzed through content analysis. Initial results were presented based on analyses conducted with a total of 10 teachers. The interviews are ongoing, with a target number of 50 teachers.
Results: The majority of teachers confirmed that they had not received any training on neuroscience. They used different sources (e.g. social media, books, or journals) to gain knowledge in this area, but in a very limited manner. The majority of the teachers surveyed expressed a belief in a relationship between the brain and learning. In addition to neuromyths related to the learning process (e.g., "the dominant brain hemisphere affects learning"), the study found that teachers possessed some knowledge about types of memory. The majority of the teachers expressed the view that neuroscience knowledge could be applied to education. When asked about the methods of application, the responses focused on potential adjustments in teaching methods and techniques, such as guiding students with interpretative questions or incorporating games into lessons. However, it was also noted that the applicability of neuroscience in educational settings might be hindered by factors such as the characteristics of students (e.g., younger students being more concrete thinkers), the gap between theory and practice (e.g., schools not being suitable environments for application), and teachers' lack of sufficient knowledge. The teachers emphasised the importance of teachers being knowledgeable about neuroscience, as it could positively influence the teaching and learning process. Finally, the teachers emphasised that neuroscience training should include topics such as the structure and functioning of the brain, how this knowledge can be applied in educational settings, and examples from real-world practices. The pedagogues emphasised that such training should be uncomplicated, pragmatic, and oriented towards application.
Conclusion: The findings of the study revealed teachers' lack of knowledge about neuroscience and educational neuroscience. However, they stated that neuroscience could be used in educational settings and could have a positive impact on learning. This indicates the teachers' positive cognitive and emotional attitudes toward neuroscience and educational neuroscience.

Implications: Educational neuroscience studies in Turkey are quite limited. The findings of this study also indicate that teachers' knowledge in this area is highly limited. Therefore, it is recommended that the topic be incorporated into educational programs for teacher training faculties and professional development programs for in-service teachers.

A small-scale exploration of the differing ways in which a sample of young people with mathematics difficulties use finger-counting to help them calculate

Diana Ball (University of Chester)

Background: While many young children use their fingers when they are taking their first steps in counting and arithmetic, the general consensus in the literature is that children usually move away from this practice by the age of 7 or 8 (e.g. Costa et al., 2011, Poletti et al., 2022). However, others have found that children may continue to use their fingers to count after this age (Butterworth, 2019), and that this may be more common in those with mathematical difficulties. This project investigated the ways in which young people with mathematics difficulties use their fingers to help them when counting or calculating in order to understand the underlying reasons for their continuing finger use. It was hypothesised that this could stem from underlying cognitive deficits and other barriers to their learning, preventing them from progressing to more efficient methods.
Methods: Four participants between the ages of 14 and 17 took part in this project. They were asked questions about how they used their fingers in relation to tasks involving counting, skip-counting, addition, subtraction, multiplication and division, and they were encouraged to demonstrate their finger-counting strategies. The interviews and conversations were filmed and transcribed to allow the data to be qualitatively analysed and common themes identified.
Results: Thematic analysis revealed that the young people in the sample use their fingers extensively, both for counting and calculating, and in unique, varied and at times sophisticated ways. Four main reasons were identified for the participants' ongoing finger use: for security and reassurance, to represent numbers physically, to supplement their working memory, and to compensate for the extensive gaps in their basic number fact knowledge.
Conclusion: The age group on which this project focussed is an under-researched and under-represented group into which further investigation is warranted. These findings contribute to the existing knowledge on finger use by showing that young people use their fingers in ways which go well beyond the simple counting and addition tasks explored in much of the existing literature.
Implications: This study suggests that the term 'finger counting' is simplistic, reductive and inadequate. It is argued that new terminology with clearer definitions would be helpful and better reflect the extraordinary richness and complexity of young people's finger use.

Why are they still using their fingers?

Diana Ball (University of Chester)

Background: For my Master's dissertation I investigated the ways in which young people with mathematics difficulties use their fingers to help them when counting or calculating in order to understand the underlying reasons for their continuing finger use.
Methods: A qualitative methodology was employed, and the different ways in which the participants used their fingers were explored through filmed interviews.
Results: Analysis revealed that the young people in the sample use their fingers extensively, whether they are engaged in counting or calculating, and in unique, varied and at times sophisticated ways.
Conclusion: Four main reasons were identified for their ongoing finger use: for security and reassurance, to represent numbers physically, to supplement their working memory, and to enable unmemorised number facts to be worked out on demand.
Implications: The age group I studied is an under-researched and under-represented group of people, from which I would suggest we have a lot to learn. My findings contribute to the existing knowledge on finger use by showing that young people use their fingers in ways which go well beyond the simple counting and addition tasks explored in much of the existing literature. I would therefore suggest that the term 'finger counting' is simplistic, reductive and inadequate, and I would like to put forward a case for a new approach.

Ensuring Representative Sampling in Pediatric Neuroimaging Research: A Longitudinal Math and Memory Case Study

Anna Ballantyne (University of Virginia), Analia Marzoratti (University of Virginia), Cynthia Fioriti (Georgetown University), Ian Lyons (Georgetown University), Tanya Evans (University of Virginia)

Background: Human research is often conducted in homogenous samples; lack of diversity makes application of research findings less equitable. Historically, minority populations have been mistreated in research, contributing to mistrust, and limiting participation. In a more diverse world, addressing these issues will improve understanding for all people. Marzoratti & Evans (2023) stress a need for inclusive research, suggesting that representation will reduce biases and make scientific findings more generalizable and reliable.
Methods: Marzoratti & Evans (2023) reviewed studies from various fields, focusing on how people that differ in race, ethnic background, gender, age, and socioeconomic status (SES) were included - outlining recent changes in National Institutes of Health (NIH) guidelines encouraging broader inclusion. Using our ongoing neuroimaging study on memory systems' role in math skill development in a neurotypical pediatric population as a case study, we review recruitment practices through the lens of Marzoratti & Evans (2023), and identify several limiting factors - specifically, a disproportionate skew in SES and below target diversity in race and ethnicity.
Results: Marzoratti & Evans (2023) showed that minority and marginalized groups are often underrepresented, highlighting the need for more diversity in human subject research populations. The proximity of our current study to the University of Virginia and its community has contributed to a narrow range of SES in our study participants - 64% of parents have a graduate degree and 62% are in an income bracket of & US$200,000. We also see minimal racial and ethnic diversity: ~57% white, ~12% African American, ~9% Asian American, and ~5% Hispanic/Latinx. Other limiting factors include our geographic location, resource constraints, and minimal participant diversity. These challenges to achieving equitable sampling align with the barriers identified by the article, including research teams failing to adequately represent the target population or engage with perspectives, reliance on convenience sampling, and insufficient attention to the inclusion of individuals from marginalized identities in sampling goals.
Conclusion: A lack of diversity in human subject research makes it harder to generalize and apply findings for everyone. When different populations are not included, important factors that affect health, education and wellbeing may be missed. The combination of a lack of differing perspectives and understanding in research can lead to unfair differences in treatment and application.
Implications: To improve future recruitment efforts, we recommend early engagement with community partners and offering a more flexible schedule for assessments and scans. Leveraging research databases, community partnerships, and connections with a diverse range of stakeholders are also likely to strengthen recruitment strategies.

Challenges in Conducting Evaluations of Complex School-based Interventions

Astrid Bowen (Birkbeck University of London), Andrew Tolmie (UCL Institute of Education), Michael S. C. Thomas (Birkbeck University of London)

Background: Challenges in establishing 'what works' to improve outcomes for struggling students in education have persisted despite decades of interest. As part of this, there is currently no evidence for the efficacy or effectiveness of the majority of educational interventions taking place in schools (Pegram et al., 2022). This project explored the challenges of producing evidence for educational intervention provision through a three-year research partnership with an educational intervention company that aimed to evaluate impact and implementation processes in a complex school-based intervention for struggling students. The first author will share her work on this project, including some of the methodological challenges that occurred along the way and how they were surmounted.
Methods: This presentation will cover a mixed-methods process and impact evaluation of a school-based intervention. The impact evaluation used a quasi-experimental method to assess change in student self-reported well-being scores between an intervention and control group across the academic year. Covariates to control for and assess the impact of other factors including participant socioeconomic status (SES) and implementation quality were also included. The process evaluation used a combination of 21 interviews with three types of intervention stakeholder and a quantitative assessment of inter-rater agreement on ratings of intervention quality.
Results: During the first year of the project, only SES emerged as a significant covariate for well-being score change over time. This was interpreted to reflect issues with the emerging cost of living crisis at the time of data collection. During the second year, findings from an earlier pilot study were replicated, showing a significant effect of intervention on participants in the intervention condition. Two dimensions of intervention quality relating to fidelity and school support also emerged as significant predictors of well-being outcomes for intervention participants, which agreed with findings from the process analysis on the major factors which support effective intervention implementation.
Conclusion: There are many challenges to evaluating educational interventions, particularly complex or multi-pronged interventions. Longer-term research partnerships (as opposed to one-off trials) that combine process and impact evaluation can provide insight into not only whether the intervention is producing the intended effects, but also the implementation factors that support outcomes.

Assessing cross-domain contributors to numeracy in children with Down Syndrome, Fragile X Syndrome, and Williams Syndrome: Preliminary lessons learned from the MathMIND Project

Jennifer C. Bullen, Katie Costello, Zahra Siddiqqui, Emily K. Farran, Jo van Herwegen, Gaia Scerif

Background: Numeracy is an important skill for independent living. However, most research regarding the development of numeracy skills has focused on neurotypical samples and therefore, cannot be generalized to other populations. The Department for Education lists Special Education Needs and Disabilities (SEND) as a priority for research and as more countries move towards inclusive models of education, thus there is an urgent need to understand how to best support neurodivergent children in education. The current talk focuses on methods and lessons learned from the MathMIND project, which seeks to understand numeracy development in children with Down syndrome (DS), Fragile X syndrome (FXS), and Williams syndrome (WS). We will focus on lessons learned from our cognitive battery. Data collection is ongoing, but preliminary results will be presented where appropriate.

Methods: 240 children (balanced across groups) between 4-9 years old will complete measures of early mathematics achievement, foundational numeracy skills, executive functioning, spatial reasoning, and general cognitive ability. Mathematics achievement will be measured using the Early Numeracy Test - Revised (ENT-R) to measure early mathematical competency. Numeracy skills will be captured using the Centre for Early Mathematics Learning (CEML) Early Numeracy Protocol and includes measures of cardinality, number knowledge and counting. Executive functioning measures will measure working memory (spatial memory, verbal memory), inhibition (Black and White Stroop, Flanker Task), and cognitive flexibility (Dimensional Card Sort Change). Spatial abilities will measure spatial transformation (Children's Mental Transformation Task), pattern construction (British Ability Scales), and spatial scaling. Finally, the British Picture Vocabulary Scores and Ravens Progressive Colour Matrices will provide an estimate of general cognitive ability.

Results: Preliminary group-level observations will be presented as appropriate. The presentation will focus on the opportunities and challenges of measuring cross-domain cognitive predictors of numeracy ability in children with genetic conditions. We will discuss adaptations to protocol and efforts towards including measures of strengths, as opposed to focusing on deficits.

Conclusion and Implications: Numeracy skills are implicated in many aspects of daily living, and yet, are understudied in children with SEND. As a result, it is unclear how to support mathematical learning and thinking in children wit SEND. Thus, understanding the cognitive profiles of neurodivergent children is important for informing theoretical models of early numeracy and educational practices. This research can present challenges as tools for capturing cognition often do not take the unique needs of children with SEND into account. Therefore, it is important for researchers to communicate modifications, successes, and lessons learned in conducting cognitive research for children

Developmental Trajectories of Sensory Processing in Children with Tuberous Sclerosis Complex (TSC)

Cheyenne Contreras (King's College London), Jo Van Herwegen (University College London), Tony Charman (King's College London), Charlotte Tye (King's College London)

Background: Tuberous sclerosis complex (TSC) is a rare genetic condition highly co-occurring with neurodevelopmental conditions (NDC) such as autism, ADHD and intellectual difficulties/disabilities. Individuals with NDC often exhibit atypical sensory processing including hyporeactivity, hyperreactivity and sensation seeking (SS) behaviors. Sensory atypicalities can disrupt an individual's learning leading to dysregulated behaviors. Understanding sensory processing differences will optimize classroom practices and intervention to facilitate increased engagement and decreased dysregulated behavior.
Methods: Children with TSC were age-matched to typically developing (TD) children and administered a battery of neurocognitive, intellectual and behavioral measures from birth to preschool age (3-5 years). Sensory processing was measured at 5, 10, 14, 24 months and 3-5 years, and internalizing and externalizing (CBCL; TD n=28, TSC n=30) behaviors at 3-5 years. Mixed effects models characterized sensory behaviors in TSC and TD children. CBCL group differences were explored. Linear regressions were run to determine if sensory behaviors, extracting intercept and slope, from birth to 3-5 years predicted internalizing and externalizing behaviors.
Results: Hyperreactivity (p= .027) and SS (p = .017) showed significant group and age interaction effects; however, hyporeactivity (p = .154) was not significant. Post hoc comparisons at each timepoint showed significant group differences at 14 months for SS (p = .02) and at preschool for hyperreactivity (p = .046) and SS (p = .001). The TSC group displayed significantly more externalizing behaviors (p =.009), and internalizing behavior differences were non-significant (p = .066). The hyperreactivity model explained 41% of variance in internalizing behaviors with significant effects on intercept (p=.002) and slope (p=.002) with no significant group interactions. Hyperreactivity explained 24% of externalizing behaviors with no significant main effects or interactions. The hyporeactivity model explained 32% of the variance in internalizing with significant intercept (p<.001), slope (p=.012) and group-intercept interactions (p=.025). Hyporeactivity explained 27% of external behaviors with significant intercept (p=.004) and no significant slope or group interactions. SS explained 18% of the internal behaviors with significant intercept (p=.04) effects, marginal slope significance (p=.051) and no group interactions. SS explained 35% of external with no significant main or interaction effects. The TSC group attends a mix of nursery, mainstream and SEN programs, and all TD children attend mainstream education.
Conclusion: Atypical sensory processing is identified as early as 14 months which continues to remain atypical into preschool age in children with TSC compared to TD children. Overall models of hyperreactivity, hyporeactivity and sensation seeking were significant on internal and external behaviors.

