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Relating Neurodevelopment to Early Intervention Special Education: Implications for Developing Best Practices

Abstract

Through the merging of neuroscience and education, neuroimaging will impact the field of early intervention as awareness grows concerning the developing brain. The reauthorization of the Education of the Handicapped Act Amendments and the subsequent formation of the field of early childhood special education has advanced best practices of school psychology and early intervention. Functional neuroimaging has led to advances in our understanding of brain functions enabling neuroscientists, psychologists, and educators to challenge prevailing theories and intervention approaches employed in schools today. Concerns abound when research introduces untested or unsupported instructional strategies into classroom settings based upon misinterpretation or misunderstanding of resulting data. Best practices within the fields of neuropsychology and early intervention special education does provide information regarding how children learn and provides guidance that should lead to best educational practices, but they must be based upon neuroscientific evidence which either supports traditional practices or challenges the prevailing theories.

Keywords: *Early intervention, brain development, IDEA Part C, educational neuroscience.*

Relating Neurodevelopment to Early Intervention Special Education: Implications for Developing Best Practices

Within the last 20 years a field has emerged, often referred to as educational neuroscience, which bridges together education and neuroscientific findings. However, there has been a great deal of controversy over the role of neuroscience in informing educational policy and the ethical considerations of using neuroimaging to inform

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instruction. Many researchers continue to suggest the disconnect between neuroscience and education needs to be overcome (Willingham, 2009; Willis, 2008) while others historically suggested that it is "a bridge too far" (Bruer, 1997). Early childhood education in the 1980's was supported by findings of new brain imaging technology which lead to the field of cognitive psychology. This collaborative effort between neuroimaging experts, psychologists, and educators resulted in practical solutions and recommendations which were applied to learning activities in the home, child care centers and classrooms (Wellhousen & Kieff, 2001). Additional research studies turned the focus to children at even earlier stages of development (e.g., prenatal and perinatal stages of development) because much of the basic structure of the brain is formed during the prenatal period. As "60% of human genes are dedicated to brain development, and most neurons are generated during the 12 to 20 week prenatal period," (Bergen & Woodin, 2011, pp. 15) research supports the notion that most of the basic life-essential components of the brain are connected and operating at birth.

Advances in neuroscience during the past twenty years have also yielded important insights into mental functioning, but their implications for the field of early intervention have remained largely unexplored or are in dispute. To further illustrate this point, the 1994 Carnegie Task Force's report, "Starting Points: Meeting the Needs of Our Youngest Children*,*" stated "the influence of early environment on brain development is long lasting, yet even after a decade little has come from this awareness," (pp.7). Due to neuroimaging technology, by the late 1990's, it had become well known that the knowledge gained by children during developmental activities formed the foundation for the future learning success of these young children (Shaywitz, 2003). Neurodevelopmental changes that occur during windows of opportunity have been well documented and some researchers, such as Sousa (1998), would suggest that the window of opportunity which occurs during the early childhood period is the most critical in regards to learning. Nonetheless, early childhood learning encounters are indispensable because these experiences serve as building blocks for later learning and if the essential foundation is not in place later skills, such as critical thinking, integration, and abstract reasoning, may not occur during typical periods of development.

Historically, science and educational research have not appeared to be complementary in design. Educational researchers believe that the mind and brain must be examined together in exploring how the two relate to learning; while neuroscientists believe that the mind and brain are separate entities (Howard-Jones, 2008). Neuropsychological assessment has the potential of furthering the science of neuroimaging beyond the medical model into the educational field by offering diagnostic recommendations. As far back as 1975, school psychologists were espousing that a neuropsychological assessment could and should play a key factor in the design of psychoeducational batteries for the identification of specific learning needs (Gaddes, 1981).

Awareness of different rates of brain development as noted in neuropsychological assessment encouraged teachers to turn their attention to the cognitive, language and motor changes that occur during each child's development (Schweinhart & Weikart, 1985). During the past 35 years, school psychologists have moved well beyond thinking children with learning disabilities were suffering from minimal brain damage. School psychologists are now better able to communicate with teachers and parents about the ever increasingly complex nature of today's psychoeducational test batteries. However, much of the neuroscientific, developmental, and cognitive research that can inform early intervention is not being transmitted into practice because there is a lack of interdisciplinary communication and the information remains compartmentalized in distinct academic disciplines (Shonkoff, 2003). By integrating research into practice it is hoped that prevention and intervention for children at-risk and those with developmental disabilities will be improved, but in order for this to occur a universal language needs to be established to enhance cross-discipline understanding. Shonkoff (2003) stressed the importance for those individuals bridging the fields of being able to speak with neuroscientists about brain mechanisms, parents about their children, and legislators on policy. Caution must be taken as noted by Mason (2009), because schools commonly have misconceptions about neuroscientific facts and because teachers generally do not have an understanding of the language used. Neuroscientific research has the potential to contribute to educational research and practice, but it cannot be applied directly without taking into account other fields that also contribute to learning processes.

