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From Neuroscience to the Classroom

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The Neuroscience of Development and Training of Mathematical Abilities during Childhood

Abstract:
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The adult brain contains a cortical area specialized for the analysis of numbers (the number form area, NFA). How and when the NFA establish specific connectivity to the rest of the brain during development is unknown.

In a study of resting state connectivity, we showed striking difference in the age at which specific functional connectivity emerged: the right intraparietal cortex (IPS) was connected to NFA at the earliest age tested (age 3.5) while the connectivity of the left IPS and the right dorsolateral prefrontal cortex was not established until 11.5 and 13.3 years, respectively. The latter was also associated with increase in mathematical ability. These results show a network of regions with specific connectivity to the NFA, some of which are established very early in life, and some of which only emerges through years of education and training.

The intraparietal cortex is consistently associated with mathematical performance, but also spatial attention and visuo-spatial working memory. This suggests that spatial coding of numbers, such as incorporated in the numberline representation, should be useful. We therefore investigated the effect of numerical training using a number-line (NLT), visuo-spatial WM training (WMT), or the combination of the two on a composite score of mathematical ability.

We randomly assigned 308, 6-year-old children to WMT, NLT, WMT+NLT or a control intervention. Overall, there was a significant effect of NLT but not WMT. The WMT+NLT was the only group that improved significantly more than the controls. Higher WM and maths performance predicted larger benefits for WMT and NLT, respectively. Neuroimaging at baseline also contributed significant information about training gain. Different individuals showed as much as a three-fold difference in their responses to the same intervention.

These results show that the impact of an intervention is highly dependent on individual characteristics of the child. If differences in responses could be used to optimize the intervention for each child, future interventions could be substantially more effective.

About:
Torkel Klingberg is Professor of Cognitive Neuroscience at the Karolinska Institute in Stockholm, Sweden. Klingberg's work on child brain development, education and cognitive training is at the international front line with publications including *Science, Nature Neuroscience, PNAS* and *Nature Reviews Neuroscience*. He led the original studies demonstrating that working memory can be improved by training, and leads several large Swedish project on child brain development and academic abilities. He is head of a non-profit organisation, CognitionMatters.org, and has written several books of popular science.