The Numbers Count Intervention: Evaluation of Long-term Effectiveness

Ann Dowker (Department of Experimental Psychology, Oxford University)

Background: Dyscalculia and related numeracy difficulties have received increasing attention in recent years, resulting in the development of interventions for children with such difficulties. However, most interventions have not received very long-term follow-up. Starting in 2008, Edge Hill University developed a new intensive mathematics intervention, termed Numbers Count, for Year 2 pupils considered to be in the lowest 5% for mathematics attainment. Children of approximately six years receive half an hour of individualised, or very small-group intervention per day for approximately one school term. The Numbers Count programme involves fine-grained assessment of individual children's strengths and weaknesses and the intervention is targeted at addressing specific weaknesses. It addresses many aspects of numeracy, especially counting and number representation. Children, who received this intervention, were found in an initial evaluation study to perform much better than controls on standardized tests (Torgerson et al., 2011).
Methods: In a long-term follow-up study, funded by the KPMG Foundation 6359 children who underwent Numbers Count intervention in 2010-2011 or in 2011-2012 were followed up at the end of Key Stage 2, using information from the National Pupil Database. As Torgerson et al.'s (2011) study had used a waiting list control group, it was nor possible to use their control group for the long-term study, Therefore, anonymized data fro the Numbers Count children were compared with a group, whose Key Stage 1 results had placed them in the bottom 5% in mathematics.
Results: Chi-square tests showed that the Numbers Count children's performance on Key Stage 2 tests was very significantly better than that of the other initially low attainers.
Conclusion: The intervention appears to have persistent, long-term effects over a period of at least five years. The Numbers Count children did not perform quite as well as their entire year cohorts (of all prior attainment levels), but still mostly performed at an adequate level, and considerably better than other children who began as very low attainers.
Implications: The Numbers Count intervention appears effective in the relatively long-term, and, despite its intensiveness and cost, should continue to be used with children with significant mathematical difficulties. More generally, the results indicate that even quite severe mathematical disabilities can be susceptible to intervention. More research is desirable to develop further interventions for dyscalculia and mathematical disabilities and to find better ways of predicting individuals' response to particular interventions. This is an important goal for educational neuroscience.

Co-producing an agenda for research into the impact of artists in schools

Amy Fancourt, Saul Argent, Diana Omigie

Background: Research in education studies into how artists in schools enhance the teaching environment has emphasised artists' flexible use of space and time, their use of artefacts and provocation and their encouragement of shared endeavour. However, to date there has been little work from psychological research into the broader psychosocial outcomes related to artists' specific styles of pedagogy.
Methods: We brought psychologists and education researchers together with teaching artists and cultural education organisations to set an agenda for co-produced research into the impact of artist in schools. Over a 4-hour workshop, discussion was structured around 3 questions:

1. What questions could benefit from a psychological approach to capture the impact of artists in schools?
2. What are the challenges and opportunities of taking a psychological approach to measuring the impact of artists in schools?
3. What steps should be taken to arrive at sound and ethical co-produced research?

In advance of the workshop, attendees reflected on their work and prepared a response to one of the three questions. On the day, the attendees assigned to each question initiated the discussion by introducing their work and sharing their insights.
Results: The roundtable discussion has been used to inform a collaborative paper setting an agenda for researching the impact of artists in schools. One insight that came from the discussion was how a psychological approach can support cultural education organisations to implement evaluation frameworks that can be replicated and contribute to larger scale research programmes. Another observation was that there are challenges in bringing different disciplines together to reach joint conclusions in a short period of time: Discussion has necessarily spanned beyond the meeting but this is proving beneficial in triggering a more careful exploration of how impact should be understood.
Conclusion: Knowledge exchange between psychologists, educators, artists and cultural education organisations should be encouraged to advance understanding of the impact of arts-based education. The insights from cultural education organisations have been immensely useful in formulating considerations for research more broadly e.g. the value of measuring not just impact on young learners, but also on teachers and school culture.
Implication: The roundtable discussion has established an inter-disciplinary network of practitioners who share the same goal of seeking to evaluate the impact of arts-based education. This collaboration has already resulted in effective collaboration on the recent Department for Education Curriculum Review. A further implication of the roundtable is a recognition of the need to consider arts education within the broader context of the Science of Learning movement. Arts-based education affords learning experiences that need to be further understood and effectively evaluated.

Teacher delivered block construction training improves children's mathematics performance

Emily K. Farran (University of Surrey), Katie Gilligan-Lee (University College Dublin), Denis Mareschal (Birkbeck, University of London), Marija Živković (Technological University Dublin), Santa Bartušēvica (University of Latvia), Derek Bell (Learnus), Tim Jay (University of Nottingham), Camilla Gilmore (University of Loughborough)

Background: Spatial abilities include understanding the properties of objects such as their shape, size and location, and the relationships between them, as well as the ability to mentally visualise and manipulate objects in space. Research has shown that children who are good at spatial thinking are good at mathematics and that spatial training transfers to mathematics. Furthermore, the effects spatial training on mathematics are largest when spatial training includes physical manipulatives. However, to-date most research has been lab-based with spatial training delivered by researchers.
Methods: The current study investigates the efficacy of the SPAtial Cognition to Enhance mathematical learning (SPACE) programme for improving children's spatial and mathematics skills. The SPACE programme is a whole-class teacher-delivered LEGO® block construction intervention. The aim of the programme is to (a) improve teacher's confidence, understanding and perceived importance of spatial reasoning and increase their use of spatial language; (b) increase children's exposure to spatial language (through teachers' use) and encourage practice of spatial thinking skills, such as visualisation, through Lego building. The programme was delivered by teachers following a half-day professional development training course. This study had a quasi-experimental, controlled, pre-post intervention design. Each child completed three measures before and after the intervention period, spatial language, spatial ability (mental rotation) and mathematics (geometry and problem solving). Pre- and post-testing were delivered by the classroom teacher. The intervention consisted of 12 30-minute sessions delivered by the teacher across six weeks in place of their usual mathematics teaching. In each session, each child was given a different booklet of Lego models to build and a tray of Lego which contained 250 Lego bricks (the same tray each session). Using a quasi-experimental design, N=409 children completed the SPACE training and N=103 children formed a business-as-usual control group.
Results: Three ANCOVAs were used to explore the main effect of the intervention, with post-intervention score as the dependent variable, group as the between-participant factor and pre-intervention score as the covariate. One ANCOVA was performed for each measure. For spatial language, there was no significant effect of group, indicating no significant impact of the intervention on spatial language performance. For spatial ability (mental rotation) and mathematics there was an effect of group, such that the intervention group had significantly higher scores than controls at post-assessment.
Conclusion and Implications: This finding extends evidence of the positive effects of spatial training to an ecologically valid, classroom-based, practitioner-delivered context. The findings suggest that classroom opportunities to engage in block building using pictorial instruction are an effective activity for

Working memory as a mediator of math vocabulary and performance

Roberto A. Ferreira, Cristina Rodríguez, Bárbara Guzmán, Felipe Sepúlveda

Background: Understanding the interplay between vocabulary and mathematical performance is critical for enhancing educational outcomes, particularly in early childhood. Vocabulary encompasses both general language skills and mathematics-specific terms, yet their distinct contributions to mathematical performance—and the cognitive mechanisms underlying these relationships—are not fully understood. This study examines the mediating role of working memory in the relationship between general and mathematics-specific vocabulary and mathematical performance.
Methods: The study involved 503 second-grade children from 16 schools in Chile, aged approximately 8 years. General vocabulary was measured using a semantic fluency task, while mathematics-specific vocabulary was assessed with an auditory word recognition task. Working memory was evaluated using age-appropriate standardised tasks, and mathematical performance was assessed through the Test of Early Mathematics Ability, Third Edition (TEMA-3). Structural equation modelling (SEM) was employed to explore direct and indirect pathways between vocabulary types, working memory, and mathematical performance.
Results: Both general and mathematics-specific vocabulary significantly predicted mathematical performance. However, mathematics-specific vocabulary exhibited a stronger direct relationship with mathematical outcomes compared to general vocabulary. Working memory emerged as a significant mediator of the relationship between mathematics-specific vocabulary and mathematical performance, indicating that working memory facilitates the translation of mathematics-specific vocabulary into mathematical proficiency. Conversely, no mediation effect was observed for general vocabulary, suggesting that general language skills support mathematical performance through different cognitive mechanisms.
Conclusion: The findings highlight the pivotal role of mathematics-specific vocabulary in fostering mathematical skills, mediated by working memory. This underscores the need for targeted interventions that build mathematics-specific vocabulary and enhance working memory to improve mathematical outcomes, particularly in culturally diverse and under-researched populations such as Chile. Furthermore, the results reveal distinct cognitive pathways linking general and mathematics-specific vocabulary to mathematical performance, pointing to the specialised nature of mathematics learning.
Implications: This study contributes to the broader understanding of mathematical cognition by identifying working memory as a critical mediator between mathematics-specific vocabulary and mathematical performance. The findings suggest that early educational practices should focus on integrating mathematics-specific vocabulary instruction with strategies to strengthen working memory. By addressing these areas, educators can better support students in mastering the foundational skills necessary for long-term success in mathematics.

The Impact of Multilingualism and Socio-Economic Status on Academic Performance: Evidence from the SCAMP and the UK National Pupil Databases

Roberto Filippi, Andrea Ceccolini, Roisin C. Perry (UCL Institute of Education), Michael S. C. Thomas (Birkbeck University of London)

Background: We present a study that investigates the impact of multilingualism and socio-economic status (SES) on academic performance using data from 3,213 pupils from the National Pupil Database and the Study of Cognition, Adolescents, and Mobile Phones (SCAMP). It focuses on the developmental trajectories of multilingual learners (ML), simultaneous multilinguals (SM), and English monolinguals (EM) across Key Stage 2 (SATs) and Key Stage 4 (GCSE).
Methods: Participants from 25 State schools in London were categorized based on their linguistic background and SES, with data analysed using multilevel modelling. Academic performance in English, Mathematics, and Science was compared across linguistic groups at Key Stage 2 and Key Stage 4, with free school meals used as a proxy for SES. Baseline academic abilities at Key Stage 2 were used to measure growth at Key Stage 4.
Results: At Key Stage 2, MLs scored lower than EMs, while SMs showed no significant differences. By Key Stage 4, MLs achieved parity with EMs, and SMs outperformed both groups, particularly in Mathematics and Science. Pupils from lower SES backgrounds consistently underperformed; however, multilingualism appeared to help mitigate these disadvantages, especially for SMs at Key Stage 4.
Conclusion and Implications: The findings highlight the academic resilience of multilingual learners, who overcome early challenges, and the significant benefits of early multilingual exposure. We will also discuss ongoing analyses exploring the mediating role of cognitive (executive function) skills in any observed multilingual advantage. These results challenge misconceptions about multilingualism and underscore its protective role against SES-related disparities. Educational policies should leverage linguistic diversity to promote equity and optimise academic outcomes.

Children with Colour Vision Deficiency are Disadvantaged in KS2 and KS2 Maths.

