CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)
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Project Number
S0403

Project Title
Understanding Arithmetic Learning in Young Children through a Neural Network Model of Number Representation

Abstract

Objectives/Goals
Numbers are a universal, easily-measured concept taught to children by parents/caregivers. The goal is to understand the effect of different number representations in children's learning of numerical concepts as a mechanism behind learning disabilities like dyscalculia, thus leading to potential development of educational interventions.

Methods/Materials
Different inputs were used to represent the possible number representations that the child uses: random, weighted (as if fingers are held up cumulatively/non-orthogonal with semantic overlap), and one-by-one (orthogonal with no overlap). The random one is the baseline. With learning rate defined as the number of trials that the model requires before successfully learning to match the input of the number to the concept of the number, I predicted that the widely-used weighted representation will have the lowest learning rate because it simulates magnitude knowledge.
I built a supervised learning algorithm in Python to model number learning. The algorithm is based on a neural network using a tanh activation function, backpropagation to calculate weights, and Gaussian noise to account for randomness. The differences in learning rates of numbers were then analyzed.

Results
On average, the algorithm learned fastest using the orthogonal one-by-one input representation, rather than the hypothesized non-orthogonal weighted representation. This may be due to the lack of semantic overlap, which makes it an easier representation to learn. The most efficient representation is not necessarily the easiest to learn due to its non-orthogonality. (ex. Binary is an efficient representation, but it is not commonly used due to its difficulty and non-orthogonality)

Conclusions/Discussion
Despite the insight it gave, this project is not sufficient to fully understand how children learn numbers. An element of learning numbers that was not modeled is the interactive correction between the caregiver and child: when the child gets a number wrong, the parent will put emphasis on that number. Other confounding variables need to be considered such as differentiation between the object and language representation of a number. Future directions for this project include mapping these mechanisms to neural pathways and exploring representational effects on higher-level math.

Summary Statement
The effects of different number representations on young children first learning numbers were observed through a computational model, revealing that the fastest learning occurred using an orthogonal representation with no semantic overlap.

Help Received
My mentor, Professor Jeff Shrager, provided the general direction for the overarching project. Dr. Lang Chen and Professor Vinod Menon (Stanford Cognitive and Systems Neuroscience Lab) also provided invaluable guidance.