Historical Perspective of US Education Law

One of the first attempts made at the federal level to improve education for children with disabilities was an amendment to the Elementary and Secondary Education Act of 1965 (P. L. 89-750) followed by the Education Amendments of 1974 (P. L. 93-380) which increased federal funding for special education. In 1968 the federal government passed legislation entitled The Handicapped Children's Early Education Assistance Act (HCEEAP; P. L. 90-538) with the intent of establishing model programs of early intervention. HCEEAP funded the National Early Childhood Technical Assistance Center with the goal of promoting research and evidence based practices to support early intervention programs. A merging of perspectives among school psychologists and special educators was further spurred by legislation aimed at inclusionary and environmental practices for children with special needs beginning with Public Law 94-142, Education of All Handicapped Children Act, in 1975. At this time it was estimated that more than eight million children had disabilities and only half of them were receiving services, while one million were excluded from public education completely (Jacob, Decker, & Hartshorne, 2011). This law included a voluntary incentive grant program for early intervention for infants and toddlers with disabilities ages' birth to two years and a mandatory preschool component for children ages three to five. When amendments were made in 1990, the Education for All Handicapped Children Act became the Individuals with Disabilities Education Act (IDEA). IDEA has been reauthorize twice since then, 1997 (P. L. 105-17) which stressed the importance that early intervention for infants and toddlers with disabilities should be provided in natural environments, typically in the child's home and 2004 (P. L. 108-446) which emphasized evidence-based early reading interventions and early intervening services. This allows schools to use a portion of their funding to assist those students who are struggling in the general education classroom that have not been evaluated for special education in order to intervene before the problem becomes severe. The No Child Left Behind Act of 2001 (NCLB, P. L. 59-10) stipulates that educational and behavioral interventions be scientifically based and implemented with fidelity. Additionally, the focus on increased accountability and school improvement requires schools ensure students are proficient in core skills through the use of testing and assessment. As schools started being held to this higher level of accountability it became more important than ever that students with disabilities be identified and provided with scientifically validated interventions, so that every student could make adequate yearly progress.

After the passage of the Education for All Handicapped Children Act (P. L. 94-142) and later the 1990 Individuals with Disabilities Education Act (P. L. 101-476), learners with neurodevelopmental disorders became a priority group who received improved psychoeducational assessments which were criterion-referenced or behaviorally-based. The 1997 Individuals with Disabilities Education Act (P. L. 105-17) extended the developmental delay category and urged the formation of the academic field of early childhood special education. Part B of IDEA provides funds for services to children with disabilities between the ages of three and 21 years. While Part B is funded permanently, Part C, which provides services for children age birth to three, has to be reauthorized every four to five years (Jacob, Decker, & Hartshorne, 2011). IDEA has a Zero Reject Principle that "requires states to locate and evaluate pupils with disabilities and provide them with full educational opportunity, regardless of the severity of the disability," (Jacob, Decker, & Hartshorne, 2011; pp. 86). Because of this, the state is required to develop and implement policies and procedures that actively work to locate children with disabilities in order to evaluate them for services better known as Child Find.

Role of Early Intervention

Early intervention consists of a wide variety of educational, nutritional, childcare and family supports, all designed to reduce the effects of disabilities or prevent the occurrence of learning and developmental problems later in life for children presumed to be at risk for such problems.

> "Early intervention can be further defined as a loosely structured confederation of publicly and privately funded home and classroom based efforts that provide (1) compensatory or preventative services for children who are assumed to be at risk for learning and behavioral problems later in life, particularly during the elementary school years, and (2) remedial services for problems or deficits already encountered . . . Simply put, early intervention must provide early identification and provisions of services to reduce or eliminate the effects of disabilities or to prevent the development of other disabilities, so that the need for subsequent special services is reduced," (McConnell, 1994, pp. 75-78).