Anna Franklin, Taysa-Ja Newman, Kathryn Albany-Ward, Jenny Bosten

Background: Colour vision deficiency (CVD, also known as 'colour blindness') is the most common congenital visual disorder and affects around 8% of males and 0.4% of females (approximately one child in every co-educational classroom). For anomalous trichromats, all three types of retinal cone photoreceptor are present, but there is an abnormality in the cone photopigment's spectral sensitivity for Long- or Medium- wavelength sensitive cones. For dichromats, the Long- or Medium-wavelength sensitive photopigment is absent. CVD causes a greater range of colour confusions than just red and green (e.g., purple and blue), and CVD can affect many aspects of daily life. Here, we assess the extent to which maths exercises and resources are accessible to children with CVD.
Methods: We randomly sampled 8869 maths exercises from the top 10 most commonly used UK maths textbooks and online resources (Marks et al., 2023), including two textbooks endorsed by the Department for Education. Each exercise was coded to determine whether there was: no colour, purely decorative colour, or informative colour. We coded all colour-informative exercises to identify whether they would be accessible or problematic for children with CVD, and noted the reasons for this. We also coded whether the use of colour followed accessibility guidelines (WCAG2.1 AA). Additionally, we simulated the CVD-appearance of colour-informative exercises, and coloured maths manipulatives (e.g., Numicon, Compare Bears, Base10, Cuisenaire Rods, Fraction Tiles) using Vischeck software (Dougherty & Wade, 2002).
Results: Coding revealed that 16% of the KS1 and KS2 maths exercises used or relied on colour. Seven percent used colour in a way that would be problematic for a child with CVD, due to: CVD-confusable colours being pivotal to the question, or insufficient contrast (confirmed by Vischeck); reference to colour in instructions; distracting, irrelevant colour; no colour labels (e.g., on coloured graphs); and requiring a coloured response (e.g., such as colouring in). Vischeck also identified that the maths manipulatives analysed are likely inaccessible for children with CVD, with items in CVD-confusable colours in the absence of other cues. Even when manipulatives are labelled (e.g., fraction tiles), the use of CVD-confusable colours creates potentially confusing false similarities between items in the set.
Conclusion & Implications: Children with CVD are disadvantaged in KS1 and KS2 maths: we estimate that approximately 7% of KS1 and KS2 maths exercises are problematic or inaccessible for children with CVD. The findings highlight the need for CVD-inclusive design of educational resources, and findings are being shared with resource publishers. The study also supports the call for CVD screening to be reintroduced in schools, so that children with CVD can be identified and supported with simple interventions to overcome barriers that they face in education.

Investigating the Impact of Emotional Modulation on Attentional Numerical Representations in Childhood

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Background: Emotion dysregulation has been shown to increase attentional biases toward threat, divert attention away from goal-directed tasks, and deplete working memory resources, thereby impeding learning (Eysenck & Calvo, 1992; Eysenck et al., 2007). While the interplay between emotion regulation and cognitive demands on numerical processing has been extensively studied in adults (Suárez-Pellicioni et al., 2015; Daker et al., 2023), its developmental trajectory remains underexplored. This study investigates whether children's capacity for emotional modulation, indexed by high-frequency heart rate variability (HF-HRV; Thayer, 2012; Tang et al., 2021), is associated with neurophysiological markers of numerical attention as observed in ERP studies (Temple & Posner, 1998).
Methods: To address this question, we developed a novel, developmentally appropriate pirate-themed paradigm incorporating a symbol-learning task (Merkley & Scerif, 2015) and a numeral comparison task. The symbol-learning task involved a gamified learning phase where children learned novel symbols in an ordinal context (similar to the count-list), followed by a symbol comparison phase assessing their learning. The second task, the numeral comparison task used familiar Arabic numerals presented within a consistent gamified theme.
Results: A total of 81 children aged 4, 6, and 8 years participated. Neurophysiological data (EEG and ECG) were recorded during the learning task, alongside self-reported emotional states and parent-reported behavioural profiles. While self-reports indicated generally positive emotional states, more variability was observed in both HF-HRV indices and parent-reported measures of emotion regulation. Notably, HF-HRV emerged as a robust predictor of task performance. Results further revealed a significant relationship between children's emotional modulation capacity and ERP markers of attentional numerical representation, underscoring the critical role of emotion regulation in early symbolic number learning and representation.
Conclusion & Implications: This study introduces a novel framework for exploring how emotional processes influence the acquisition of numerical concepts, particularly the ordinal relationships between numbers. Our findings also highlight the potential developmental underpinnings of mathematics anxiety, suggesting that early emotional dysregulation and attentional disruption may play a more prominent role than failures in mathematical performance alone. By implicitly examining the effects of emotional and attentional mechanisms on conceptual development, this work provides new insights into the reciprocal relationship between emotional regulation and mathematics performance, getting one step closer to answering the chicken and egg problem of mathematics anxiety (Carey et al., 2016).

Enhancing Cognitive and Academic Skills in Children through Adaptive Virtual Reality and Tablet-based Interventions.

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Background: This study examines the effectiveness of the Mastermind Cognitive Training Program™, a personalised and adaptable training intervention tested here with 8–9-year-old children on academic and cognitive measures. Preliminary results demonstrate significant improvements in participants' reading comprehension, highlighting its potential for educational enhancement. Both theoretical and empirical research to date suggests that cognitive control abilities, including attention and working memory, play an integral role in math processing (Baddeley, 1996; Baddeley, 2001) and reading comprehension (Conesa and Duñabeitia, 2021), with recent work demonstrating that adaptive cognitive training can improve reading fluency. Here we looked to evaluate the effectiveness of a new platform for school aged children (Mastermind Cognitive Training Program™) designed to enhance core cognitive control abilities delivered via virtual reality (VR) and tablet platforms.
Here we present the preliminary findings of this study from school 1 (N = 60, aged 8-9; note the total targeted enrollment is N=200 across 3 schools from diverse educational backgrounds and with varied reading ability).
Methods: This study is designed to evaluate the effectiveness of the Mastermind Cognitive Training program through a randomized controlled trial on VR (N = 20) or tablets (N = 20) versus an expectancy-matched placebo control arm where participants trained on selected math and coding education applications (N = 20) engaged in free educational apps on tablet. Participants completed a ten-week training program, consisting of three 30-minute sessions per week. Outcomes were assessed using measures of i) academic performance measurements such as reading fluency and math fluency, ii) eye tracking measures, as well as iii) measures of cognitive performance, including working memory, sustained attention, and cognitive flexibility.
Results: Preliminary analyses reveal significant improvements in reading fluency for children in the VR intervention group compared to controls (p= .011). No such difference was present for the tablet versus control group (p= .161). For math fluency, the VR group also showed a significant improvement from baseline (p= .001), with a trend in the control group that trained on math and reading exercises (p= .062).
Conclusions & Implications: These preliminary findings suggest that the VR version of the training was more effective in engendering academic improvements than a tablet approach. Follow-up analyses will describe how these results evolve with the inclusion of students from each additional school, the impact of expectancy-based effects, potential changes in eye tracking and cognitive abilities, as well as possible changes in inattention as measured by teacher-led reports on the Vanderbilt Survey of Attention.

SIMS: Spatial Thinking in Mathematics Study

Katie Gilligan-Lee (University College Dublin), Andrew Roe (University College Dublin), Corinne Bower (California State University)

Background: Spatial thinking is the ability to reason about shape and space. There is convincing evidence of a causal effect of spatial skills on mathematics performance (Hawes, Gilligan-Lee & Mix, 2022). However, the mechanisms that underpin space-mathematics relations remain undetermined, and it remains unclear under what conditions and for whom spatial skills can optimally support math problem solving. Here we use a novel dual-task paradigm to test the spatial visualisation hypothesis that spatial skills have a causal effect on mathematics due to the recruitment of spatial visualisation in mathematical problem solving (Hawes et al., 2023). We will test whether spatial interference reduces performance in mathematics more than verbal interference and no interference conditions. We will also present a novel model for the development of dual-task paradigms with three stages: load comparability, validity and dual-task interference.
Methods: This study has a repeated measure experimental design.120 participants (age range 18-30 years; 50% male) completed three primary tasks under different dual-task conditions (no interference, spatial interference, verbal interference). The use of the word interference here refers to participants completing two tasks at the same time. Spatial interference was elicited using a shape sorting task- selecting objects from a bowl and orienting them correctly to fit into an opening in a box. Verbal interference was elicited using a word categorisation task- determining whether a target word belonged to a category, i.e., respond for fruits and not animals. Primary tasks included a Go/No-Go task (comparability measure), mental rotation task (validity measure) and an arithmetic task (dual-task interference target measure). Pre-registered, repeated measures ANOVAs with Tukey post-hoc comparisons were used for all analyses.
Results: Data collection is ongoing. We hypothesise that: (a) spatial and verbal interference will lead to comparable reductions in executive function performance compared to no interference, i.e., confirmation of load comparability; (b) spatial interference will lead to greater reduction in mental rotation compared to verbal interference and no interference conditions, i.e., confirming validity of the spatial interference paradigm; (c) spatial interference will lead to greater reduction in mathematics compared to verbal interference and no interference, i.e., demonstration of dual-task interference of spatial interference on mathematics suggesting a role for spatial visualisation in mathematics problem solving.
Conclusion and implications: Determining that spatial visualisation is one of the mechanisms underpinning spatial-mathematical associations would lead to substantial educational policy implications in the form of development of spatial visualisation interventions for the classroom. Improving mathematics attainment may have knock-on economic implications for the STEM industry.

Neural activation during the teaching experiences

Giancarlo Gola (University of Applied Sciences and Arts Southern Switzerland)

In the paper, we discuss the building blocks of neural activation processing by conducting a systematic evaluation of modern neuroscience theories focusing on the recruitment of neural systems. We compare functional connectivity profiles by analysing their predictive accuracy within a connectome-based framework and the relationship to educational neuroscience. The challenge is to understand whether neural mechanisms are also carriers of implicit knowledge to support new trends in education.
Our proposed multi-methodological research design promises to produce impactful and actionable results that can be directly applied to educational practices. The evidence gathered can significantly improve our understanding of the brain, teaching strategies, student engagement and learning outcomes. The use of neuroscientific knowledge of brain functions would infer models and theories of action, including teaching practices, with due caution.

Learning outside the box: The impact of learning outdoors on urban children's noise, stress, attention and behaviour

Gemma Goldenberg, Molly Atkinson, Sam Wass (University of East London)

Background: A growing body of evidence suggests that time outdoors, especially in natural settings, supports children's wellbeing, cognition and development. However, less is known about the pathways through which this effect occurs and whether such benefits can be conferred in urban outdoor environments, and when carrying out everyday learning activities rather than a specific forest school programme. This project, the first of its kind worldwide, compared 4–5-year-old children's learning and behaviour across indoor and outdoor settings which were carefully matched in terms of size, resources and pedagogy. Throughout, individual differences were explored and noise, heart rate and the amount of natural features in outdoor areas were investigated as potential mediators of effects.
Methods: This quasi-experimental study utilised wearable equipment including ECG monitors, head mounted cameras and actigraphs to gain objective new insights into children's experiences of indoor and outdoor learning environments. Data was collected from 76 children across 8 indoor and 8 outdoors sessions repeated across 7 classes of ethnically diverse children from 4 different state primary schools in Newham, London.
Results: Results reveal that children's noise levels and resting heart rates were significantly lower outdoors, suggesting lower physiological stress. Analyses of attentional capacity show that children who struggle the most with their attention indoors, show significantly better attention in an outdoor environment. Boys, and children with an outdoor preference were most likely to show improved attention outdoors. Finally, data indicates that children behave more prosocially in an outdoor environment, and that children who display the most antisocial behaviour indoors, are significantly less antisocial when interacting with peers outside.
Conclusion and implications: Study findings indicate that even short periods of time outdoors in urban environments can support stress reduction, reduced noise levels and improved attention and behaviour in children who struggle indoors at school. Schools should make use of the outdoor space they have available, even if it is for everyday activities e.g. relocating story time outdoors. Some children were more likely to engage with particular activities e.g., maths- and literacy-based tasks in one environment compared to another, illustrating the importance of a full provision both indoors and outside. Outdoor areas should not be seen as only for playtime and physical development. Data indicates differential effects of the environment, with some children finding outdoors more optimal and others performing better inside. The implications of this are that no single environment is optimal for all children. Conducting all learning indoors hampers some children's capacity for success. Knowing childrens preferences and observing them in different environments is an important part of providing an inclusive education.

