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Conceptualizing the NET: The Neuroeducation Translational (NET) Research Model – A Framework for Neuroscience Research to Special Education Practice

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ABSTRACT

Advances in neuroscience related to developmental disorders could substantially impact individuals with disabilities and the field of special education. However, several challenges impede the current translation of neuroscience research for special education practice, such as misinterpretations of neuroscience findings. An investigation of translational research in medicine and social sciences revealed a common conceptual framework founded by the National Institutes of Health (NIH). Using this model as a guide, the authors introduce a new framework, the Neuroeducation Translational (NET) Research Model, to scaffold neuroscience research from the laboratory to special education practice in four phases. Potential benefits to developing a framework for neuroeducation include improved outcomes for individuals with disabilities and knowledge sharing across disciplines.

Keywords: neuroeducation, neuroscience research, special education, transdisciplinary, translational research

Researchers in neuroscience are now exploring how cognition, motivation, behavior and other brain processes are connected to learning (Basset et al., 2011; Howard-Jones, 2010). Advances in brain imaging have confirmed that the brain is plastic into adulthood, and neural pathways can change based on environmental experiences (Chiao & Immordino-Yang, 2013; Giedd, 2009; Gogtay et al., 2007; Lenroot & Giedd, 2008; Lerner et al., 2011). Findings suggest that emotions may affect all aspects of learning, including memory, attention, decision-making, and social functioning (Bechara, 2005; Damasio, 2005; Gazzaniga, Ivry, & Mangum, 2009; Goswami, 2008; Immordino-Yang, 2008; Immordino-Yang & Damasio, 2007).

Research in neuroscience may have profound implications for individuals with disabilities. Scientists currently are investigating a biological basis for neurodevelopmental disabilities, such as autism, attention-deficit hyperactivity disorder (ADHD), and dyslexia (Barrett, Coyle, & Williams, 2012; Katzir & Pare-Blagoev, 2006). Magnetoencephalographic (MEG) studies measuring brain activity in real time have revealed atypical brain activity with auditory processing and stimulus responses in children with autism spectrum disorders (ASD; Barrett et al., 2012; Oram Cardy, Flagg, Roberts, Brian, & Roberts, 2005; Roberts et al., 2010). Brain imaging studies have detected differences in size and activity in the prefrontal cortex (PFC) for individuals with ADHD that relate to challenges with organization, concentration, and hyperactivity (Barrett et al., 2012; Makris et al., 2007; Seidman et al., 2006). Findings from neuroimaging studies focused on literacy have shown decreased activity in the posterior brain regions and increased activity in the anterior brain regions of adults with dyslexia while completing phonological activities (Katzir & Pare-Blagoev, 2006).

These findings offer new insights into the various brain processes for individuals with disabilities. However, education researchers and practitioners have achieved limited success in directly applying neuroscience research to special education practice. A new conceptual framework, inspired by the National Institutes of Health (NIH) Roadmap that is utilized by biological and social science researchers is needed to carefully scaffold and integrate these findings effectively to the field of special education. The Neuroeducation Translational (NET) Research Model is proposed to advance translational research in special education.

Current Status of Application of Neuroscience to Educational Practice

To a limited extent, researchers already are applying neuroscience findings to intervention research. For example, education researchers have examined neural activity in children and adolescents with ASD when interpreting a speaker's ironic communicative intent. When the youth were taught specific strategies to process a speaker's facial expressions, tone, and voice, they exhibited increased activity in the brain regions involved in understanding a speaker's intentions (i.e., medial prefrontal cortex; Wang, Lee, Sigman, & Dapretto, 2007).

