

Do Redeployed Finger Representations Underlie Math Ability?

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Introduction: Finger Gnosis and Math

Finger gnosis is the ability to distinguish, without visual feedback, which fingers have been lightly touched. Developmentally, finger gnosis has been found to predict children's mathematics performance (for a review see Penner-Wilger et al., 2007). The question of *why* finger gnosis and math are related is an issue of debate.

Research to date has focused on two views, one "localist" and the other "functional". According to localism, finger gnosis predicts math ability because the two abilities are supported by neighboring brain regions, which tend to have correlated developmental trajectories. On this view, there is no direct causal link between the abilities (Dehaene, et al., 2003). In contrast, according to the functional view, finger gnosis and math are related because the fingers are used to represent quantities and perform counting and arithmetic procedures. As a result, the representation of numbers and of fingers become entwined (Butterworth, 1999).

Empirical support for each view has been mixed. Localism predicts that all co-located cognitive functions—such as left-right orientation and handwriting—should be correlated, *ceteris paribus*, a prediction that is not generally supported. Likewise, the functional prediction that facility in finger use (e.g. speed of finger tapping) should predict math ability at least as well as finger gnosis has also not been borne out (Penner-Wilger et al., 2007).

Our purpose in this poster is to (1) outline a novel hypothesis explaining the observed correlation, (2) point out some evidence in support of the hypothesis, and (3) suggest some further empirical predictions of the hypothesis.

Redeployment of Finger Representations

We propose that part of the neural circuit supporting finger gnosis is also part of the neural circuit supporting certain mathematical abilities. That is, a functional circuit originally evolved for finger representation has since been redeployed in support of magnitude representation, and now serves both functions. This hypothesis makes the finger gnosis-mathematics relation one particular instance of the more general phenomenon of redeployment in the evolution of the brain (Anderson, 2007).

Consider from a computational perspective that one foundational element in any calculating circuit is a register for storing the number(s) to be manipulated.

Such a register requires a series of switches that can be independently activated; abstractly speaking, the ability to individually represent whether and which fingers have been touched requires the same. As such, the finger-gnosis circuit would be a candidate for redeployment by a later-developing need with the same abstract structure.

Evidence and Predictions

Consistent with our view that the same circuit is responsible for the representation of fingers and of magnitude, Zago et al. (2001) found that a region associated with the representation of fingers (left parieto-premotor circuit) was activated during adults' arithmetic performance. Also consistent with our view, rTMS applied to the left angular gyrus has been found to disrupt adults' performance on both finger gnosis and number magnitude tasks (Rusconi, et al., 2005). Moreover, given that in our view the connection does not rest on the use of the *actual* fingers in calculation (although it might suggest reasons we find it natural to use them), it is compatible with the finding that math is more highly correlated with gnosis than with finger agility (i.e. tapping).

This last finding suggests a novel prediction: children who do not, or cannot, use their fingers to count (but who perform normally on a finger gnosis test) will nevertheless show activations in the finger circuit during magnitude comparison tasks. We are currently designing an experiment to test this prediction.

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