Scaffolding or explanatory: The effect of teaching style on neural synchrony in teacher-student interactions

Imogen Green, Paola Pinti, Denis Mareschal (Centre for Brain and Cognitive Development, Birkbeck University of London)

Background: Interpersonal neural synchrony (INS) – the rhythmic coordination of brain activity between interacting participants – has been shown to predict learning outcomes, making it a potential neural biomarker for the learning process (Zhang et al., 2022). Pan et al. (2020) found that INS was related to instructional strategy, with synchrony between teacher and learner being higher during sessions which used an interactive scaffolding approach rather than an explanatory style. Greater synchrony during learning was also associated with improved retention of concepts learned in the session. Visibility may also be a significant moderator of the relationship between INS and learning outcomes (Zhang et al., 2022). The visibility of the interacting partner (especially eyes and faces) provides opportunities to exchange information and provide non-verbal feedback (De Felice et al., 2022). This study aimed to extend prior research by exploring the link between INS, teaching styles, visibility and learning outcomes in a developmental population.
Methods: Twenty-four teacher-child dyads participated in the experiment. Children (mean age = 10.17, 12 females) took part in one-to-one learning sessions with qualified teachers (50% female), lasting 30-45 minutes. The teacher explained science concepts using two different teaching methods: explanation, in which the teacher made statements and the child could ask for clarification, and scaffolding, in which the teacher would ask guiding questions to the student to promote conversation. Visibility was also manipulated using a curtain between participants in 50% of trials. Children were tested on their knowledge of the learning material before the session, afterwards and one week later. fNIRS hyperscanning was used to record brain activity from both participants in the prefrontal cortex and the bilateral temporoparietal junction, measuring changes in oxyhemoglobin (HbO) and deoxyhemoglobin (HbR). Wavelet transform coherence was calculated as a measure of INS.
Results: There was a significant effect of teaching tyle on HbO coherence, with scaffolding techniques associated with higher coherence than explanatory techniques ($p = .05$). This suggests that the greater turn-taking involved in the scaffolding method may result in greater synchrony between participants. There was also a significant effect of visibility on HbR coherence, with higher coherence in the non-visible condition than in the visible condition ($p = .03$). This was an unexpected result which may be related to the increased demands upon working memory when visibility is obscured. HbO coherence during learning was correlated with retention of learned material one week after the learning session for two conditions: scaffolding no screen ($r = .47$, $p = .03$) and explanatory screen ($r = .46$, $p = .03$).
Conclusion: These results suggest that teacher-child neural coherence during learning may be positively related to the child's long-term retention of the information.

Connecting the Dots: EEG Coherence and Early Math Ability

Bethan Grimes, Sophia M Shatek, Gaia Scerif (University of Oxford)

Background: Frontal and parietal brain regions have been identified as key regions of interest in both executive function (EF; Sauseng et al., 2005) and mathematical development (Arsalidou & Taylor, 2011). Research has also shown a connection between math ability, as measured by standardised tests, and the activation of frontal, parietal, and fronto-parietal networks during magnitude comparison tasks (Gonzales-Garrido et al., 2018). However, there is still limited understanding of the temporal dynamics of brain activity and its relation to math ability, especially in younger children, and in relation to EF. This study explores EEG coherence in 4- and 6-year-olds during executive deployment and symbolic number processing, in relation to math ability as measured by standardised test performance.
Methods: Children completed a standardised math test; The Early Years Toolbox Numeracy Task for 4-year-olds, and the Numerical Operations subscale of the WIAT for 6-year-olds. To explore how brain connectivity relates to math ability, we recorded EEG whilst children completed a series of cognitive measures. Measures included a magnitude comparison task, in which children had to select which of two numerals represented a larger quantity, and executive function tasks designed to measure inhibitory control (Flanker Test), shifting (Dimensional Change Card Sort Task) and visuospatial short-term working memory (CORSI Block-Tapping Task). To examine connectivity, we calculated coherence within and across frontal, parietal, and fronto-parietal channels in alpha (8-12Hz) and theta (4-8Hz) bands.
Results: Both standardised measures showed a good spread of performance. 4-year-old children scored an average of 50.13 points on the EYTN, with a range of 65. On the WIAT, 6-year-olds scored an average of 10.66, with a range of 15. Preliminary EEG results suggest that children with lower standardised math results have higher increase from baseline to task coherence in alpha band (8-12Hz) coherence across all regions and tasks. Data analysis is ongoing for EEG coherence within-region, age group, and in the theta band (4-8Hz).
Conclusion: In conclusion, our results show that connectivity in the frontal and parietal regions during EF and symbolic number processing is related to mathematical ability as measured by standardised tests. For higher ability children, a smaller increase in alpha coherence might indicate that brain networks in the fronto-parietal region are more efficient, whereas lower ability children may require more cognitive effort to engage in tasks that involve executive function.
Implications: These findings highlight how individual differences in math ability are associated with distinct patterns of neural coherence during EF and symbolic processing tasks. Further analysis on within-region coherence will help us to identify how connectivity within and across regions relates to cognitive development and mathematical ability.

A Meta-Analysis of EEG Spectral Power for Measuring Cognitive load in Educational Contexts

Abdul Karim Ismail, Lars-Erik Malmberg, Sonali Nag

Background: Cognitive load, understood in a broader sense as relating to the intensity of task-related cognitive processes, is a multifaceted concept with significant pedagogical implications. Cognitive load typically increases with task demand, reflecting task engagement, but tends towards a maximum threshold, beyond which continued engagement becomes unsustainable. Continuing educational research aims to complement self-report-based procedures of assessing cognitive load with increasingly accessible neurophysiological monitoring to provide real-time data unaffected by recall cognitive biases. This meta-analysis is part of an ongoing doctoral research programme investigating the utility of EEG spectral power as a measure of cognitive load in educational settings.
Methods: Findings from 32 studies (N=1096, mean age 23.6 years) were synthesised to examine the effect of increasing cognitive load on regional EEG spectral power in the theta, alpha, beta and gamma bands during educational tasks. These tasks involved working memory, arithmetic, reading, listening, verbal or visuospatial reasoning, designed to produce low or high cognitive load experimental conditions.
Results: Increasing cognitive load reflected in increasing frontal theta power [r=0.44, CI: 0.35, 0.52, p<0.001], decreasing occipitoparietal alpha power [r=-0.41, CI: -0.54, -0.33, p<0.001], increasing overall beta power [r=0.52, CI: 0.27, 0.70, p<0.001], and increasing overall gamma power [r=0.94, CI: 0.89, 0.97, p<0.001].
While the synthesis of theta and alpha power studies did not demonstrate significant between-study heterogeneity, the synthesis of beta and gamma power studies did, likely due to variation in electrode positioning and smaller sample sizes, in addition to between-study task variation.
Conclusion and Implications: This study advances current literature by examining the effect of cognitive load exclusively in healthy students under classroom-transferable experimental conditions, by including gamma power in the synthesis, and by having the youngest mean age and largest sample population of similar cognitive load-EEG spectral power syntheses to date. Outstanding questions remain regarding how EEG may differentiate adaptive and maladaptive cognitive load, as well as how emotional states relate to different cognitive load conditions. The findings presented support EEG as an ecologically valid tool for measuring cognitive load in classroom environments. Potential applications include the continued examination of the nature and factors affecting cognitive load, and utilising EEG to facilitate adaptive, biofeedback-informed classroom interventions to manage cognitive load optimally. The next stages of this doctoral research, outlined in the paper, aim to use a classroom-based, combined EEG and self-report method to compare cognitive load in school-age children receiving or not receiving cognitive load biofeedback with adaptive interventions during mathematics tasks.

The Emerge of symbolic numerical knowledge in early development – An fNIRS Registered Report

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Background: The cardinality principle (CP) is the ability to associate each number word in the count sequence with item sets (e.g., 'five' means 'five things'), and it forms the core of symbolic numerical knowledge, which can predict how well children develop numerical skills (Geary et al., 2018; Wynn, 1990). Despite the abundance of behavioural studies of the CP, not much is known about brain changes accompanying its acquisition. Studies in older children and adults suggest that the left parietal region plays a key role in number word processing and may support the transition from subset-knowers, who do not understand the CP, to CP-knowers (Hyde, 2021). We hypothesised that CP-knowers will reveal higher left parietal activation, as compared to the subset-knowers. Moreover, we expected the group difference to be stronger for higher number words as compared to smaller number words (that both CP- and subset-knowers understand), as CP-knowers are more advanced.
Methods: 92 children (46 CP-knowers and 46 subset-knowers) between 2.9 and 4.9 years old participated in the study. Using the give-a-number task (based on Krajcsi, 2021, and Marchand et al., 2022), children were categorised as CP-knowers or subset-knowers. We measured bilateral parietal activation using functional near-infrared spectroscopy (fNIRS) during the auditory numerical adaptation task (adapted from Vogel et al., 2017), in which a continuous stream of the number word 'two' was periodically interrupted by one of the three conditions: number word 'four', number word 'eight', and a quasi-number word 'rin'. As this was a block-based design, the conditions were not mixed, and each condition was presented separately in four blocks. Each block had 10 trials and was approximately 16 seconds long. The data was analysed using the Brain AnalyzIR (Santosa et al., 2018).
Results: When testing the left parietal region, the Mann-Whitney U test indicated a significant difference in brain activation for the number word 'eight' between CP-knowers (Median = 2.186) and subset-knowers (Median = 1.137), U =1364, p = .008, but not for the number word 'four'. When testing the right parietal region, neither condition with number words 'eight' nor 'four' was significantly different between the groups.
Conclusion: Our results provide the first empirical support for the current theories of the initial development of symbolic numerical knowledge and its association with the left parietal region. Namely, that the understanding of the number word is accompanied by the increased activation of the responsible for symbolic numerical processing in the left parietal region.
Implications: Theoretically, our study can further develop theories about the origin of symbolic knowledge in early development (Hyde, 2021). Practically, understanding brain

changes that signify the acquisition of symbolic numerical knowledge can be the first step in learning to identify early biomarkers of individual maths learning differences.

The problem of sampling diversity in EN research

Temitope Ladenika (UCL Institute of Education)

Background: This paper provides a critical exploration of a potential drawback to effective research practice in Educational Neuroscience (EN) in the UK. This is the problem of limited sampling diversity in EN studies (Dotson & Duante, 2019; Marzarotti & Evans, 2024).
The development of EN as a disciplinary field of knowledge is significant as it centralises the physiological processes that define human learning and aims to translate this to practices involved in learning in the classroom (Thomas et al., 2024). For example, understanding how learning takes place involves, among others, understanding aspects of the brain such as synaptic mechanisms and brain structures (Goswami, 2004). EN presents a new and evolving world of knowledge and understanding about how we learn and provides a scope for development in pedagogical practice. Four areas proposed as necessary to the successful development of EN includes the construction of an evidence base, the translation of research into knowledge, application of knowledge in the classroom and evaluation of methods and factors that influence outcomes (Thomas et al., 2024, pg. 462). The construction of an evidence base necessitates rigorous research methodological practices which should provide knowledge outcomes that are reliable and usable for application in the classroom. The classroom is a context that draws together variables that influence learning. These variables are also understood as having an impact on learning within the human brain – specifically 'neural structure, function and related cognitive performance' (Dotson & Duante, 2019, pg.182), Consideration of these variables within study samples addresses the problem of sample homogeneity and provides a basis on which findings might be generalised to a diverse population.
Methods: Using a synthesis matrix, this study carries out a documentary analysis of 25 original UK studies in educational neuroscience to identify the extent to which the study samples are diverse and the extent of consideration of demographic data in the discussion of findings. Indicators of diversity include at least 2 of the 6 areas identified by Dotson and Duante (2019) and Marzarotti and Evans (2024)- - Disability, Income, Race/Ethnicity, Socioeconomic status, Educational Attainment, and Gender.
Results: A trend has been identified in several original educational neuroscience studies, of diverse demographic variables being ignored. Studies may include data on these variables however they are rarely addressed in the analysis and discussion of findings (Dotson & Duante, 2019; Marzarotti & Evans, 2024). Early indications show that at least 2 of the demographics may be considered, one of which is gender. Analyses of gender related responses for most studies are absent in the discussion, as well as the limitations.
Conclusion and implications: Findings from this study consider not only the very important issue of rigour in research methodology e.g., generalisability

“Research, the more we see it, the more we believe in it” – Investigating the concept of “evidence” with French Primary School Teachers involved in an evidence-based educational network.

Jessica Massonnie, Isabelle Le Brun, Adeline Lucchesi

Background: Evidence-based education is expanding in France, yet efforts to centralise pedagogical decisions and assert ‘what works’ have met resistance. This study investigated the nature and functions that a small group of French Primary School Teachers’ involved in an evidence-based network attribute to research findings. Importantly, it was the first study that unpacked the concept of ‘evidence’, asking how they knew that a pedagogical method works, and whether it was the same type of evidence that is put forward by the Ministy of Education’s expert committee named le Conseil Scientifique de l’Education Nationale. Sensevy’s (2022) distinction between practice-based evidence and evidence-based practice, was used as a theoretical framework.
Methods: Fourteen teachers participated in semi-structured focus groups, analysed with thematic analyses.
Results: Although most teachers were familiar with research, they saw scientists as belonging to a different ‘crew’. Teachers used evaluation tools, a positive classroom climate and observations of children taking ownership of their learning as evidence of a method that ‘worked’. They considered that research evidence brought legitimacy to their decisions, yet did not replace their professional intuition. They would like to work with scientists to identify research measures addressing their own pedagogical research questions, building flexible and direct partnerships. They would like research to be visible and palpable, akin to the concept of evidence as an indicator pointing at a situation they would co-analyse with researchers.
Implications: Results provided innovative insight into teachers’ epistemological position, contributing to international debates about how to facilitate collaborations between researchers and practitioners.

