Conference Agenda

Session

24 June - S 18: Symposium

Time: **Wednesday, 24/June/2026: 9:00am - 10:15am**

Location: **T2 - CLA**

110 people

Presentations

Spatial skills as a foundation for mathematics: development, diversity, and educational impact

Chair(s): **Eylül Turan** (University of Washington, United States of America)

A growing body of research highlights spatial skills as a key foundation for mathematical development, yet important questions remain regarding underlying mechanisms, developmental timing, individual differences, and educational impact. This symposium brings together complementary evidence addressing these gaps. Talk 1 adopts a longitudinal developmental perspective, examining how verbal (spatial language) and non-verbal (mental rotation) spatial skills emerge in early childhood and jointly contribute to later numeracy. Talk 2 investigates heterogeneity in the spatial–mathematics association, using a cross-country design to identify for whom and under what conditions spatial skills support mathematical learning. Talk 3 situates spatial skills within a socioeconomic framework, demonstrating how spatial abilities predict later mathematics and partially account for SES-related achievement gaps. Finally, Talk 4 translates theory into practice by presenting large-scale evidence that embedding spatial instruction within mathematics curricula yields to gains in mathematics. Together, these studies provide a comprehensive account of how spatial skills support mathematics.

Presentations of the Symposium

Early verbal and non-verbal spatial skills as precursors of mathematical development

<u>Eylül Turan</u>; Claudia Wimsatt; Alice Aizza; Ariel Starr
University of Washington

Both non-verbal (e.g., mental rotation; Cheng & Mix, 2014) and verbal (e.g., spatial language; Turan & De Smedt, 2023) spatial skills predict mathematical development. However, most studies examined verbal or non-verbal spatial skills in isolation (e.g., Cheng & Mix, 2014). Only a small number of studies investigated both components of spatial skill simultaneously, and these have focused on concurrent associations (Bower et al., 2020) or on older children (Gilligan et al., 2021). To better understand the mechanisms through which spatial skills -both verbal and non-verbal- support mathematical development, longitudinal studies that assess these spatial domains from early childhood are needed.

We examine how verbal (spatial language exposure and comprehension) and non-verbal (mental rotation) spatial skills relate to one another over development, and how each of these components is associated with mathematics both concurrently and longitudinally.

At Wave 1, data are being collected from 70 children (current n = 64; Mage = 31.2 months, 31 female). Non-verbal spatial skills were assessed using an eye-tracking mental rotation task in which children had to mentally transform a giraffe to predict its movement direction. Verbal spatial skills were assessed via shared picture-book reading and block play. These interactions were transcribed for spatial language use by both parents and children.

Children are now returning for Wave 2 (Mage = 42 months), where they complete the same mental rotation task to assess developmental change in non-verbal spatial skills. They also complete a spatial analogies task measuring the ability to map spatial relations across objects. Finally, we measure their spatial language production and comprehension, as well as their early numeracy skills.

Preliminary analyses from Wave 1 indicate that children performed well on the mental rotation task (Mmaxangle=51.59, range=0-165 degrees). Child spatial language use was not related to mental rotation performance. However, gender differences emerged: females outperformed males on mental rotation ($t(58)=2.14$, $p=.04$), despite a trend for parents to use more spatial language with males during play.

Planned analyses will examine concurrent relations among non-verbal spatial skills (mental rotation and spatial analogies), spatial language, and numeracy at Wave 2; bidirectional longitudinal associations between verbal and non-verbal spatial skills across Waves 1 and 2; and the extent to which early mental rotation and spatial language exposure predict later mathematics. Together, these findings will advance our understanding of how non-verbal and verbal elements of spatial skills jointly contribute to early mathematical development and help identify early targets for intervention.

Who can benefit from spatial skills in mathematics and when?

<u>Ilse Coolen</u>[1]; Gaia Scerif[2]; Bert De Smedt[3]
1: University of Leuven, University of Oxford; 2: University of Oxford; 3: University of Leuven

Previous research shows a robust association between spatial skills and mathematics, identifying spatial training as a promising contributor to improve mathematics performance. Nevertheless, how and why spatial skills contribute to mathematics learning remains less well understood. Understanding individual differences related to the spatial-maths association is important to explain potential variability in transfer outcomes and to identify who can benefit from spatial training or how to adapt training to ensure that it could work for all.

In this study, we test group differences and how these group differences impact on the spatial-maths association, clarifying for whom and under what conditions spatial skills can support mathematics learning. We used a cross-country design testing 5-7-year-old children in Belgium and England on four spatial and four mathematics measures. Multigroup analyses in a Structural Equation framework will allow us to investigate whether subgroup characteristics influence the nature of the spatial-maths association. Grouping variables under investigation are sex, education, maturation, parental education, and low or high spatial performance. Additionally, interaction between these variables will be included. Indeed, novel insight can be provided when exploring interactions and this unique cross-country design combining a sample matched in age (5-6 years) but not in educational stage (kindergarten vs primary school), offers the potential to partly untangle maturational influences from educational influences.

