UTILIZING COGNITIVE NEUROSCIENCE TO IMPROVE THE MATHEMATICAL

PERFORMANCE OF ELEMENTARY-AGED STUDENTS IN TEXAS

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Statement of the Problem

The United States performance in mathematics is below average. According to the Programme of International Student Assessment (PISA) and the Organisation for Economic Co-operation and Development (OECD), the United States ranks 32 out of 38 countries (https://data.oecd.org/united-states.htm). Between 2012 and 2015, the United States' performance in math decreased, as well (OECD, 2016).

The root causes of this lackluster performance in mathematics are still being studied. Opinions such as the emphasis on standardized testing and teachers not utilizing research from other disciplines; i.e. cognitive and developmental psychology are discussed and researched (Davies et al, 2016). Integrating cognitive neuroscience research into instructional strategies may be the solution to this performance issue.

Purpose of the Study

The purpose of this research proposal is to explore the effectiveness of integrating cognitive neuroscience research into elementary schools as a method of predicting and improving the mathematical performance of students, as well as helping to identify students requiring additional assistance with mathematics. Hypotheses will be developed to test the effectiveness of cognitive neuroscience in the elementary school setting.

Hypothesis

Hypotheses, both null (H0) and alternative (HA), will be designed to test for statistically significant differences between the dependent and independent variables within each sub-question (Creswell, 2008). These hypotheses will be:

H01. Integrating cognitive neuroscience research into instructional strategies will predict and improve the mathematical performance of students.

HA1. Integrating cognitive neuroscience research into instructional strategies will not predict and improve the mathematical performance of students.

Significance of the Study for Practice and Theory

Testing the hypotheses will help to advance research and theory by exploring the relationships within the data to either generalize the results of the study or to develop additional theories to be tested regarding best practices within elementary-school mathematics programs and curriculum. Reviewing the current literature regarding cognitive neuroscience and mathematical performance will be necessary to develop the methodology utilized to conduct this study.

Review of the Literature

In order to determine how cognitive neuroscience is related to mathematical performance, as well as to develop a conceptual framework for this study, an extensive review of the literature will be performed. The literature review will be divided into main topics. These main topics will be:

1. Cognitive neuroscience as a predictor of mathematical-related success.
2. Cognitive neuroscience as a predictor of school readiness and student achievement.
3. Cognitive neuroscience as a tool/methodology to identify students requiring additional assistance with mathematics.

Cognitive Neuroscience: Mathematical-Related Success

Nemmi et. al (2016) utilized working memory and number-line training, as well as fMRI to demonstrate how cognitive neuroscience can be utilized to shape curriculum and instruction to increase mathematical performance in kindergarten students, which also has been determined to be a predictor for future performance in mathematics. The increased grey matter volume (GMV)

as a result of increased working memory has been correlated with increased mathematics-related performances (Nemmi et. al, 2016). The authors found a statistically significant improvement in performance when combining working memory training (WMT) with number-line training (NLT). This was accomplished via integrating cognitive neuroscience into instruction.

Cognitive Neuroscience: School Readiness and Student Achievement

Cognitive neuroscience has also been found to determine students' school readiness and achievement, as well. Clark, Pritchard, and Woodward (2010) found that decreased performances in math resulted in the increased potential to have decreased performances in math at older ages. Singley and Bunge (2014) utilized cognitive neuroscience research to develop relational reasoning modules to increase mathematics-related problem-solving skills in younger ages to avoid the potential long-term decreased mathematics performance discussed above. Singley and Bunge (2014) found that determining the students' capacity is important in order to avoid exceeding that capacity, thus exacerbating math anxiety (Rubinsten, 2015).

Cognitive Neuroscience: Detecting/Identifying Students Requiring Additional Assistance

Rubinsten (2015) discussed utilizing what has been learned via the advances in cognitive neuroscience research to detect/identify students requiring additional assistance in mathematics-related activities. Math anxiety was described as a condition that may occur when an individual's capacity to learn math skills has been exceeded. According to Rubinsten (2015), approximately 20% of people have developmental dyscalculia, or low numeracy skills (p. 2). This is extremely important when considering the best methods for providing mathematics-related instruction. Wasserman (2007) discussed the importance of matching the curricula and instructional methodologies to the age- and capacity-specific needs of the learners, especially when

considering the needs of at-risk students. Based on the results of the literature review, a research methodology to test the original hypothesis will be determined.

Research Methods

Participants

Kindergarten students in a rural elementary school in south central Texas will be the study participants. The participants will consist of 235 students of five and six years of age. Although an even mix of male and female participants would be ideal, the kindergarten students are mostly female (58% or n = 136) compared to male (42% or n = 99).

Procedures

The school administration will be contacted to participate in the study. A letter outlining the study, as well as the benefits and risks of the study, will be sent via mail to each family with a child attending the school in the study. This letter will also contain an informed consent sign-off sheet for the participant's parent/legal guardian to sign and return with acceptance or rejection of study participation. Permission and consent for the children to undergo a functional MRI (fMRI) will also be asked for and obtained.