Researchers also have utilized brain imaging techniques to better understand the neurological underpinnings of dyslexia (Lyon & Moats, 1997; Shaywitz et al., 2003; Temple et al., 2003). Brain imaging has suggested that individuals with dyslexia who receive targeted interventions begin to demonstrate brain activation patterns similar to children without reading disorders, as well as activation in other brain areas to compensate for challenges with language processing (Katzir & Pare-Blagoev, 2006). For example, one study (Shaywitz et al., 2004) investigated the effect of a targeted phonologically mediated reading intervention on fluency and the development of neural systems associated with skilled reading. The intervention provided second and third grade poor readers with 50 minutes of daily individual tutoring focused on helping them understand how letters and combinations of letters represent phonemes. Children's brain activity was measured using fMRI before and after the intervention. Findings of the study showed that the phonologically-based reading intervention led to development of neural systems in the inferior frontal gyrus and the middle temporal gyrus. This research suggests that providing a phonologically-based reading intervention at an early age could improve reading fluency and promote development of neural systems that are necessary for skilled reading (Shaywitz & Shaywitz, 2005). These studies highlight the initial attempts and exciting potential for future intervention research in which neuroscientists and education researchers collaborate to improve cognitive and social skills for individuals with disabilities.

Despite advances in brain imaging and intervention research, practitioners are struggling to translate findings from neuroscience to improve strategies for teaching and learning. Attempts to translate neuroscience findings to education often fail because teachers' understanding of neuroscience is misguided by the prevalence of neuromyths, (i.e., common misconceptions about the application of brain research to relevant uses in education, which reflect overgeneralizations and misinterpretations of neuroscience findings; Goswami, 2006). Over the past two decades, a proliferation of books identifying applications of brain research to educational practice has spurred great impetus among educators to apply information about brain-based learning to their curricula and teaching methods (Freed & Parsons, 1998; Lucas, 2006; Luhmkuhl, 1993; Tokuhama-Espinosa, 2011). Neuromyths and over-interpretations of neuroscientific studies are embedded in many of these applications, and educators typically are not trained to identify valid and effective brain-based research, synthesize research findings, or transfer these ideas into everyday classroom practice.

Common neuroscientific misconceptions held by teachers include: (1) the need to time educational interventions with periods of synaptogenesis; (2) the belief in critical periods for learning; and (3) the idea of hemisphere-specific differences within the brain (Goswami, 2004). Goswami (2004) refutes each of these myths, noting that: (1) educational interventions and remediation programs do not need to coincide with periods of synaptogenesis as brain plasticity continues throughout a lifespan; (2) although sensitive periods of learning exist, learning occurs outside of these sensitive periods; and (3) findings from brain imaging reveal cross-hemispheric connections during all learning activities, indicating that both the left and right sides of the brain are involved in all tasks.

An additional neuromyth relates to the promotion of learning styles. Howard-Jones (2010) suggests that the belief that individuals can be categorized by their preferred learning style stems from misinterpretations of neuroimaging studies that produced "static pictures of well-defined islands of activity" (p. 25). In actuality, performance of learning tasks requires complex interactions and activation of multiple areas of the brain during learning.

The prevalence of neuromyths demonstrates a need for translational research to assist educators to effectively apply findings from neuroscience research to program and strategy development for improving student learning. Successful translation of neuroscience may deepen teachers' understanding of the diverse ways in which students acquire knowledge and influence environmental factors related to learning in the classroom. Critical to the translational process is that educators share their knowledge, skills, and experiences about teaching and learning with neuroscientists. Educators can serve as an important resource for neuroscientists in developing relevant research questions and effective interventions for individuals with neurodevelopmental disorders.

Given the challenges in translating neuroscience research to special education and the potential benefits of successful translation, education researchers can learn from translational research models currently being used in other disciplines, such as medicine and the social sciences.

Translation of Neuroscience Research in Medicine

By the 21st century, scientific discovery in medicine, including the fields of biology, chemistry, genetics, and health science, was rapidly accelerating (Zerhouni, 2003).

Research in clinical practice in the United States, however, was not expanding as quickly. As a result, knowledge from the medical community about common biological pathways was not applied effectively to developing therapeutic approaches to treating health conditions. On average, it took 17 years for scientific discoveries to be applied in daily clinical practice, and only 14% of these discoveries were translated into work with patients (Balas & Boren, 2000). Doubling of the NIH budget between 1998-2003 (NIH, 2013) raised public expectations to improve clinical practice. In an effort to accelerate the translation of basic research into tests and treatments to enhance clinical practice and to benefit patients, the NIH consulted with the scientific community and public constituencies to develop a *roadmap* or model to translate basic scientific research for medicine (Zerhouni, 2003).

