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Mathematical Play and Neuroplasticity in Children with Cancer

Overview and Research Questions (3 min)

In a 24-week study, I investigated an intervention for children with cancer using the Lego Mindstorms EV3 robotics kits. The intervention is designed to address issues of children's mathematical thinking and learning and functional and structural changes to the brain following chemotherapy and/or radiation or stroke.

Pediatric cancer survival rates have seen a steady increase in the US over the past three decades (Jones, Parker-Raley, & Barczyk, 2011). Because of technological advancements in pediatric medicine, it is anticipated that 83% of children and adolescents with cancer will become long-term survivors (Jones, Parker-Raley, & Barczyk, 2011). Approximately one in 285 children will be diagnosed with cancer before age 20, and one in every 530 adults (aged 20-39) is a childhood cancer survivor (Ward, DeSantis, Robbins, Kohler, & Jemal, 2014). To date, there are 379,112 survivors of pediatric cancer in the US of which it is estimated that there were 60,620 cancer survivors ages 0-14 years and 48,690 survivors ages 15-19 living in the US as of January 1, 2014 (Ward et al., 2014).

While treatments for pediatric cancers are continually improving, many children are surviving cancer, re-entering school, and resuming their lives, increasing the need to examine the quality of life of those children living with a chronic illness.

In educational studies that compare school performance between chronically ill children and their healthy peers, Bartel and Thurman (1992) report that one-third to one-half of children with Acute Lymphoblastic Leukemia (ALL) require individualized education plans (i.e., attend special education classes), compared to only 15% of the healthy school population requiring specialized assistance. Additionally, a higher than usual percentage of children with ALL repeat one or more grade levels (Bartel & Thurman, 1992). Cognitive delays or impairments caused by chemotherapy regimens and ALL treatments include difficulties in attention, memory, and processing speed (Shaw & McCabe, 2008). Additionally, toxicity of the central nervous system (CNS) for children diagnosed with cancer may result in confusion, loss of memory, and below-average school performance, which may be misinterpreted for inattention, forgetfulness, and school failure, respectively (Henning & Fritz, 1983). Children with neuroblastomas experience significant cognitive and neuropsychological difficulties with reading and numeracy, as well as increased social, emotional and behavioral problems (Shaw & McCabe, 2008). In a landmark study on intellectual and neuropsychological dysfunction over time, Meadows, Gordon, Massari, Littman, Fergusson, and Moss (1981) reported on children with ALL who received cranial radiation. Children were evaluated both at the time of diagnosis and every six months for three years afterward. After three years of coincident treatments of radiation and methotrexate, the children's average I. Q. score dropped to 89 points, as compared to 109 points at the time of diagnosis. Meadows et al. concluded that the decline in I. Q. was not readily obvious until a minimum of three years after treatment. They also argued that the age of the child at the time of diagnosis was a determinate in cognitive dysfunction, with younger children (i.e., < 4) suffering greater adverse effects. The rationale being that treatment may affect the developing brain of a younger child (Bartel & Thurman, 1992). Additionally, children who received cranial radiation experienced a greater number of adverse effects than children treated with methotrexate in the absence of radiation. Bartel and Thurman (1992) claim that the results of this study are typical of a number of similar studies (e.g., Henning & Fritz, 1983; Rausch & Stover, 2001); many similar studies have found an I. Q. decline of 12 to 20 points for children with ALL, with specific types of intellectual and academic deficits frequently observed. In one such study, Thies (1999) described the effects of treatment for childhood leukemia (e.g., ALL). Children who received prophylactic central nervous system (CNS) therapy, which includes intrathecal administration of chemotherapy and/or radiation of the brain and spine, or both scored lower than their healthy peers on measures of reading ability, spelling accuracy, and mathematics three years after initial diagnosis. Up to 14 years after completion of treatment, deficits in academic achievement were still observed. Deficits in verbal coding, memory, and attention were especially salient (Thies, 1999).

In my previous study on chronically ill children's conceptual understanding of mathematics gained through the use of robotics, all of the participants made anecdotal claims that they felt use of the robotics was changing how they think and ameliorating the effects of 'chemo brain'. This study was designed to investigate these claims. Therefore the research question for this study asked: Does the use of robotics in the learning of mathematics up-modulate neuroplasticity in children with cancer, and, if so, how?

I conducted this small scale mixed-methods pilot study using structural MRI (MRI) in conjunction with qualitative task based interviews (Goldin, 2000) with children undergoing treatment for cancer in a Children's Hospital.