The study participants will be randomly assigned to one of three training groups. Group 1 will consist of participants receiving 100% working memory training. Group 2 will consist of participants receiving 100% number-line training. Group 3 will consist of participants receiving 50% working memory training and 50% number-line training. Each of these trainings will occur at the same time of day for 30 minutes per day for 30 total days.

Instruments. The participants will utilize iPads to perform the Corsi block-tapping test and Backwards Corsi block-tapping test at pre- and post-training intervals. This test is useful for spatial memory and non-verbal working memory (Nemmi et. al, 2016).

The participants will complete math tests in one-on-one sessions using iPads for addition and subtraction problems. A math test from the Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV) will be administered, verbally, by the researchers reading the question/problem out loud and then having each participant respond verbally, as well. (Nemmi et. al, 2016). These tests will be administered pre- and post-training, as well.

The participants will utilize computers already in the classroom linked to the proprietary software. The working memory training will consist of utilizing the touchscreen on the computer to play a memory flip game. The memory flip game involves flipping over a card by touching the screen to reveal an object easily identified by a child of this age and then trying to find the other card that is hiding the match to the original card. The number of cards will increase with each progressive level. Mastery of each level will be achieved by matching each respective item to its pair.

The number-line training will consist of utilizing the touchscreen on the computer to determine where a number is on a number line by sliding the finger to the left or right of the zero (in the middle of the number line). Movements to the right will result in an increase in the size of the number, while movements to the left will result in a decrease in the size of the number. Participants will learn that subtraction will require movements to the left of the original number, while addition will require movements to the right of the original number. The addition and subtraction problems will progress in difficulty with mastery of each level. The algorithms in the software will allow the participant to progress to the next progressive level of difficulty after completing an assessment with a score of at least 70%.

Group 1 participants will complete 30 minutes of working memory training as described above. Group 2 participants will complete 30 minutes of number-line training as described

above. Group 3 participants will compete 15 minutes of working memory training and then will

be automatically switched/connected to 15 minutes of number-line training as described above.

Each participant providing informed consent to undergo a fMRI will complete working

memory activities during the imaging studies at pre- and post-training intervals. This will be

utilized to determine grey matter volume, which has been correlated to mathematical abilities

(Nemmi et. al, 2016, p. 44).

Data analysis. The pre- and post-training score for each group will be recorded and analyzed via

SPSS software. The results of the fMRI will also be compared at pre- and post-training intervals.

Correlation analysis, specifically Pearson's *r*, will be utilized to objectively quantify the degree

of association between two or more of the variables (Creswell, 2008). Pearson's *r* will provide a

coefficient that will be utilized to assign a correlation strength, or degree of correlation, between

two or more variables (Creswell, 2008).

These correlations will be utilized to determine whether or not the null hypothesis will be

rejected or accepted. In order to reject the null hypothesis, a *strong* or *very strong* correlation

must be determined, as well as a sig = 0 or sig < 0.01. A *strong* or *very strong* correlation

translates into a correspondingly high predictive nature from one variable to another (Creswell,

2008).

References

Clark, C.A.C., Pritchard, V.E. & Woodward, L.J. (2010). Preschool executive functioning abilities predict early mathematics achievement. *Developmental Psychology, 46*(5), 1176-1191. http://dx.doi.org/10.1037/a0019672

Creswell, J.W. (2008). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research (3rd ed.).* Upper Saddle River, NJ: Pearson Education, Inc.

Davies, S., Janus, M., Duku, E. & Gaskin, A. (2015). Using the Early Development Instrument to examine cognitive and non-cognitive school readiness and elementary student achievement. *Early Childhood Research Quarterly, 35,* 63-75. https://doi.org/10.1016/j.ecresq.2015.10.002

Singley, A.T. Miller & Bunge, S.A. (2014). Neurodevelopment of relational reasoning: Implications for mathematical pedagogy. *Trends in Neuroscience and Education, 3*, 33-37.

Nemmi, F., Helander, E., Helenius, O., Almeida, R., Hassler, M., Räsänen, P. & Klingberg, T. (2016). Behavior and neuroimaging at baseline predict individual response to combined mathematical and working memory training in children. *Developmental Cognitive Neuroscience, 20,* 43-51. https://doi.org/10.1016/j.dcn.2016.06.004

OECD (2016), *PISA 2015 Results (Volume I): Excellence and Equity in Education*, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264266490-en

Rubinsten, O. (2015). Link between cognitive neuroscience and education: The case of clinical assessment of developmental dyscalculia. *Frontiers in Human Neuroscience, 9*(304), 1-8. https://doi.org/10.3389/fnhum.2015.00304

Wasserman, L.H. (2007). The correlation between brain development, language, acquisition, and

cognition. *Early Childhood Education Journal, 34*(6), 415-418.