The association between children's socioeconomic status (SES), their spatial skills and later mathematics understanding

Sarah McCarthy, Debbie Gooch (University of Surrey), Michael S. C. Thomas (Birkbeck University of London), Angelica Ronald, Emily K. Farran (University of Surrey)

Background: Poor mathematics attainment is associated with worse life outcomes: lower income levels, lower physical health, and less community involvement. Given only 59% of 11-year-olds receiving free school meals achieved the expected standard in mathematics compared to 79% of their peers, a key focus of education in England is how to close this widening socioeconomic status (SES) attainment gap. Improving children's spatial ability has been shown to improve children's mathematics attainment across childhood (1 to 18 years). Initial research has shown that spatial training may be particularly beneficial for children from low SES backgrounds. However, the mechanisms which explain the relationship between spatial ability and SES are not yet well understood. This study aimed to explore the relationship between SES, spatial skills and mathematics, taking account of children's language skills, which we also know are critical for mathematics.
Methods: To address our research questions data were sought from the Twins Early Development Study (TEDs), a longitudinal study of twins born from 1994 – 1996 in England and Wales. Cross sectional data were drawn from 2454 participants (1350 female, 1104 male) whose family had a SES composite score, which was constructed from both parents' educational levels and occupations and the mother's age at the birth of the first child. Spatial measures included block building (age 2), matching shapes (age 2), visuo-spatial patterns (age 4 and age 9) and shape relations (age 9). Language measures were expressive vocabulary (age 2 and 4) and receptive vocabulary (age 9). Mathematics at age 10 was measured using an extract from the National Foundation for Educational Research (NFER) Nelson Maths 5-14 Series.
Results: Hierarchical regression models were run to determine if spatial skills predicated later mathematics performance, whilst controlling for gender, SES and language ability. Spatial skills at age 2, 4 and 9 contributed unique variance to children's mathematics ability age 10. There is no evidence to suggest that the SES of the individual changes the relationship between spatial skills and mathematics understanding. Mediation analysis to examine whether spatial ability mediates the relationship between SES and mathematics will also be reported (yet to be completed).
Conclusion: Children's spatial ability at age 2, 4 and 9 predicts their mathematics performance at age 10. The relationship between spatial skills and mathematics is unaffected by the socioeconomic background of the child. Implications: This research has implications for targeted spatial training. Spatial training at key points in Early Years and Primary schooling could improve the mathematics performance of children from low socioeconomic backgrounds. This strategy should be considered by policymakers seeking solutions to close attainment gaps for the most vulnerable children.

The AIM Collective: Connecting Research and Practice in Early Math Education in Canada

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Background: The AIM (Assessment and Instruction for Mathematics) Collective is a network of Canadian researchers and educators committed to sharing research-informed, teacher-approved math education tools and resources. One of these tools is the Early Math Assessment @ School (EMA@School), a formative assessment package that is based in research on early mathematical learning and developed in response to the need for a valid and reliable assessment of number skills in students from kindergarten to grade 4 (Douglas & LeFevre, 2021). The EMA@School was designed to be administered by classroom teachers. Through a research-practice partnership with a Canadian school district, we used the EMA@School to evaluate the effectiveness of an educator-developed math intervention for third grade students (ages 7-8-years).

Methods: Researchers collaborated with school board staff to evaluate the effectiveness of a 12-week numeracy intervention. All third-grade students completed the EMA@School at the start of the school year and students were identified as needing additional support if their scores were near or below the normed 25th percentile. The study was a wait-list control design, and students needing support received the intervention, in one of three different cycles. Data were included from 516 students:175 received the intervention in the first cycle (October 2023), 201 received the intervention in the second cycle (January 2024), and 140 received the intervention in the third cycle (April 2024). All students also completed the EMA@School after each intervention cycle for a total of 4 times over the schoolyear. The intervention was led by Math Support Teachers who worked with small groups of 3-4 students for 30 minutes per day, 4-5 times per week. Intervention activities targeted foundational numeracy skills (e.g., number line estimation, place value, number relations, arithmetic, and equations).

Results: EMA@School Scores were analyzed in a 4 (time: Time 1, Time 2, Time 3, Time 4) by 3 (Intervention Group: Cycle 1, Cycle 2, Cycle 3) mixed ANOVA. There was a significant time by cycle interaction $F(5.24, 1080.2) = 68.32$, $p<.001$, $n_p^2 = .25$. At each testing point, students who received intervention showed significantly greater growth in their EMA@School scores than students who did not receive the intervention.

Conclusion: Students' math skills improved in response to the small-group intervention. The EMA@School is an effective tool for monitoring student progress and assessing response to intervention. Working in collaboration with educators can support uptake of early mathematics tools and strategies based in research.

Implications: Educator expertise is necessary for ensuring interventions are feasible in schools. The AIM Collective model is one way of building and sustaining the relationships needed to support this collaborative work.

Mathstronauts – Capturing neural and behavioural data of inhibitory control in counterintuitive maths reasoning to improve executive function in children

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Background: Executive function, a set of cognitive processes that help achieve goals by coordinating thought and action, is a crucial skill for academic success. Along with working memory and cognitive flexibility, inhibitory control- the capacity to prevent oneself from responding to a prepotent response- forms an essential component of executive function. Studies have shown that inhibitory control is recruited in learning contexts that require counterintuitive reasoning, where acting on intuitions may not give the desired result. With the advances in non-invasive neuroimaging technologies, there is a possibility to utilise data that has not been traditionally used in education systems to make evidence-based decisions to improve complex learning constructs such as counterintuitive reasoning. Multimodal learning analytics, an emerging field in education technology that combines data collection and analytics through multiple modes, can be a solution for some of the challenges involved in the pedagogical design of such complex constructs. The current research collects multimodal data through digital game (log data) and functional near infrared spectroscopy (brain data). By employing machine learning techniques, features can be selected from the data that can predict the recruitment of inhibition in counterintuitive reasoning. This can inform the long-term goal of designing a real-time feedback system that can guide the feedback relevant to the misconceptions faced during inhibition in counterintuitive maths problems.
Methods: For Phase 1 of the research, the study will adopt methods from neuromonitoring and digital game-based learning to identify and distinguish the brain data and log data in intuitive and counterintuitive reasoning. Phases 2 and 3 will use machine learning modelling and learning analytics methods to develop a feedback system to help the learner identify the intuitive errors and rectify for it. The first study involves a within-subjects design, with the participants experiencing both control (intuitive) and experimental (counterintuitive) conditions using a block design. The participants of the study will be children aged 8-9 years who will complete the tasks embedded in a 3D game. By including game mechanics such as narrative with a mission assigned to the player, the study aims to make the task engaging and improve motivation. Behavioural data such as response time and accuracy will be logged from the game alongside brain data measured using fNIRS from the prefrontal cortex that supports executive function.
Potential Implications: An understanding of the brain's response to real-world maths enables the design of feedback systems that can address learning gaps. Hence, findings of the study can corroborate feedback practices that are already being implemented by teachers and provide support for teachers. Furthermore, the features identified for feedback provide rich information for the design of education technologies.

Interventions for Executive Functions in Children and Adolescents: A Meta-Analytic Study on Efficacy and Moderators in Clinical and Non-Clinical Samples

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Background: Executive functions (EFs) are critical cognitive processes essential for regulating thoughts, emotions, and actions, supporting academic success and quality of life. However, the efficacy of EF interventions, especially for untrained regulation and academic abilities, remains unclear due to variability in participant characteristics and intervention design. This meta-analysis evaluates EF interventions' effectiveness and examines moderators such as age, clinical status, socioeconomic background, and intervention characteristics on direct and far-transfer outcomes.
Methods: The meta-analysis included experimental studies with control groups and participants aged 4–17, published from 2000 to 2024. Interventions were systematically classified by type and clinical status to address expected heterogeneity. Main outcomes included EF, regulation, and academic abilities. Effect sizes (Hedges' g) were analyzed using random-effects models with restricted maximum likelihood estimation. Heterogeneity was assessed with Q, I^2, and τ^2 statistics, and publication bias was evaluated using funnel plots, trim-and-fill methods, and Rosenthal's fail-safe N.
Results: A total of 141 studies with 14,137 participants were included. Half involved children with clinical risk factors and low socioeconomic backgrounds. Interventions showed moderate effects on EF outcomes and small but significant far-transfer effects ($g = 0.20$ to $g = 0.30$) for regulation and academic abilities. Effect sizes were larger and less heterogeneous for participants with clinical risks or low socioeconomic backgrounds. Meta-regression revealed moderation by clinical status, socioeconomic background, and intervention spacing. Publication bias assessments indicated robust findings, with adjusted models retaining significance.
Conclusion: Unlike prior meta-analyses, this study identified significant far-transfer effects for behavioral and cognitive regulation, literacy, and ADHD symptoms. These results reflect improved statistical power, systematic classification, and inclusion of multi-domain interventions. No effects were observed for emotional or social regulation or delay discounting, which may depend more on environmental factors. Intervention type did not significantly moderate outcomes, but meta-analytic differences underscore the importance of intervention design for specific effects.
Implications: EF interventions can achieve far-transfer effects, especially for children with EF deficits. Findings align with evidence-based theories suggesting shared cognitive processes drive transfer. Practical implications include targeting populations with EF impairments, as modest improvements can enhance quality of life. Blending direct training with mindfulness or meta-cognitive strategies may increase transfer across domains.

Limitations include excluding studies without far-transfer measures, limited power for rare interventions, and restricting articles to English and Spanish.

Digital Gamified Interventions to Enhance Executive Functions in Children with ASD and ADHD: Insights from an Exploratory Clinical Study in Colombia

Nicholas Napolitano, Cristian Andres Rojas-Barahona (Faculty of Psychology, University of Talca)

Background: Executive functions (EFs) are critical cognitive processes enabling goal-oriented behaviors. Deficits in EFs are commonly observed in children with ADHD and ASD, impairing cognitive flexibility and inhibitory control, which negatively affect adaptive functioning. Evidence suggests that digital gamified interventions (DGIs) can improve EFs by combining cognitive training with engaging game elements that foster intrinsic motivation, accessibility and provide advantages in their implementation. This exploratory study evaluates the efficacy of a DGI targeting inhibitory control and cognitive flexibility in children with ASD and ADHD in Colombia.
Methods: Fifty-eight participants aged 5–16 years, all diagnosed with ASD and ADHD comorbidity, were randomized into group 1 and group 2, where group 1 received the intervention between evaluations one and two, and group 2 received the intervention between evaluations two and three. The intervention consisted of two cognitive games, "Gwakkamole" (inhibitory control) and "All You Can E.T." (cognitive flexibility), played over five sessions. Control participants played a non-cognitive game for the same duration. Evaluation assessments included modified Eriksen Flanker and DCCS tasks, measuring accuracy and reaction time. Random-effects regression models were used to analyze intervention efficacy.
Results: Preliminary findings indicate that reaction times on the Flanker task decreased marginally from Evaluation 1 to Evaluation 2 for the intervention group but were not sustained by Evaluation 3. Older children demonstrated faster reaction times overall ($p = 0.02$). Error rates significantly decreased for Group 1 from Evaluation 1 to Evaluation 2 ($p = 0.010$), and for Group 2 from Evaluation 2 to Evaluation 3 ($p = 0.014$), coinciding with their respective interventions. On the DCCS task, no significant group differences in reaction time or error rate improvements were observed. However, age significantly moderated outcomes, with older participants generally exhibiting better performance.
Conclusion: These preliminary findings suggest partial efficacy of the DGI. While no significant effects were observed in cognitive flexibility, the participants exposed to the intervention were able to significantly improve their error rates on the Flanker task, suggesting improvement in their inhibitory control. Additionally, these preliminary findings also highlight the importance of age as a moderator, with older participants tending to have better performance.
Implications: These results underscore the potential of DGIs to support specific EF domains in a clinical sample, but further research is needed to optimize their design and investigate their long-term impacts. This study has several limitations. The cognitive flexibility intervention may have been too challenging for younger participants, as noted by clinicians, potentially limiting its efficacy.

Knowledge is Power: Exploring the Knowledge Change of Early Years Practitioners Who Partook in The ONE (Orchestrating Numeracy and The Executive) Programme.