Early intervention is the period of a child's life from age zero to three. During this span, children show marked increases in physical, cognitive, language, and social domains. This critical period of development not only requires early identification of potential risk factors, but also the timely design and implementation of specific early interventions that address the individual needs of the child.

IDEA Part C has five goals: 1) enhance development of children with disabilities age zero to three and minimize risk of developmental delay, 2) minimize the cost of education, 3) increase the potential for people with disabilities to be independent productive members of society, 4) maximize families abilities to help their child with a disability, and 5) increase the state's ability to identify, evaluate, and serve all children (Jacob, Decker, & Hartshorne, 2011). Under Part C, a child is defined as having a disability if they require early intervention services due to experiencing developmental delays or they have received a diagnosis of a physical or mental condition which will likely lead to a developmental delay. However, it is up to the individual state to determine the eligibility category for those who are exhibiting delayed development. Additionally, states have the discretion to assist children at-risk, due to biological or environmental reasons, for experiencing a developmental delay if early intervention does not occur. Once it is determined a child should be evaluated for developmental delay, a multidisciplinary assessment must be conducted to identify the child's strengths and weakness in order to develop an individualized family service plan (IFSP) of appropriate services. Five areas of functioning must be evaluated; cognitive, physical, social/emotional, communication, and adaptive. The types of services children can receive as part of their IFSP include: family training, counseling, home visits, special instructions, speech-language pathology and audiology services, occupational therapy, physical therapy, psychological services, medical services, nursing services, nutrition services, social work, vision services, assistive technology, and transportation (Jacob, Decker, & Hartshorne, 2011). Although a large number of children are served by early intervention programs, there continues to be dearth discussion between neuroscientists and early interventionists possibly due to the fact that many early childhood interventionists are not knowledgeable about brain development, brain organization, or the effects of various outcomes of brain injury.

Brain Development

Much of the formation of the brain is completed during the prenatal period, thus making it possible for neurons to migrate and develop "ladders" which form a rudimentary cortex consisting of six specific layers (Bergen & Woodin, 2011). During normal prenatal development, approximately 60% of a fetus's genes are committed to brain development (Bergin & Woodin, 2011). Hence, there are nearly 100 billion neurons in place at birth for effective communication among the brain's life-essential regions. When injury occurs prenatally or during the first three years of life, this damage can interfere with the brain's ability to acquire new information. Injury to the brain may disrupt the neurodevelopmental processes that are known to occur across the lifespan; this makes early intervention a critical component in a child's future academic success.

At birth, only the lower portions of the brain are structurally and functionally well developed while the upper regions, including the cerebral cortex, are still at more primitive levels and require additional time for full development. By the time we reach adulthood, our brains have acquired more than 140 billion nerve cells, or neurons. The brain is compartmentalized into two hemispheres, each containing four lobes: temporal, parietal, occipital, and frontal. These different regions are connected by the corpus callosum which allows for the independent regions to communicate and function together. As a baby develops, everyday experiences begin to change the structure of the brain such that perceptual systems (better known as sensory, motor and cognitive processes) develop. These brain changes result from electrical impulses which shape the way each circuit is joined together. Every experience encountered by the child activates selected circuits while leaving others inactive. When selected electrical impulses are turned on for longer periods of time, they become strengthened and subsequently they become neural pathways wired together. Circuits that are not commonly used are pruned away. Pruning is a form of removing unused neural circuits so that the remaining ones work more efficiently (Miller & Defina, 2009). This process of eliminating the excess synaptic connections is known as synaptogenesis and the pruning occurs in various regions of the brain at different rates (Penkman & Butler, 2008).

Neuropathways are strengthened during each developmental period through a process of dendritic arborization, a treelike branching of nerve vessels. Pruning usually occurs during windows of opportunity within a child's development when the brain is better prepared to acquire fundamental abilities critical for learning future skills. Pruning allows neural pathways to adapt to information inherent in the infant’s environment. For instance, Broca's area of the brain, which is located in the frontal lobe of the left cerebral hemisphere, controls speech production and has a relatively long window of opportunity spanning early to middle childhood. This part of the brain is also associated with phonological processing, but it is not thought to be as efficient as the occipital-temporal pathway (Miller & Defina, 2009). The occipital lobe, which is involved in visual processing, has a window of opportunity ranging from the second to eighth month of life; and the cerebellum, which contributes to motor function, has a window of opportunity ranging from the fifth to twelfth months. When infants are not properly exposed to various visual, auditory or tactile stimuli during these windows of opportunity, they run the risk of brain underdevelopment and could later become at risk for academic difficulties (Perfetti, 1985). According to Schiller (2003), this means that although infants are born with predispositions to certain conditions, the environment that the infant is exposed to will be the “architect” that shapes the brain. Neuroimaging studies have determined that the brain of the developing learner changes metabolically in response to selected interventions (Shaywitz, 1998). For example, individuals with no musical experience were found to have activation within the bilateral superior partietal cortex after 15 weeks of musical training that was not present before the training (Stewart et al., 2003). The hope is with early intervention children will be exposed to stimuli which will strengthen their neuronal pathways before pruning occurs.