Three major themes emerged from the NIH Roadmap for Medical Research: *New Pathways to Discovery*, *Research Teams of the Future,* and *Re-engineering the Clinical Research Enterprise* (Zerhouni, 2003). The *New Pathways to Discovery* theme emphasized the need for quantitative knowledge about networks of molecules, and how they regulate and interact with each other. *Research Teams of the Future* encouraged scientists to reach beyond the boundaries of their own disciplines by exploring models for team science, which examines ways to combine skills and expertise across the physical and biological sciences. *Re-engineering the Clinical Research Enterprise* promoted the creation of integrated networks to develop new partnerships among clinicians, community stakeholders, and academic researchers (Zerhouni, 2003).

The NIH Roadmap informed a new initiative for conducting research; however, efforts to advance translational research using the Roadmap were hindered by a shortage of research scientists trained in clinical and translational science. In 2007, the NIH announced the launch of a national consortium, to be funded through Clinical and Translational Science Awards (CTSAs), to ensure that advances in medical research benefitted patients and their families. The CTSA program supports two critical areas of translational research: (1) applying discoveries from laboratory research and preclinical trials to the development of studies for humans; and (2) enhancing the implementation of best practices in the community (Zerhouni, 2007). Emphasis is placed on "creating graduate degree-granting and postgraduate programs in clinical and translational science" (Zerhouni, 2007, p. 127) and training "investigators from diverse disciplines for effective translational research" (Zerhouni, 2007, p. 127). Currently, approximately 61 medical research centers in 30 states and the District of Columbia are active members of the CTSA consortium.

Translational Research in Social Sciences

The social sciences, including the fields of communications, economics, family violence, mental health, nursing, psychology, sociology, and social work, utilize the NIH Roadmap as a guide for developing translational research efforts (Palinkas & Soydan, 2012). Professionals in the social sciences seek to support the translation of medical research by utilizing basic scientific investigations to promote the well-being and health of patients, practitioners, and the community (Wethington & Dunifon, 2012). In child psychology, for example, researchers aim to advance basic findings towards the creation of new treatments and the prevention of physical, behavioral, and emotional problems for children (Cicchetti & Gunnar, 2009). In the field of nursing, researchers evaluate the effects of scientific discoveries and interventions to develop evidence-based practices and to improve clinical decisions in health care (Mulnard, 2011).

Community-Based Participatory Research (CPBR), which involves members of the public as partners in the research process, provides another way to translate research in the social sciences (Callard, Rose, & Wykes, 2011). The National Institute for Health Research (NIHR) maintains a database, *INVOLVE*, that lists current and recent CBPR projects. Representative research projects include: (1) developing user-focused evaluations to support people with mental health problems by promoting dialogue between service users and project workers; and (2) evaluating a crisis house and telephone helpline by training mental health service users as researchers who interview and send out questionnaires (NIHR, 2013). The NIH's Office of Behavioral and Social Science Research (OBSSR) also funds CBPR grant projects, including one that assesses the impact of a CBPR school program on obesity-related outcomes in underserved youth and another that uses Photovoice to engage community members in promoting cancer awareness (U.S. Department of Health and Human Services, 2013).

Translational Research in Education

The field of education currently does not utilize the NIH Roadmap in attempting to translate brain research to educational interventions. Although CBPR commonly is used in education, professionals have yet to apply this approach to translational research. To date, translational research in education focuses on developing partnerships to support the dissemination of findings and the implementation of evidence-based practices and programs (Beeghley, 2006; Boden, Borrego, & Newswander, 2011; McFadden, Chen, Munroe, Naftzger & Sellinger, 2010; Obendorf, 2010). The KIDTALK TACTICS Project (KTTP), for example, is a community-based, early communication intervention model for young children with significant language disabilities and their families. KTTP focuses on addressing the special needs of students by partnering with parents, teachers, speech language pathologists, and other related service providers. Other research initiatives at education and brain science laboratories investigate the neural correlates of children's learning through partnerships with professionals in the fields of education, psychology, and neuroscience. Exemplary projects at education and brain science laboratories focus on children's struggles to read and to develop comprehension skills, as well as strategies to design interventions to support these skills (Vanderbilt Kennedy Center, 2013). For individuals with autism, translational research studies include: (1) using functional near spectroscopy (fNIRS) during therapy sessions to improve treatment and (2) examining brain responses to social/nonsocial rewards through electroencephalography (EEG) and event-related potential methods (ERP; Autism Speaks, 2013).