Preliminary findings show that the spatial-maths association is generally consistent across groups, with the exception of low performing children in spatial skills or younger children, potentially as they might not (yet) make use of spatial strategies within their early mathematical tasks. Further analyses including interactions between variables will further clarify these patterns. Understanding these interactions enable us to better understand the heterogeneity in the strength of the spatial-maths association in children.

The association between children’s socioeconomic status, their spatial abilities and later mathematics proficiency

Sarah McCarthy[1]; Debbie Gooch[2]; Michael S.C. Thomas[3]; Angelica Ronald[2]; Emily K. Farran[1]
1: University of Surrey; Centre for Educational Neuroscience; 2: University of Surrey; 3: Birkbeck University of London, Centre for Educational Neuroscience

Low mathematics attainment is associated with poorer life outcomes such as lower income levels, lower physical health, and less engagement by individuals in their communities. This issue is particularly acute among children who are experiencing socio-economic disadvantage: in 2023-24 only 59% of 11-year-olds eligible for free school meals in England met the expected standard in mathematics, compared to 79% of their socio-economically advantaged peers. A key focus of educators and policy makers in England is how to close this widening attainment gap. Research shows that children's spatial abilities are associated with their mathematics performance, and that children from low socioeconomic status (SES) families have lower spatial and mathematics skills than their high-socioeconomic peers. Evidence is mixed, however, regarding how SES impacts spatial-mathematics associations. This research examined the associations between SES, spatial abilities, and mathematics through early and middle childhood using the Twins Early Development Study (TEDS) (N= 2,454 participants), a large longitudinal study. For the first time, associations were considered from age 2, as well as at ages 4 and 9, with mathematics at age 10 as the outcome measure.

Three research questions were posed:

1. Does spatial ability at age 2, 4 and 9 years predict mathematics performance at age 10 years?

2. Does the socioeconomic status (SES) of the child change the relationship between spatial ability and mathematics performance?

3. Does spatial ability explain part of the relationship between SES and mathematics performance?

Spatial abilities at each age predicted mathematics performance at age 10, independent of demographics (SES and gender) and language (βs = 0.08–0.27, ps < .001), with small effects in early childhood and moderate effects by age 9. SES, at age 9 only, significantly moderated the spatial-mathematics association with the greatest effect of spatial abilities on mathematics being observed for the lowest SES group. Spatial abilities at age 9, but not ages 2 or 4, partially mediated SES effects on mathematics. Educators and policy makers looking for ways to narrow the mathematics attainment gap could consider exposure to more spatial content in the curriculum for all children, particularly those from socio-economically disadvantaged backgrounds.

Mathsburst in Scotland: primary school maths lessons with deliberate spatial instruction lead to spatial, maths and computational thinking gains

Jack Parkinson; Quintin Cutts
Turner Kirk Centre for Spatial Reasoning, University of Glasgow

This paper demonstrates the benefits of deploying a maths-based spatial intervention at scale. For the past two years, work has been carried out across Scotland to deploy MathsBURST lessons: lessons covering typical curriculum maths, but with a specific and deliberate focus on improving spatial skills while doing so. The first year of the programme involved just over 800 pupils in 22 schools (+10 control) with a single level of content (Year 3/P4). The second year involved nearly 2000 pupils in 63 schools (+17 control) with two years of content (Years 3 & 4/P4 & P5).

Teachers received training and resources to deliver assessments and lessons. Pre-tests in spatial skills, maths and computational thinking (CT) were issued in late August and early September, followed by a period of teaching (including MathsBURST lessons for the experimental group and "business-as-usual" maths for the control group) until December, and post-tests in January.

In the first year, P4 control group classes improved by an average of 8% in their maths outcomes and did not statistically significantly improve in their spatial or CT outcomes. By contrast, the experimental group improved by 20% in maths, 22% in spatial skills and 12% in CT. In the second year, the P4 control pupils improved by 5% in maths, 4% in spatial skills and did not statistically significantly improve in CT. The experimental P4 pupils improved by 19% in maths, 19% in spatial skills and 15% in CT - similar gains to the first year of the study. The P5 control pupils did not statistically significantly improve in any of the assessments, while the experimental group improved by 17% in maths, 19% in spatial skills and 10% in CT.

Initial differences in gender and SES followed historic trends (boys from wealthier backgrounds had the highest spatial skills) however the gaps were reduced for the experimental group and grew for the control group. Additionally, teachers reported high levels of engagement, improved skills and attitudes (such as resilience and confidence) and higher levels of class inclusion for those who did not typically enjoy maths. These results demonstrate that an intervention for spatial skills delivered at scale can yield substantial positive outcomes for involved pupils.