Neuroscientists as yet do not fully understand the biological basis of these windows of opportunity for learning, but they are aware that some brain areas take longer to develop the neural pathways necessary to perform multistep problem-solving tasks. A growing number of neuroimaging studies indicate that disabled readers often show a failure of the left hemisphere, posterior brain system (Brunswick, McCrory, Price, Frith, & Frith, 1999; Paulesu et al., 2001; and Shaywitz, 1998) and that these anatomical abnormalities are due to a pre-existing neurobiological deficit (Linkersdorfer, Lonnemann, Lindberg, Hasselhorn, & Fiebach, 2012) as evidenced by the fact that these deficits are present before reading difficulties are identified or instruction begins. Further studies indicate that when dyslexic readers exhibit a dysfunction in posterior brain systems, they are capable of developing compensatory systems in both hemispheres, including the left occipito-temporal word form area (Shaywitz et al., 2002). Dyslexic readers have an increase in activation in the cerebellum and subcortical areas during reading tasks and Linkersdorfer, et al. (2012) hypothesized this is caused by increased effort on the part of the reader due to using compensatory mechanism. Due to the culminating evidence, Shaywitz and colleagues (2004) later came to the conclusion that specific interventions derived from theory and application should be neuro-biologically based.

These findings lead to questions about the expected pace of development in both neurotypical and impaired brains (Shaywitz, Morris, & Shaywitz, 2008). The field of early childhood intervention has been aware of the capability of the brain to develop new neural pathways that take alternate, re-purposed routes, but which ultimately establish necessary neural connections. New neural pathways require additional time to develop and become functional. One wonders if the expectations for special needs students held by some educators are appropriate considering the additional time that might be necessary for the re-wiring of the brain to occur.

Typically a child's brain is not fully developed until the early adult years. The newborn's brain works more slowly and less efficiently than that of an older child because the axons in a child's brain are still being myelinated. The myelin sheath is the insulation which allows electrical charges to pass through neurons more quickly leading to more efficient communication between neurons. The process of myelination starts prenatally; however, it is not finished until early adulthood. Additionally, effective pruning speeds up the rate of neural processing in the brain from infancy to childhood. Awareness of different rates of development will allow early interventionists to realize that when children experience developmental delay or slower ability to demonstrate a given skill, this weakness is possibly the result of a lack of evolvement in a specific region of the brain as brain regions develop at different rates. For instance, the prefrontal cortex of the brain matures at a slower rate than other brain areas and it typically is not fully developed until young adulthood (Squire & Kandel, 2000). When a child's development does not proceed as expected, early childhood special educators can use their understanding of brain processes to modify and individualize intervention strategies as evidenced by experimental findings showing a phonologically-based intervention not only lead to gains in reading fluency, but also increased activation in the left hemisphere including areas associated with dyslexia (Shaywitz et al., 2004).

Neuroimaging Applications

The advent of functional neuroimaging techniques has led to great advances in our understanding of select biological brain functions. Neuroimaging is a series of procedures designed to create visual images of the brain. The regions of the brain that indicate a high level of activity are then highlighted using various colors for distinction. There are many different types of neuroimaging tools and each one provides data that can answer a different type of question. These tools, which include functional magnetic resonance imaging (fMRI) and Diffusion Tensor Imaging (DTI), enable the measurement of specific aspects of brain function by examining cortical electrical activity and blood flow. These techniques are noninvasive and there is no exposure to radiation, as opposed to Positron Emission Tomography (PET) which utilizes the injection of radioactive substances. Photo-Topography is so non-invasive that it allows for the imaging of the infant brain. Magnetroen-Cephalography (MEG) and Photo-Topography, as indicated by Kevan and Pammer (2009), now afford us the opportunity to link neuroscientific information about patterns of brain activation to research initiated by the field of early childhood intervention. Although, fMRI can provide information about localization of functioning, because it is a cumulative image it does not provide information about the time sequencing of the network activation. On the other hand, electroencephalography (EEG) can measure millisecond time differences in activation by observing the electro-chemical reactions on the individual cell level, there by leading to the time course of processing stimuli (Goswami, 2008). Combining fMRI and EEG methods leads to a fuller picture of what is occurring in the brain by allowing us to examine the time sequence at which neural circuits are activated as a result of a given stimuli.