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Background: Recent research highlights the importance of executive function (EF) skills in early mathematics (Coolen et al., 2021). Yet, early years practitioners (EYP) may not be aware of this research nor have the necessary knowledge and skills to support EF in the classroom. Indeed, many EYPs have reported low confidence regarding maths knowledge and pedagogy due to a lack of formal training (Costa et al., 2023). Interventions targeting EFs in the early years should therefore explore the role of teachers in supporting early EFs and maths. The current paper aims to explore the knowledge change of EYPs who participated in The ONE (Orchestrating Numeracy and the Executive) Programme.
Methods: The ONE Programme is a 12-week, play-based intervention with the primary aim of improving the early foundations of numeracy and EF in children aged 3 to 4. The programme involves professional development (PD) sessions for educators over four weeks explaining EFs and preschool maths skills, and how to incorporate both into practice. A mixed method approach was taken where quantitative and qualitative data was collected at three separate time points: T1: the start of the programme (pre-PD training), T2: post-PD training and T3: at the end of the programme. At T1, practitioner baseline knowledge about preschool maths and EF was collected via 'Mindmaps' during the first PD session (73 settings, 381 practitioners). Similarly, at T2 the Mindmaps were repeated (73 settings, 332 practitioners) and anonymous Post-PD Survey Data was collected (n=225, average=3.04 per setting). Finally, at T3 interviews were conducted with the leading practitioners (n=71 interviews).
Results: Preliminary analyses suggest, at setting level, there was no significant difference between T1 (M=12.29, SD=5.68) and T2 (M=13.29, SD=6.48) for preschool math skills (t(144)=0.19, p<.05). However, the Mindmaps did report a significant increase of terms related to EF in T2 (M=6.97, SD=4.59) than T1 (M=5.74, SD=3.42), t(144)=0.03, p<0.05. Additionally, 99.1% of practitioners completing the T2 Post-PD Survey agreed or strongly agreed that their understanding of EF had improved following the PD sessions. Interview data from T3 was analysed using deductive thematic analysis (Braun & Clarke, 2006). Themes regarding practitioner knowledge of preschool maths and EF, as well as an increased confidence to implement activities into their practice were evident in the interview data.
Conclusion and Implications: Our mixed methods analyses reveal that The ONE Programme improved EYPs knowledge of EF but not preschool maths skills. Yet, despite this, practitioners were able to recognise specific maths and EF skills at the end of the programme and reported more confidence in implementing activities involving both skills into their practice. Results will provide insight into the wants and needs of EYPs and inform future PD opportunities to ensure they are aligned with educators' knowledge and goals.

A Novel Collaborative Spatial Skills Training for Primary-aged Children to Improve Science Learning

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Background: Spatial skills are foundational to science learning throughout school and beyond. This is because science learning involves understanding how different entities interact and transform over time and space, requiring learners to form and manipulate dynamic spatial mental representations. In the last two decades, many training programmes have been developed for improving spatial skills in primary school-aged children, but effects of most do not replicate when transferred to the school environment.
Methods: Here, we developed a spatial training programme which incorporated a classroom learning approach, collaborative learning, in a bid to make an effective spatial training which is classroom ready. Children in groups (N = 40, 8-10-year-olds), or individually, (N = 40; 8–10-year-olds) built Duplo block constructions based on four schemas taken from different viewpoints, thus requiring them to gather information and integrate it for building (either alone or together). Before and after training, we measured children's science reasoning, spatial skills and spatial vocabulary, using cognitive tests.
Results: Comparing these test scores, preliminary results suggest larger gains in children working in groups, supporting our idea that learning collaboratively may help children develop spatial abilities related to science. Incorporating eye-tracking data, also gives us insight into the neural mechanisms by which spatial skills are improving.
Conclusion and Implications: Combining our understanding of mechanisms, and a design which can work in classrooms, this intervention has potential to have real impact in primary education.

Mathematics Anxiety, Executive Control and Sleep: Extending Harrington & Cairney's (2021) Hypothesis Beyond Clinical Mental Health Disorders

Eleanor Redfern, Lisa Henderson, Silke Goebel, Scott Cairney, Emma Sullivan, (University of York)

Background: Maths anxiety (MA) is characterised by feelings of tension and worries in response to maths stimuli. It is moderately correlated with general anxiety and thought to share some underlying factors. For instance, both are characterised by intrusive thoughts which can disrupt cognitive processing and solicit greater dependence on suppression, overloading executive control (EC) mechanisms. Harrington & Cairney (2021) propose a mediatory role for EC in the relationship between sleep and mental health. Sleep loss is theorised to impair the ability to suppress intrusive thoughts, leading to greater feelings of anxiety and increased intrusions. This, in turn, contributes to further sleep disturbances and increased anxiety and intrusive thoughts, potentially leading to the development of mental health disorders, like anxiety. We examine if this theory may extend to specific forms of anxiety, such as MA.

Methods: A two-part individual differences study is being carried out. The first part (n=95) had participants complete self-report questionnaires to measure sleep quality, MA and general anxiety and a speeded arithmetic test online. The second part (in progress, proposed n=170) uses in-person tasks to assess maths ability, reading efficiency and EC measures of working memory and inhibition in addition to self-report measures.

Results: Pearson's correlations were run between sleep quality (where higher values equate to lower quality), MA, general anxiety and maths performance measures. Significant correlations were found between MA and general anxiety ($r=.428$, $p<.001$), general anxiety and sleep quality ($r=.521$, $p<.001$) and MA and sleep quality ($r=.364$, $p<.001$). A partial correlation found the relationship between MA and sleep quality became non-significant when general anxiety was controlled for ($r=.183$, $p=.091$). For part 2, multiple regression will assess the relationship between EC measures and MA, and a mediation model will examine the relationship between sleep quality and MA with EC as a mediator. General anxiety, maths ability and reading efficiency will be included as control measures.

Conclusion: Part 1 found adults with higher anxiety showed lower sleep quality and higher MA, consistent with previous studies. The study demonstrated a relationship between MA and sleep quality where lower sleep quality was associated with higher MA. The correlation became non-significant when general anxiety was controlled for, suggesting sleep may be a shared risk factor for general and MA. The impact of sleep on anxiety may extend to specific academic contexts, such as maths.

Implications: Studies often investigate mental health and academic outcomes separately. There is a consistent relationship identified between MA and maths outcomes so understanding how sleep interacts with MA provides a convenient case study to investigate how it may influence not only mental health, but also academic motivation, performance and outcomes.

Academic performance and dual mechanisms of cognitive control in school-age children.

Manuel Redondo-Vidal, Pablo Brañas Garza, Patricia Román Fernández

Background: According to the Dual Mechanisms of Control (DMC) theory, there are two types of cognitive control: proactive and reactive. Proactive control occurs when individuals anticipate and plan their responses based on contextual information before a stimulus appears. In contrast, in reactive control, the control processes only happen after the stimulus's appearance. Throughout the development of children, they typically shift from relying primarily on a reactive style to adopting a more proactive one (Ricó-Picó et al., 2021). Proactive profiles have been associated with better academic performance (Kubota et al., 2020), and probably improved health outcomes, higher economic stability, and lower rates of antisocial and criminal behavior (Grisetto et al., 2021). In this study, conducted in a school context, we examine the relationship between a proactive profile and academic performance in Language, Mathematics, and English among primary school students.
Methods: A sample of 103 participants between 8 and 10 years (mean age = 107,88 months, SD = 7,38 months) completed the AX-CPT task, to measure cognitive control style. Additional data were collected on academic performance in Language, Mathematics, and English, as well as sociodemographic variables.
Results: The results showed that children with a proactive profile achieved better results in Mathematics and English as a second language. However, no significant differences were observed in Language. Regarding gender differences, boys exhibited a more proactive profile compared to girls. Nevertheless, this gender difference did not alter the overall direction of the results concerning academic performance.
Conclusion: Changes in cognitive style have been associated with improved academic performance in Mathematics and English in our study. On one hand, Mathematics tasks require analysis and prior planning to achieve the right outcomes (Zimmerman, 1990); on the other hand, second language learning involves inhibition and the control of interference from the native language (Morales et al., 2014), both of which are linked to a more proactive cognitive style. Contrary to previous results (Kubota et al., 2020), we did not find a relation between Language outcomes and cognitive style. Language performance in our study was assessed as a composite measure, including areas beyond those previously linked to proactive profiles, such as decoding (Simos, Breier, & Fletcher, 2001) and reading comprehension (Arrington et al., 2014; Cain et al., 2004; Cirino et al., 2019). This broader assessment may have influenced the lack of a relation between proactive profiles and Language performance.
Implications: Our findings suggest that activities designed to enhance executive control could improve learning outcomes and, consequently, students' academic performance.

Early Cognitive Predictors of Reading and Mathematical Disabilities: A Longitudinal Study of Comorbidities

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Background: Reading disabilities (RD) and mathematical disabilities (MD) often co-occur at rates exceeding what would be expected by chance. The Multiple Deficit Model offers an explanation, suggesting that a combination of cognitive deficits contributes to the emergence of specific learning disabilities. Recent research has identified unique and shared cognitive factors underlying RD and MD; however, few studies have simultaneously examined both reading- and mathematics-specific factors alongside domain-general abilities. Moreover, even fewer studies have analyzed these relationships longitudinally. The present study investigated kindergarten-level domain-general and domain-specific skills as predictors of children's disability status in second grade.
Methods: From an initial sample of 414 students, we focused on 195 children (55.9% girls)—categorized as typically developing (TA), RD, MD, and comorbid RD and MD (MRD), tracked from kindergarten through second grade. These children were assessed on a comprehensive battery of domain-general abilities and domain-specific skills.
Results: Multinomial logistic regression revealed that kindergarten skills significantly predicted disability status two years later, particularly for the MRD group. The model was highly successful at classifying MRD and MD children into groups with disabilities, and less successful at classifying children specifically into RD. Letter sound and symbolic number comparison were strong predictors for all disability categories, demonstrating their broad protective roles across learning disabilities. IQ was uniquely predictive for MD, emphasizing its specific relevance to mathematical learning challenges. Non-symbolic number comparison, rapid automatized naming (RAN), and visuospatial working memory specifically contributed to MRD classification, indicating their unique roles in identifying children with comorbid conditions.
Conclusion: The model incorporating domain-general and domain-specific skills measured in kindergarten successfully classified children's disability status two years later, demonstrating particularly high accuracy for the MRD group. These findings align with the Multiple Deficit Model, which posits that a combination of shared and unique cognitive deficits contributes to the development of learning disabilities. Moreover, our results confirm that, while shared cognitive deficits are present across RD, MD, and MRD, distinct deficits uniquely characterize each disorder.
Implications: The identification of both shared and unique cognitive deficits across RD, MD, and MRD highlights the need for precision in diagnosing learning disabilities and tailoring interventions to individual cognitive profiles. Recognizing unique deficits ensures more targeted support, while understanding shared challenges enables broader strategies

Does socioeconomic status moderate the spatial-mathematics association over time? An investigation using the Millennium Cohort Study.

Shannon Rosbotham, Michelle Downes, Katie Gilligan-Lee

Background: A disparity in mathematics achievement exists between children from low socioeconomic-status (SES) households and their affluent peers (Betancur et al., 2018), limiting career prospects within the Science, Technology, Engineering and Mathematics (STEM) industry (Cannaday et al., 2017). Spatial cognition may offer an avenue to reduce this disparity. Spatial cognition is the ability to reason about space (Jirout & Newcombe, 2015) and has consistently been linked to mathematics performance in correlational (Atit et al., 2022) and causal studies (Hawes et al., 2022). Furthermore, longitudinal research indicates that spatial skills are predictors of mathematics performance throughout childhood (Casey et al., 2015; Gilligan et al., 2017; Gunderson et al., 2012; Johnson et al., 2022). Anecdotal evidence suggests that the spatial-mathematics correlation may be stronger for individuals from lower SES backgrounds (Bower et al., 2020; Gilligan-Lee et al., 2023). However, research remains insufficient to inform policy, and no studies have investigated developmental SES differences in spatial-mathematics associations. This study will examine whether SES moderates the spatial-mathematics association through child development from five to 17 years.
Methods: The study will use secondary data from the Millennium Cohort Study and linked education administrative datasets (UCL Social Research Institute, Centre for Longitudinal Studies, 2024) across four waves (ages: 5, 7, 14, 17). Structural equation modelling will assess whether SES moderates the spatial-mathematics association across development, accounting for confounders such as, verbal ability and gender. SES will be measured via OECD equivalised income scores and mothers' education level at each wave. Spatial ability will be assessed using the British Ability Scales: Pattern Construction task (ages 5 and 7) (BASII; Elliott et al., 1996; Hill, 2005). Mathematics outcomes will include National Foundation for Educational Research Progress in Maths test results (age 7) (NFER, 2004), National Curriculum Mathematics levels (ages 7, 11, 16), GCSE Mathematics results (age 16), and Number Analogies activity (GL Assessments) (age 17).
Results and Conclusion: The analysis will conclude in February 2025 as part of the Transnational Access Visit Programme, funded by the European Union's Horizon 2020 programme under grant agreement No. 101008589. Findings are expected to confirm that spatial skills predict mathematics achievement in childhood (Casey et al., 2015; Gilligan et al., 2017; Gunderson et al., 2012; Johnson et al., 2022). Based on prior evidence, we also anticipate a stronger spatial-mathematics association for individuals from lower SES backgrounds (Bower et al., 2020; Gilligan-Lee et al., 2023).
Implications: Practically, findings might highlight whether spatial training is worth pursuing for closing attainment gaps and identify the most effective developmental age for intervention.

