The early development of arithmetic skill is an important, enduring, and widely studied topic. It is known that children's arithmetic strategies transition from overt, effortful, unreliable skills such as finger counting, to more efficient, reliable, and often covert skills, such as highly proceduralized covert strategies, and sometimes direct memory retrieval. In the '80s and '90s specific theories, often instantiated in computational models, were proposed to explain these transitions. However, these early computational models were ***learning*** models instead of ***developmental*** models which, by strengthening and weakening connectivity between systems, can address fundamental discrepancies between major theories (don’t know yet). More importantly, recent systems neuroscience has produced detailed descriptions of how multiple cognitive systems (memory, language, control, visual, motor, etc.) interact via distributed brain networks (dPFC, hippocampus, SPL/IPS, VOTC, etc.) in complex cognition, and how these interactions change during development. On one hand, existing models of arithmetic development, as an exemplar process of such multi-system interactions, do not have the capacity to encompass these results. On the other hand, some system neuroscience findings also pose challenges to existing theories that require computational models to address. The present proposal aims, first (1) to establish a new and [open-to-public [secondary activity?] [?? Data Repo]] neurocomputational framework that advances previous theories and models by encompassing findings from systems neuroscience; and second (2) to apply the new framework to provide testable hypotheses regarding the mechanism and consequences of the interaction between multiple systems such as observed comorbidities relating arithmetic and reading difficulties in children.

Specific Aims

Aim 1: Establish a new neurocomputational framework of children’s arithmetic strategy use and change to encompass our recent understanding of how the brain *typically* works and develops as a cognitive system.

*Hypothesis 1A*: [[replication]]The new models can reproduce observed regularities in strategy usage and change, as could the old models. [Do we need this? (I.e., They are no worse than the existing models in encompassing the basic performance data.)]

H1b(and c combined) could read: Based upon SNS findings and hyps re wiring changes, can we probide a better/clearer/cleaner? (or even at all) account of the same data in strat change?

*[[Hypothesis 1B:*  The new models furthermore reproduce and provide explanations for observed regularities in the interactive activation patterns among neuro-pathways in brain systems during performance. (I.e., They can additionally encompass systems data.) [E.g., explain the delay in min via SNS!]

[[Get crosssectional data, like Siegler and Shipley but with much more detailed data gathering -- video and drilling in]]

*Hypothesis 1C:* The revised models furthermore reproduce and provide explanations for observed *changes* in interactive activation patterns across development. (I.e., They can additionally encompass systems-level developmental data.)]]

An example of the sort of explanation that could be developed from this aim is how the development of cognitive control can support transition to memory retrieval of arithmetic facts, [[(p.s. meta-stragies)-> rehersal of results? Rehersal of strategy? Review of traces of execution for error correction?]] and how the dynamic change from counting to retrieval in turn stabilizes the maturation of the cognitive control system. [For example: Simple explanation of why min happens later is that you can't rearchitect your strategies until you can meta-process them. -- but see Hansen, et al]

[Secondarily: Data and model repo: Place holder: We will also aggregate existing behavioral data on the strategy changes during arithmetic development to validate predictions and performances of the models.]

Aim 2: highly modular language module

Aim 3: focus on comorbifdities Understand the interaction of multiple systems in the new model by examining an exemplar case: *Atypical* comorbidities in language and arithmetic development.

*Hypothesis 2A*: Manipulations of model parameters such as learning rate, decay rates (analogous to synaptic plasticity), and so on may enable the existing (revised) model to reproduce atypical patterns of arithmetic skill development, ONLY as regards language comorbidity. [[Prior knowledge dependencies, such as counting?]]

avoiding what amount to structural changes (e.g., zeros)]]

*Hypothesis 2B*: explore additional architectural SNS phenol. reproducing the desired patterns will require structural changes to the models, but that with such changes we will be able to accomplish the goal, and that these changes will be related to changes hypothesized (and/or observed) in the systems neuroscientific study of atypical development.

An example of where models revised in this aim may provide useful explanations is in predicting that language can support arithmetic learning by providing unique symbolic representations for numbers, but that noisy representations can hamper successful learning.

Place holder: proposing collecting new data to understand the comorbidity: (a) examining the relationship between phonological representations and arithmetic skills; and (b) examining the role of (verbal) working memory and cognitive control ability for math and reading.

(At least in my view, this is also why examining the comorbidity for math and language interesting, because it helps us understand a broader question of how different systems works, not just math and language, but also memory, and frontal control systems. )