As there are distinct purposes for the different types of neuroimaging, neuropsychological assessment provides different insights into brain functioning. The purpose of the neuropsychological assessment is to observe specific functions of the nervous system to determine the existence of either functional areas of weakness or strength, such as soft neurological impairments involving fine or gross motor functions. Unlike the neuropsychological examination, neuroimaging can only imply or suggest the possibility of a problem or physical cause of a symptom which may be related to a specific region of the brain. The advantages gained by functional MRI appear to be undeniable due to the numerous empirical studies present in the review of literature (Cattaneo & Rizzolati, 2009; Dehaene & Cohen, 2007; Draganski et al., 2006). fMRI procedures are moving in the direction of assisting neuropsychologists in designing treatment interventions based upon the neuropathological information provided by neuroimaging studies. Neuropsychologists who utilize neuroimaging should understand how the arrangement of cells within the brain and nervous system are related to difficulties children might experience, such as in phonology and syntax (Noggle, Davis, & Barisa, 2008). Until neuroimaging gains a more prominent role and new statistical tools are developed to overcome the limitations of data analysis and the field of neuroscience comes to understand how to appropriately interpret those statistics, significant neuroscientific applications to early intervention will be difficult to realize and results will continue to be misunderstood. It is well known amongst researchers and statisticians that correlation does not equal causation; however, neuroscientific results are being reported as having causal links when the current statistics used when analyzing neuroimaging results are correlational and simply indicate that a task, such as reading, is related with activity in a specific brain region (Alferink & Farmer-Dougan, 2010).

With advanced neuroimaging technology and better understanding of neuroimaging results, we can substantiate neural deficiencies in the brain with minimal invasion. Prior, we had to rely on evidence resulting from blunt force trauma or organic dysfunction. Initial advances of functional neuroimaging techniques enabled cognitive scientists to suggest that the location of a selected area of the brain may be responsible for a specific function by monitoring blood circulation and changes in metabolism. For example, previously we had to use postmortem studies, such as those conducted by Galaburda (1989), to determine structural abnormalities in individuals with dyslexia, however, neuroimaging now allows us to examine activation and grey matter volume in order to identify structural abnormalities before a child is even capable of reading (Linkersdorfer et al., 2012). This level of analysis makes it possible to link the activated area of the brain to a specific function, which can inform intervention practices.

Through rapid and steady advances in technology, neuroscientists are able to take images of the smallest parts of the brain and their structures. Caution is heeded though because some within the field of neuroscience believe that there is not currently a clearly defined path for addressing the legal and ethical guidelines for conducting this level of research (Bruer, 1997; Downie et al., 2007; Fenton, Meynell, & Baylis, 2009). Such concerns include the consent process, confidentiality issues, and simply the unexpected results or findings made by fMRI research. Many of these concerns are addressed by institutional review boards across the nation whose primary mission is to monitor research protocols and ethics of research practices involving human subjects. For a thorough exploration of ethical considerations refer to Lalancette and Campbell's "Educational Neuroscience: Neuroethical Considerations" (2012).

Establishing the Link Among Education and Neuroscience

Early in the 1990's there was a burst in "brain-based education" tools and along with this came an invasion of a plethora of neuromyths in education such as the notion that children are either left or right brain thinkers (Lalancette & Campbell, 2012). Sousa (1998) began to argue that there was a need for professional development opportunities for pre-service and in-service teachers to receive professional and personal contact with researchers involved in the field of cognitive neuroscience. In 2004 the Council for Exceptional Children recognized that the field of special education was an evolving and changing discipline, which led the organization to publish a set of standards for pre-service and certified teachers in the field. Standard 1, Foundations, implored special education teachers to gain knowledge of relevant laws and policies, assessment techniques, instructional methodology, and evidence based principles in order to demonstrate affective teaching skills. Specifically, Standard 8, Assessment, directed teachers to use multiple types of assessment in order to design effective individualized education plans. Because the Council for Exceptional Children recognizes the dynamic nature of education these forms of assessment should evolve as advances in neuroimaging are realized. However, in order to utilize neuroimaging as a form of assessment, special educators must have a broad knowledge base of the psychometric properties, inherent bias, and ethical principles of neuroimaging in order to utilize neuroimaging results to inform program and instruction planning. This information can be provided to educators through training programs and professional development. In order for neuroscience research to continue to be utilized in the field of education and not lead to neuromyths, brain imagining has to be recognized as nothing more than a statistical tool that is a means of examining something much larger.