Despite efforts to establish relationships and infrastructures to conduct research and advance knowledge across disciplines, the field of education lacks a clear framework for translating knowledge from neuroscience laboratories to classrooms.

Obstacles to Translational Research in Education

Obstacles that have hindered translational research efforts in education include the infrastructure and organization of research programs and environments, differences in intended outcomes among disciplines, and prioritization of resources and inadequate funding streams. First, the infrastructure and organization of research programs has generated research silos in which researchers from neuroscience, the social sciences, and education rarely interact or collaborate (Szilagyi, 2009). Because research studies are specific and narrowly focused within a single discipline, researchers rarely "connect the dots along the translational pathway" (Szilagyi, 2009, p. 72). Moreover, the research environment includes a limited number of qualified investigators and insufficient training opportunities for translational researchers in education and the social sciences (Szilagyi, 2009).

Second, research goals differ across disciplines, which may hinder bidirectional communication and knowledge sharing. Due to the different goals for practice, neuroscience researchers may employ methods and procedures distinct from those utilized by education researchers. The goals of medical research include a focus on the examination, diagnosis, and treatment of patients. Education researchers, rather than being driven to find a cure, are concerned with supporting the development and optimization of an individual's quality of life.

A final obstacle reflects insufficient funding for translational research targeting educational needs. The majority of funding is reserved for medical science research at the molecular and cellular level; few funds are allocated for studies involving students, clinical practice, or public health (Szilagyi, 2009). Two organizations within the Department of Health and Human Services (HHS) fund much of the translational research for medical and health-related fields: the National Center for Advancing Translational Sciences (NCATS) and the Agency for Healthcare Research and Quality (AHRQ). NCATS focuses on translating research to develop more effective and efficient treatments and cures for disease (NCATSa, 2013). Last year, NCATS received $574 million in funding from the NIH (NCATSb, 2013), three times the entire U.S. Department of Education (DOE) budget for research, development, and dissemination (DOE, 2013). AHRQ funds research to improve the quality of health care and effectiveness of health care delivery (AHRQ, 2013). In 2010, the AHRQ budget of $372 million (Carroll, 2012) well exceeded the DOE's budget of $200 million that was appropriated for research, development, and dissemination. The difference in these budgets highlights the funding obstacle in translating neuroscience findings to education.

Future Directions: Developing a Neuroeducation Model

Although a range of models could potentially contribute to progressing scientific research to improve teaching and learning, the NIH Roadmap serves as a foundational model and practical starting point for developing a conceptual framework for translational research in special education.

Adapting the NIH Roadmap

The NIH Roadmap remains the most widely used model in translational research for medicine and social sciences. The Roadmap provides a flexible paradigm for translational research that educators might adapt to align with the needs of students in special education. The NIH Roadmap describes four major phases or progressions to translational research: (1) relating findings from animal laboratory research to humans; (2) explicating human laboratory results to patients; (3) advancing work with patients to develop treatments for clinical practice; and (4) utilizing knowledge from clinical practice to benefit the community and inform policy.

Modifying the NIH Roadmap may allow researchers from varied disciplines to recognize how the process for education is both similar to and different from the translational research process in medicine. Because professionals working in translational research across disciplines are familiar with the NIH Roadmap, adapting the framework to education may be advantageous to establishing partnerships with organizations in medicine and social sciences. Ideally, all professionals will share the mission of bringing forth advancements in research from the laboratory to the community.