Theoretical Framework

Papert's theory of constructionism (1980), which informed the creation of the Lego Mindstorms robotics kits, provided the rationale for the use of robotics in this study. Constructionist theory challenges the popular belief that formal thinking is the most sophisticated form of intellectual development. Papert considered the development of individual learning styles rather than general stages of development, therefore focusing on intelligence as being situated, connected, and sensitive to variations in the environment. Papert argued "children do not follow a learning path that goes from one true position to another more advanced true position" (1980, p. 132).

Papert suggested that equity in understanding children's actions requires accepting the validity of multiple ways of knowing and thinking. Papert also demonstrated that a great deal of powerful and mathematical thinking occurs outside of formal school mathematics where children are recipients of formal, de-contextualized, content knowledge with which they have no meaningful prior experiences (Papert, 1980). Finally, Papert presented the computer as a context for the development of concrete thinking, where the concept of 'concreteness' implies rich, meaningful experiences with the content or object to be known rather than merely tangible.

Methods and Data Sources

This presentation will provide data on a single case within a 24-week study, focused on investigating children's mathematic thinking, learning, and brain plasticity. The pediatric cancer patient participated in at least one two-hour task-based interview for 24 consecutive weeks. MRI assessment took place prior to the start of the study and at weeks 12 and 24, and at a 1-month follow-up. Data collected pertaining to mathematical content knowledge included: (1) baseline data pertaining to the child's mathematical content knowledge; (2) data pertaining to robotics use and mathematical content knowledge through semi-structured face to face interviews; (3) data pertaining to the epistemology and well-being (including learning motivation and engagement) of the child through the use of robotics collected through questionnaires and spontaneous feedback.

Summary of Findings

Preliminary results suggest a significant increase in gray matter volume in several regions, including both hippocampi. MRI scans, region of interest analysis and functional connectivity analysis will be shared during this presentation. Significant growth in conceptual understanding was also evidenced in students in algebraic thinking and shape, space, and measure.

Educational Importance of the Research

This paper describes the potential for children to use robotics to form inductively developed understandings of a wide range of mathematical ideas and as mediation tool for neuroplasticity. Education of all children is the very core of the structure of our society. This is particularly true of the children in hospitals because education for them is the experience they have in common with all other children. Not only do medical authorities consider the educational program for children confined to hospitals an integral part of their therapy, but educators also regard it as an opportunity to provide continuity in the educative process so that every hospitalized child who can, will return to school without any apparent gaps in his development of knowledge, skills and attitudes. This study also provides preliminary data that supports a large study on the effects of robotics and other play based mathematical interventions for other at risk populations.

References

Bartel, N. R., & Thurman, S. K. (1992). Medical treatment and educational problems in children. *The Phi Delta Kappan*, *74*(1), 57-61.

Goldin, G. A. (2000). A scientific perspective on structured, task-based interviews in mathematics education research. In A. E. Kelly, & R. A. Lesh (Eds.), *Handbook of research design in mathematics and science education* (pp. 517–545). Mahwah, NJ: Lawrence Erlbaum Associates.

Henning, J., & Fritz, G. K. (1983). School reentry in childhood cancer. *Psychosomatics*, *24*(3), 261-269.

Jones, B. L., Parker-Raley, J., & Barczyk, A. (2011). Adolescent cancer survivors: Identity paradox and the need to belong. *Qualitative Health Research*, *21*(8), 1033-1040.

Meadows, A., Massari, D., Fergusson, J., Gordon, J., Littman, P., & Moss, K. (1981). Declines in IQ scores and cognitive dysfunctions in children with acute lymphocytic leukaemia treated with cranial irradiation. *The lancet*, *318*(8254), 1015-1018.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York, NY: Basic Books.

Rausch, D. M., & Stover, E. S. (2001). Neuroscience research in AIDS. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *25*(1), 231-257.

Shaw, S. R., & McCabe, P. C. (2008). Hospital‐to‐school transition for children with chronic illness: Meeting the new challenges of an evolving health care system. *Psychology in the Schools*, *45*(1), 74-87.

Thies, K. M. (1999). Identifying the educational implications of chronic illness in school children. *Journal of School Health*, *69*(10), 392-397.

Ward, E., DeSantis, C., Robbins, A., Kohler, B., & Jemal, A. (2014). Childhood and adolescent cancer statistics, 2014. *CA: A Cancer Journal for Clinicians, 64*(2), 83–103