Preregistered: Unveiling the Neural Foundations of Numerical Cognition: A Longitudinal fNIRS Study in Toddlers

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Background: The development of numerical cognition, transitioning from non-symbolic to symbolic understanding, is a cornerstone of human cognitive abilities. Non-symbolic numerical knowledge (e.g., estimating quantities without precise counting) emerges early in life and underpins symbolic understanding (e.g., recognising numbers like "3"). These abilities are rooted in distinct neural mechanisms, primarily in the intraparietal sulcus within the frontoparietal network. While non-symbolic number processing has been extensively studied in infants and symbolic processing in preschoolers, a gap exists in understanding the longitudinal neural and behavioural development of numerical cognition in toddlerhood. Our study investigates the neural correlates of non-symbolic and symbolic numerical processing in toddlers and their parents to uncover intergenerational patterns and developmental trajectories.

Methods: This longitudinal study will employ functional Near-Infrared Spectroscopy to measure neural responses during numerical tasks at 1 year 6 months and 2 years 6 months. Tasks will include non-symbolic numerical adaptation (e.g., detecting changes in dot arrays), non-symbolic comparison (e.g., choosing which dot group is larger), and naturalistic stimuli of Sesame Street. Numerical ratios up to 2:3 for younger toddlers and 3:4 for older toddlers are selected based on developmental studies (Hyde et al., 2010; Zorzi & Testolin, 2017). Parents' neural responses during similar matched tasks will be recorded at the first time point. We used G*Power (vrs 3.1.9.7) to calculate the sample size for a 2x2 repeated-measures ANOVA. With an effect size of 0.25, an alpha level of 0.05 and a power of 0.95, the required total sample size was 54. Behavioural measures, such as verbal counting, language, and executive functions, will complement neural data. Socioeconomic status and home-math environment will also be assessed to examine external influences on numerical development.

Results: Data collection begins in autumn 2025. We anticipate revealing neural changes within the frontoparietal network, specifically intraparietal sulcus, across the two time points. These changes are hypothesised to reflect developmental trajectories in numerical cognition. Additionally, mothers' brain activation during numerical tasks is expected to predict their children's brain activation, providing insights into the foundations of numerical cognition.

Conclusion: This study addresses a critical gap in developmental cognitive neuroscience by elucidating the neural underpinnings of numerical cognition during toddlerhood. This is the black box of the human mind, and there is currently no neural data of numerical processing yet.

Implications: The findings will enhance theoretical models of numerical cognition by clarifying the developmental trajectory of non-symbolic and symbolic systems, and inform early identification of individual differences in children.

Exploring the Impact of Executive Functions and Motivation on Science Learning

Tamer Said (Anglia Ruskin University), Michelle Ellefson (University of Cambridge)

Background: There is evidence that shows that executive functions and motivation are separately related to science learning. However, there is a gap in understanding how both constructs could impact science learning if studied in the same model.
Methods: The current study examines the role of executive functions (inhibition, working memory, and shifting) and motivation (self-efficacy, mastery and performance orientation) on learning about counterintuitive ideas in physics. Egyptian secondary school students (N= 256, N females = 126, M age = 13.5 years, SD age = 0.93 years) participated in this study — an underrepresented population in the literature. Participants responded to a 15-item questionnaire that targeted key misconceptions about density pre and post a tutorial that targeted the key misconceptions about density, mass, and volume. They also responded to a battery of executive functions tasks (response inhibition, spatial span, task switching) and the Patterns of Adaptive Learning Strategies (PALS) questionnaire about motivation.
Results: Findings from a structural equation model indicated that shifting predicted pretest scores (ß = .18, p<.05), but not conceptual gains (posttest scores, after controlling for pretest). In contrast, motivational elements predicted conceptual gains, not pretest performance. Specifically, self-efficacy was a positive predictor (ß = .15, p<.05), while performance orientation, a maladaptive orientation, was a negative predictor (ß = -.18, p<.05).
Conclusion and implications: This study with an under-researched population, offers a holistic view of science learning by integrating cognitive and motivational factors. It highlights possible relationships between executive functions and motivation and has significant implications for teaching and learning. Specifically, it underscores the potential role of motivation in science learning, beyond the influence of executive functions.

Brain connectivity during a magnitude comparison task in 4- and 6-year-old children

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Background: Magnitude comparison tasks, where one judges which of 2 numerals represents a larger quantity, are widely used to measure mathematical development. Performance is typically influenced the distance between digits, where closer numbers (5-7) are more difficult to differentiate than those further apart (2-7) (Moyer & Landauer, 1967). This numerical distance (or ratio) effect correlates with arithmetic competence in 6–8-year-olds (Holloway & Ansari, 2009), as well as with brain activity: larger behavioural and neural ratio effects predict higher mathematics ability in children (Bugden et al., 2012). However, we understand little about the temporal dynamics of brain activity during magnitude comparison, particularly in younger children. Though older work using electroencephalography (EEG) has shown ratio effects in Event Related Potentials (Temple & Posner, 1998) in 5-year-olds, there has been little investigation into changes in temporal dynamics with age, in children younger than 5, or using modern analysis techniques.
Methods: In this study, we explored changes in brain connectivity during magnitude comparison in 4- and 6-year-olds, and adults. We recorded 64-channel EEG in 40 4-year-olds, 42 6-year-olds, and 43 young adults during a single-digit magnitude comparison task, judging which of two Arabic digits (1-9) presented either side of a central fixation was larger. To explore similarities in frequency profile between electrodes, we calculated coherence across frontal and parietal electrodes and the connections between these regions (fronto-parietal).
Results: Behavioural results showed faster reaction time with increasing age and smaller ratio, and higher accuracy with age and larger ratio. Children with higher mathematics ability were also faster to respond. Within the alpha band (8-12Hz), adults showed a greater decrease in coherence from baseline than children, particularly in fronto-parietal connectivity. Within the theta band (4-8Hz), coherence increased from baseline in adults, but decreased in children, especially in frontal regions. However, these effects were highly variable within each age. Despite finding greater behavioural ratio effects for younger children, there was no evidence for ratio effects in coherence, or relationships between coherence and behavioural ratio effects.
Conclusions: Patterns of connectivity during magnitude comparison change substantially through development. The findings suggest that between 4 and 6, changes in brain activity reflect increased automaticity in number processing, though there is substantial variability across children.
Implications: These results have implications for understanding the neural correlates of mathematical development, reinforcing previous work showing early childhood is a crucial time for acquisition of numerical skills, and demonstrating that this development is reflected in neural connectivity.

MathMIND – classroom observations of numeracy classes for children with genetics conditions

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Background: Numeracy is key to support independent living from childhood into adulthood. However, most research regarding the development of numeracy skills has not focused on neurodivergent children. The Department for Education lists Special Education Needs and Disabilities (SEND) as a priority for research and as more countries move towards inclusive models of education, there is an urgent need to understand how to best support neurodivergent children in education. Mathematics classes in primary schools provide a key context in which children practice and develop their mathematics skills. Little is known about the maths classroom context for children with SEND, and how their experiences may differ from other children. As part of the wider MathMIND project, this study utilises classroom observations to explore the numeracy classroom environment for children with Down syndrome (DS), Fragile X syndrome (FXS), and Williams syndrome (WS). Specifically, this study investigates what the common characteristics of school environments are that support or hinder early numeracy development in children with genetic syndromes.
Methods: A total of 240 children, balanced across groups and aged 4–9 years, will complete a battery of numeracy and cognitive assessments. Alongside this, the researcher will join the target child during a maths lesson in their classroom. An observation of the maths class will take place, using an observation schedule based on Webster and Blatchford (2013). Key observations will include the number of adults in the room and their interactions with the target child, whether the child is in the main classroom or a separate setting, the type of mathematical manipulatives used, and the level of differentiation provided. Observations will take place in five-minute intervals, with every fifth interval focusing on the rest of the class, to compare their activities with those of the target child. These observations will be conducted in both mainstream and special schools. A survey will also be distributed to the classroom teachers to understand teacher attitudes and perceptions towards mathematics teaching, and their prior experiences of working with children with genetic conditions.
Results: As data collection is currently ongoing, preliminary results will be presented. The preliminary analysis will compare classroom observations between the three different genetic groups to understand how the numeracy school environment may be similar or differ between these groups of children.
Conclusion and Implications: This study offers a novel contribution to the field by quantitatively observing numeracy classroom environments of children with Down syndrome (DS), Fragile X syndrome (FXS), and Williams syndrome (WS).

Educational neuroscience of mathematical learning and development in South African children

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Background: Most of our knowledge about mathematical learning and development comes from the minority world or so-called WEIRD (Western, Educated, Industrialised, Rich, Democratic) populations, which is generalised to the majority world or non-WEIRD populations. However, environmental variability, values, and demands cause differences in human cognition. For example, differences between languages, socioeconomic status, and attitudes and beliefs about mathematics influence children's mathematics performance. To address this gap, we conducted two educational neuroscientific studies of mathematics learning in primary school children in South Africa.
Study 1
Methods: A total of 39 fifth graders with low and high competence in fractions completed simple and complex fraction problems while their brain responses were recorded using functional near-infrared spectroscopy (fNIRS). In the fraction comparison task, they had to identify which of the two visually presented fractions was larger.
Results: Fraction complexity led to increased activation in the right dorsomedial frontal region in the high-competence group but not in the low-competence group. This finding suggests that only the high-competence group recruited frontal cognitive resources, as evidenced by their higher behavioural performance.
Conclusion: We argue that the neural responses during fraction complexity depend on individual differences.
Study 2
Methods: A total of 42 first graders completed mathematics vocabulary recognition (e.g. "where is more/less?") in L1 (Sesotho/isiZulu) and L2 (English) while their brain responses were recorded using fNIRS. Children had to compare two sets of objects to determine where is more or less, depending on the question for each comparison, and indicate their responses.
Results: Processing mathematics vocabulary led to higher right frontal activation in L1 versus L2, which suggests higher engagement of cognitive processes during L1 rather than L2. Moreover, mathematics vocabulary in L1 led to higher right frontal activation versus non-mathematics vocabulary in L1, which suggests additional cognitive support during

mathematics versus non-mathematics vocabulary.
Conclusion: Numerical number words in South Africa are in English rather than African languages. While the African languages are considered children's L1, number words and mathematics are taught in English (L2) in South Africa. Therefore, mathematics vocabulary in L2 was less demanding than in L1 in this study.
Implications: To our knowledge, these are the first educational neuroscientific studies of mathematical cognition in sub-Saharan countries. This research will shed light on less-studied populations and provide critical insights into mathematical learning and development in South Africa that inform evidence-based educational interventions and technology development for early educational policymakers.

Validity and Reliability of Approximate Number System Measurement

Monika Szczygieł, Mehmet Hayri Sari

Background: Although it is widely accepted that numbers are represented in the mind through a mental representation of quantity, the validity and reliability of approximate number system (ANS) measurement remain subjects of debate. Questions surrounding the psychometric properties of ANS measurements are closely tied to the predictions expected of this system. While the issue of validity is complex and depends on a clear theoretical foundation, establishing the reliability of tasks should be a standard practice but is often overlooked. To address this gap, we assessed the reliability of a task measuring the ANS (non-symbolic comparison task) using the most popular indicators associated with this task. Additionally, we examined the relationships between these indicators to determine whether they can be used interchangeably, as is often assumed in the literature. Finally, we investigated whether and to what extent they correlate with other mathematical constructs, providing insights into their theoretical or practical applications.
Methods: We tested 119 Polish young adults (aged 18–32, M = 21.42, SD = 2.99) using a non-symbolic comparison task, symbolic comparison task, number line estimation task, mathematical achievement test, and a math anxiety questionnaire. Several indicators of the non-symbolic comparison task were used as measures of the ANS: accuracy (ACC), reaction time (RT), numerical ratio effect based on RT (NRE), distance effect based on RT (NDE), size effect based on RT (NSE), and Weber fraction (W). We assessed split-half reliability and conducted Pearson's correlations to evaluate relationships between indicators.
Results: The relationships between indicators of the non-symbolic comparison task ranged from non-significant (e.g., W and RT, NDE, NSE; ACC and NRE, NDE, NSE), through weak (e.g., W and NRE), moderate (e.g., RT and ACC, NSE; NSE and NDE; NSE and NRE; W and ACC), to strong (e.g., RT and NRE, NDE; NDE and NRE). Split-half reliability also varied across indicators: ACC $r = .67$, $p<.001$, RT $r = .97$, $p<.001$, NRE $r = .57$, $p< .001$, NS NDE $r = .52$, $p<.001$, NSE $r = .42$, $p<.01$. Regardless of the ANS indicator, no significant relationships were observed with symbolic numerical representation, mental number line performance, mathematical competence, or math anxiety.
Conclusion and Implications: The reliability of the non-symbolic comparison task varies depending on the indicator used, ranging from satisfactory to below expectations. This highlights the need to improve cognitive tasks designed to measure numerical representation. Although many researchers treat ANS indices as interchangeable, our findings suggest they measure distinct cognitive processes and should not be treated as equivalent. The lack of correlation with external criteria raises critical questions about whether the issue lies with the validity of the instrument or the potential irrelevance of the ANS in predicting mathematics-related outcomes in adults.