Most importantly, basic research in neuroscience cannot be directly applied to education practice. Although laboratory results from intervention research may prove effective, the same intervention may not prove effective in a classroom because of methodological differences. Laboratory research is conducted in a controlled environment, whereas research conducted in the community is mainly context-driven (Kerner, 2006; Mulnard, 2011; Slavin, 2002). Similar to medicine, translational research must be based on sound methodology and scaffolded in phases before neuroscientifically-based interventions are embedded into special education practice.

A reconceptualized model of translational research for special education, specifically for neurodevelopmental disorders, the Neuroeducation Translational (NET) Research Model, includes four phases to communicate neuroscience research findings to educators for informing special education practice: (1) connecting knowledge gained from neuroscientific studies to intervention research; (2) developing pilot studies for educational settings based on intervention results; (3) expanding pilot studies to conduct larger cross-sectional, or longitudinal studies that bring neuroscience findings to teaching practice; and (4) integrating successful neuroeducation practices and foundational neuroscience knowledge to improve professional development, teacher preparation programs, and special education policy.

At the center of the NET Model are education stakeholders, including students with disabilities and their families, general and special education professionals, related service personnel, school administrators, and policymakers in the community. The stakeholders inform all four phases of translational work by communicating their needs, inspiring research questions, and developing neuroeducation practices in professional development, teacher preparation programs, and special education policy. The phases are bidirectional, which allows for researchers in each phase to inform and improve the translational work in the other phases. For neuroscientists to inform significant areas of need in the practice of teaching, they will need to develop a stronger appreciation for the contribution of education research to the development of neuroscience studies (Tokuhama-Espinosa, 2011). Neuroscientists who use proven interventions from education may find stronger results in brain-imaging studies (Bishop, 2013). Similarly, educators need to understand how to interpret specific neuroscience research for education before they attempt to apply findings to effective educational interventions and practice.

Translational research within the NET Model is transdisciplinary in nature, meaning "researchers work jointly using [a] shared conceptual framework drawing together disciplinary-specific theories, concepts, and approaches to address [a] common problem" (Rosenfield, 1992; p. 1351). The NET Model involves multiple disciplines working collaboratively to undertake the common problem of translating neuroscientific research to enhance special education practices.

NET Phase 1

In the first phase of the NET Model, findings from neuroscientific research with humans are applied to intervention research, which is defined as testing a specific, controlled condition to improve a behavior, performance, or skill. Intervention research requires the development of research questions with educational applications, and is conducted in a restricted setting with selected participants. Results from intervention research are useful for investigating how the brain adapts to an external educational condition, such as a teaching or learning strategy.

NET Phase 2

In the second phase of the NET Model, pilot studies are created from intervention research findings and implemented in educational settings to improve student outcomes. Because education research is largely context-driven, translating intervention research to educational settings is an essential step in neuroeducation translational work. Educational settings vary across development from home-based early intervention for children birth through three years of age to postsecondary or vocational rehabilitation training for adults. Research must be adapted for each type of setting. In developing pilot studies, scientists collaborate with educators to effectively transform intervention research to an education practice that aligns with specific needs of individuals in an educational setting.

NET Phase 3

In the third phase of the NET Model, results from educational environments are applied to large-scale studies to impact learning. A large-scale study may take the form of a random sampling of classrooms at the district, state or national level, or a longitudinal study to determine the effectiveness of brain-based educational practices in teaching. For instance, because research outcomes conducted in an urban K-12 classroom often differ from those of a rural classroom, studies are needed to examine whether practices grounded in neuroscience prove valuable across a broad spectrum of educational environments. Other potential studies might target specific teacher characteristics (i.e., veteran vs. novice) or disability categories.

NET Phase 4

In the last phase of the NET Model, neuroeducation practices that are effective in large-scale studies are integrated into professional development programs and special education policies. Similar to other disciplines, research is scaffolded along the progression from laboratory research to education practice resulting in improved outcomes for teaching and learning. By carefully vetting neuroscience findings through the first three phases of neuroeducation translational research (NET Phases 1-3), professionals and policymakers can embed practices shown to significantly improve educational outcomes.

NET Research Model Example

A hypothetical case study demonstrates how to apply the NET Model to benefit individuals with disabilities in special education. In NET Phase 1, researchers connect knowledge gained from neuroscientific studies to intervention research. In this hypothetical example, neuroscience findings about the amygdala may assist in creating an effective transdisciplinary special education intervention for young children with autism. Recent findings from studies in brain-imaging with human subjects have suggested that decreased connectivity among brain regions may result in barriers to responses to complex social situations. Specifically, the activity patterns in the amygdala, an area of the brain that assesses danger in a situation and assists in the decision-making for an appropriate response (along with other regions of the brain) may be related to social and emotional deficits in individuals with autism. Brain-imaging studies have indicated that amygdala hypoactivity and sometimes hyperactivity were related to several social tasks, like eye gaze and facial processing (Buxbaum & Hof, 2012). Video modeling, for instance, is a well-known and effective strategy implemented by educators for individuals with autism to practice “the natural interactions of children in social situations” (Luiselli, Russo, Christian, & Wilczynski, 2008, p. 290). This intervention involves recording a short video clip of an individual with autism interacting with a peer or an adult to teach a specific social skill. Through translational research, education researchers, teachers, and neuroscientists could collaborate to provide added validity to this frequently used teaching strategy. Creating a study in which activity in the amygdala and other brain regions is measured before and after the implementation of the education intervention (i.e., the use of video modeling) could allow researchers to better understand the relation between the intervention and students’ comprehension of social situations and anxiety levels.

Results of this and other studies concerning brain-imaging and social situations might inform development of a pilot study in NET Phase 2 to teach the visual strategy in a classroom setting. An initial study might entail evaluating the effects of teacher-implemented video modeling with individual students in a special education classroom. Over time, other pilot studies could be created in which teachers use video modeling with small groups of children in a special education resource classroom or in an inclusive setting.

NET Phase 3 involves scaling up pilot studies to larger cross-sectional or longitudinal studies that bring neuroscience findings to teaching practice. At this point, outcomes from the pilot studies in NET Phase 2 could be transformed and adapted to meet the needs of several classrooms in a school district, and eventually, a random sample of classrooms at the state or national level. Results from cross-sectional studies would determine if the intervention is successful across varied environments and contexts such as type of disability, level of classroom inclusiveness, classroom diversity, teacher characteristics, and various geographic settings. In a large-scale study, video modeling may prove beneficial for students with autism in inclusive classrooms or when implemented by teachers who have over five years of experience. Ultimately, cross-sectional studies could provide an opportunity for deeper analysis of interventions to determine which learners and contexts showed greater improvements than others.

Provided the intervention proves effective in multiple education environments, the research would advance to NET Phase 4, in which professionals integrate successful neuroeducation practices and foundational neuroscience knowledge to improve professional development, teacher preparation programs, and special education policy. In this case, video modeling would be integrated in teacher education to enhance understandings of social situations and reduce anxiety for individuals with autism. The strategy also could be tested with children with other disabilities to determine its effectiveness. Once validated, the use of video modeling could be recommended in future special education policy. Although this tool is not new to the education community, a transdisciplinary approach to supporting their use and the scaffolding of research in refining the teaching of the strategy provides an example of how neuroeducation may be able to influence educational outcomes for students with disabilities.

Implications of Developing a Framework

Many benefits exist for establishing a framework for translating findings from the NIH Roadmap to support individuals with neurodevelopmental disorders. Educators will be better equipped to circumvent the extant obstacles related to the translation of research findings to the community. Once education researchers have an informed, conceptual method of applying neuroscience findings to educational practice, teachers will be able to incorporate these methods into their practice. These novel interventions could potentially enhance the use of evidence-based practices and improve educational outcomes for individuals with disabilities.

Establishing a framework for education may promote relationship building and knowledge sharing across disciplines, as well as increase access to educational and neuroscientific research findings for educators and neuroscientists. By creating a space for enhanced information sharing, the current research and future goals of neuroscientists can be translated to educators and the specific needs and challenges of educators can be communicated to the neuroscience community.

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