The temporal sampling hypothesis: evidence from a rhythm-based intervention in children with developmental language disorder

Li Ning Nicole Tan, Susan Richards, Usha Goswami (University of Cambridge)

Background: According to the temporal sampling (TS) framework, language deficits in Developmental Language Disorder (DLD) may be caused by impaired neural entrainment to slower acoustic rhythms in speech (Goswami, 2011). Slow amplitude modulations (AMs) carry speech rhythm information, and neural entrainment to these AMs is thought to facilitate the perception of syllable stress patterns and speech prosody (Leong & Goswami, 2015; Giraud & Poeppel, 2012). Impaired AM processing may thus hinder prosodic bootstrapping processes (Pate & Goldwater, 2011), which support children's learning of grammatical rules from speech input. As neural tracking of speech rhythms is impaired in DLD (Nora et al., 2024), we hypothesized that enhancing acoustic rhythms in language may mitigate these prosodic difficulties.

Methods: We designed an intervention that adapted Melodic Intonation Therapy (MIT, devised for aphasic adults) (Albert, Sparks & Helm, 1973) for children with DLD. This was piloted with 10 children with DLD aged 7-11, and 10 age-matched controls. Each child received 16-20 intervention sessions (1-to-1, approx. 30 minutes each), where they were taught to tap along to the syllabic rhythm of children's rhyming books while chanting (rhythm-only) or singing (rhythm+pitch) the words. For example, a child could tap to phrases from Hairy Maclary's Rumpus at the Vet (Dodd, 1990), tapping harder on stressed syllables and lighter on unstressed syllables. When singing, one pitch was used for stressed syllables and a lower pitch for unstressed syllables. By TS theory, this highlighting of stress patterns should mitigate some language difficulties in DLD. Before and after the intervention, the Test for Reception of Grammar, version 2 (TROG-2) (Bishop, 2003) was used to measure children's understanding of grammatical structures. Sensitivity to AM onsets (rise times) was also measured.

Results: Regardless of whether storybooks were chanted or sung, children with DLD (Pretest: mean=74.6, SD=15.7; Posttest: mean=85.2, SD=13.4) and age-matched controls (Pretest: mean=97.7, SD=6.02; Posttest: mean=106.9, SD=7.95) showed significant improvement in TROG-2 scores (10.6 and 9.2 standard points respectively, $p < .05$) after the intervention. TROG-2 scores are standardized by age (mean=100 and SD=15).

AM onset discrimination thresholds also improved in both the DLD group (Pretest: mean=125 ms, SD=38.4 ms; Posttest: mean=101 ms, SD = 33.4 ms) and the age-matched control group (Pretest: mean=113 ms, SD=36.9 ms; Posttest: mean=82.6 ms, SD=39.9 ms). However, these effects failed to reach significance (control p-value=0.059, DLD p-value=0.093).

Conclusion: Overall, our pilot data highlight the potential value of rhythm-based interventions in DLD. We are currently testing an unseen control group to estimate normative change over time.

Implications: The rhythm-based intervention seems effective in improving receptive grammar. This provides support for a TS-approach to DLD remediation.

The impact of spaced learning within physics lessons in secondary schools

Andy Tolmie, Rachel Hartley, Alessio Bernadelli, Yuxi Zhou (UCL Institute of Education)

Background: Spaced learning (SL) provides distributed learning opportunities with distraction breaks. The latter are thought to facilitate consolidation of novel information in long-term memory by accommodating the neural recovery period and accompanying biochemical changes in neuronal potentiation (Smolen et al., 2016). The application of cognitive neuroscience including SL has grown considerably in recent years and become commonplace across UK teaching as well as featuring in government guidance (DfE, 2019). However, there have been few research trials, especially within secondary schools, and none addressing the abstract content of physics, though Kelley & Whatson (2013) showed an hour-long learning input in secondary biology with ten-minute breaks yielded exam performance equivalent to regular teaching across many months.
Methods: The present study adapted Kelley and Whatson's regime, using in class video to deliver content on atomic structure to students aged 14-16 years. As well as 'business as usual' controls, the research included groups that only experienced the SL lesson, and those who were exposed to it prior to traditional teaching. Impact on learning was assessed using test questions similar to GCSE examinations. Students studying combined sciences and those taking separate physics were divided into groups, cutting across conditions, with the former taking a shorter test. Six state schools covering a range of demographic backgrounds participated in the study, with 336 students completing all the appropriate pre- and post-intervention (immediate and delayed) tests.
Results: SL led to immediate benefits for the separate physics students, but for the SL only group there was no further gain at delayed post-test, with performance then equal to controls as in Kelley & Whatson. In contrast, the SL plus group showed additional gains at delayed post-test, following traditional teaching, with overall gains between 50% and 90% greater than the other groups. For combined science students, the SL plus group showed gains at delayed post-test some 60% greater than controls. These effects were consistent across different schools.
Conclusion and implications: The implication is that SL provides a foundation for subsequent learning, nearly doubling its efficiency regardless of context, and that it does so with minimal additional input.

Investigating the Neural Profiles of Children Identified for Math Support with Resting-State Functional Connectivity MRI

Eric D. Wilkey, Isabella Starling-Alves, Omair A. Khan (Vanderbilt University)

Background: Approximately 25% of school-age children experience mathematics difficulties (MD), which negatively impacts their academic success and well-being. Recent research has provided a robust understanding of the behavioral and cognitive profile of MD, but its neurobiological underpinnings remain obscure. One issue preventing consensus is the high degree of variability in analysis techniques among neuroimaging studies. Analysis of resting-state fMRI data is one potential solution. In the current presentation, I will present a brief overview of the state of the field of resting-state functional connectivity (rsFC) analyses of the mathematical brain alongside two unpublished rsFC studies of children with math learning difficulties in 1st grade (6-8 yo; Study 1, USA sample) and 3rd grade (8-10 yo, Study 2, Singapore sample). In both studies, we take complementary approaches to build on and then extend previous work.

Methods:

Study 1: In this study, we investigated the rsFC of 46 1st graders with MD and 60 typically achieving (TA) peers, identified in a classroom setting. We conducted a seed-to-voxel analysis contrasting the rsFC profiles of MD and TA children in cytoarchitectonically defined subdivisions of the intraparietal sulcus (hIP1, hIP2, and hIP3) and the angular gyrus (PGa, and PGp), bilaterally. We then conducted a multivariate classification analysis based on the rsFC maps.

Study 2: In this study, we investigated the rsFC of 30 children with MD based on school-system screening and 37 of their TA peers. Again, we contrasted seed-to-voxel connectivity in subregions of the intraparietal sulcus and angular gyrus with addition of the hippocampus. We then we took a modified connectome-based predictive modeling approach to predict MD based on whole-brain connectivity patterns.

Results:

Study 1: There was a pattern of hyperconnectivity between the right hIP2 and the left hippocampus and hypoconnectivity between the right PGa and the right ventral temporal occipital cortex in children with MD. The classifier distinguished between groups based on the rsFC of the left hIP1, the right hIP3, and the left PGp.

Study 2: The seed-based connectivity analysis showed differences in functional connectivity between the bilateral IPS and left hippocampus and frontal structures, with a general pattern of stronger functional connectivity for TA. Results of the CPM analysis are forthcoming.

Conclusion: Together, these findings suggest that MD is associated with a pattern of both hypo- and hyperconnectivity between subdivisions of the IPS, AG, and hippocampus, brain regions related to number processing and arithmetic fact consolidation and retrieval as well as attentional allocation more broadly.

Implications: These results imply that resting-state functional connectivity maps may serve as biomarkers for understanding relatively stable neural differences between children with MD and their TA peers, even those identified in naturalistic settings.

Individual Differences and Mathematical Profiles in Williams syndrome and Down syndrome

Stella Xu (UCL Institute of Education), Michael S. C. Thomas (Birkbeck University of London), Jo Van Herwegen, (UCL Institute of Education)

Background: Individuals with Williams Syndrome (WS) and Down Syndrome (DS) are frequently compared due to their similar levels of learning disability and uneven cognitive profiles. While past studies have identified mathematics as a weakness in both conditions, mathematics is a complex componential subject (i.e., counting, procedural knowledge, number sense, arithmetic) and thus, it is important to examine the variability of strengths and weaknesses for each of these components within each condition. This study aims to examine 1) the individual differences within these component skills, 2) what the profiles of these components look like in WS and DS, and 3) whether profiles are characteristic of each syndrome or alternatively represent transdiagnostic groupings.
Methods: In total, 60 participants aged 5-18 years are currently being recruited, with a goal of 30 participants in each group. Data has been collected for 10 participants with DS and 21 with WS. Data collection involves a battery of cognitive and math measurements.
Results: Initial MANOVA analysis and profile plots revealed varying strengths and difficulties across mathematical abilities within children with WS and DS, as well as significant differences between the two groups.
Conclusion and Implications: The implications of this study extend to moving away from diagnostic labels and focusing on meeting individual needs to address specific needs in mathematical development.

The Relationship between Theory of Mind and Evaluative Language Use in Narratives of Cantonese-speaking Adults

Esther Wing-Chi Yip, Hale Ögel-Balaban (Faculty of Education, University of Cambridge)

Background: Narrative production, also known as the act of storytelling, refers to the process of constructing a cohesive discourse with a sequential, temporal and causal structure. One of the underlying factors of narrative production was proposed to be the theory of mind, the ability to attribute mental states to others. This socio-cognitive ability may enable narrators to create comprehensive stories by using evaluative language including expressions referring to characters' emotions and motivations and narrators' interpretation of the events, allowing their narratives to better align with the audience's perspectives. While some studies have shown a relationship between theory of mind and evaluative language use in narratives by young children and in Indo-European languages, findings are inconsistent when investigated in other languages and older age groups. The present study aimed to contribute to the literature by examining the relationship between theory of mind and evaluative language use in two genres of narratives - fictional and personal - constructed by Cantonese-speaking adults.
Methods: Thirty participants aged between 20 and 35 years (Mage = 25.47; SDage = 3.60), who are either bilingual or multilingual, completed the Strange Stories task as a theory of mind task and two narrative elicitation tasks. For fictional narratives, participants were asked to construct a story based on a six-picture, wordless story about a goat family. For personal narratives, participants were asked to tell a personal experience of a problem they had fixed. Clauses in both narratives were coded as either evaluative clause including at least one evaluative expression such as emotional states, hedges, and character speech, or referential clause. The ratio of evaluative clauses over the total number of clauses was calculated as the evaluative language score.
Results: Pearson's bivariate correlations between the Strange Stories task score and the evaluative language score in each narrative genre demonstrated no significant relationships, $r(28) = -.24$, $p = .21$ for the fictional narrative, and $r(28) = .24$, $p = .21$ for the personal narrative.
Conclusion: Theory of mind was shown to be not associated with the evaluative language use in both fictional and personal narratives by Cantonese-speaking adults. Consistent with some previous studies, this suggests that cognitive and linguistic demands of narrating might interfere with the use of theory of mind in narrative production. Another reason for the lack of the relationship might be the narrators' preference to keep the evaluations at the implicit level.
Implications: The present study was one of the first studies to examine the relationship between theory of mind and evaluative language in narratives of Cantonese-speaking adults. Future research examining developmental, cross-cultural and cross-linguistic patterns might provide more insight into the relationship between theory of mind and narrative production.

Open-skills sports, especially team ball games, are associated with cognitive functions in adolescents: A time use diary study

Yuxi Zhou, Youyou Wu, Andrew Tolmie (UCL Institute of Education)

Background: In the past few decades, there has been ongoing debate regarding whether and how physical activity is related to cognitive development. The current study attempted to advance our understanding of this topic by exploring how various facets of physical activity—both quantitative and qualitative—are linked to specific cognitive functions in adolescents.
Methods: The sample was 3527 adolescents from the United Kingdom Millennium Cohort Study. At age 14, adolescents' daily activity content, duration, and intensity on weekdays and weekends were assessed using both an activity monitor and a time-use diary. Cognitive skills, including executive function and academic achievement, were measured at ages 14 and 17, respectively.
Results: Multiple hierarchical regressions revealed that a greater amount of time spent in moderate-to-vigorous activity (MVPA) was predictive of better executive function at age 14 but unrelated to academic outcome at age 17. Analysis of adolescents' activity diaries revealed that open-skills sports (i.e., cognitively engaging sports like tennis and football) were more closely associated with EF compared to other activities also at moderate-to-vigorous intensity (e.g., cycling). Among open-skills sports, team ball games emerged as the strongest predictors of adolescents' EF, exceeding the effects of MVPA. Furthermore, we found that regular engagement in individual ball games and swimming was longitudinally linked to better academic outcomes.
Implications: Our findings confirm the link between MVPA and cognitive functions in the adolescent population and highlight the beneficial effect of open-skill sports on adolescents' cognitive development. These findings provide insights into the underlying mechanisms of the motor-cognition relations, suggesting that activities involving motor control or adaptation (e.g., competitive team ball games) might provide a key stimulus for cognitive development in adolescents, with potential downstream benefits for academic achievement.