Advances in imaging technology over the last 20 years have led to an explosion in the number of studies providing theoretical templates of the inner workings of the brain (Kim, Smyth, & Stern, 2006). Research begun in the 1990’s indicates that it may be advantageous to modify intervention practices based upon neuroscience. Fisher (2009) advanced theoretical constructs for the building of a scientific foundation for learning and teaching. He has collaborated with Vallotton (Vallotton & Fisher, 2008) whose research areas encompass early childhood development, specifically focusing on cognitive development. Other neuroimaging research indicated that using a pictorial representation assists algebra students to solve word problems (Terao et al., 2004), while other studies suggested that "differences in neural activation patterns after one year of musical training can be revealed" (Overy, Norton, Cronin, Winner, & Schlaug, 2005, pp. 217).

Research supports the notion that instructional design is critical and the ways that children are taught can foster the development of compensatory automatic neural systems that competent readers employ (Shaywitz et al., 2008). Most empirical studies concerning brain-based research within the past ten years have been focused on the secondary school level and not the primary or pre-primary level, but that too is changing (Milam, 2005; Nunley, 2002; Pool, 1997). Unfortunately, the period from birth to age three has received the least amount of attention from educational researchers. Racine, Bar-llan & Illes (2005) reported that after a key-word search on fMRI press coverage beginning in January, 1991 and ending in June, 2004, they uncovered that adults were featured 84% of the time, followed by school-aged children and adolescents getting 14% of the coverage, and infants were featured only 2% of the time. Further findings indicated that 35% of the articles contained descriptions of clinical research, 44% non-clinical research, and 20% indicated both clinical and non-clinical research. Non-health related early childhood interventions accounted for only 17% of the findings. Because little research has been compiled on the pediatric population, it has been difficult to develop a systematic mapping standard between mental and neural processes in the brain (Stippich, 2008).

To date, both neuroscience and education have focused on cognitive development, yet both sides have only recently realized the importance of working collaboratively to identify and monitor brain patterns which can produce clinically based results applicable to early intervention practices (Koch, Timmerman, Pieffer, & Laurienti, 2013). Due to the advances in neuroimaging and the emerging practice of pediatric neuropsychology, school psychologists have a better understanding of child development and can use this knowledge to identify impairments in cognitive, social and emotional areas of functioning. The focus is moving beyond identifying specific brain lesions and toward determining how to design specific treatments that address a child's weaknesses (Hale & Fiorello, 2004). There is discussion by many researchers that a bridge needs to be built between education and neuroscience. Mason (2009) has a different vision than most and suggests we need a two-way bridge where outcomes from neuroscientific research influences education while at the same time education influences neuroscientific research by suggesting the concepts and theories in need of investigation. Educators should propose educational constructs that they need investigated in order to best serve students. As the research is uncovered by neuroscientists it will be their responsibility to advance scientific work into a forum that can be shared and practically utilized by the educational community. However, evidence exists that suggests diverse disciplines, such a neuroscience and education, each have their own culture in which they remain submerged, making it difficult for the two disciplines to converge into one i.e. educational neuroscience (Becher & Trowler, 2001).

Conclusions and Recommendations

The evolving specialized discipline of school neuropsychology and educational neuroscience appears to be minimizing the disconnect between research and practice to some extent. A nontraditional link-up among neuroscientists, early intervention specialists and school neuropsychologists may challenge prevailing theories and early intervention approaches being applied in schools today. However, in order for this partnership to work, a transdisciplinary perspective needs to be utilized in order for this diverse group to solve problems in a meaningful way (Beauchamp & Beauhamp, 2013). Otherwise we are destined to become entrenched in misconceptions and neuromyths, such as those noted by Bruer (1999) and others (Spellman & Willingham, 2004, and Sylwester, 2003) over the past ten years, thus impeding our ability to conceptualize the relationship among cognition and specific brain functions. Endeavors in pediatric neuroimaging have provided us an opportunity to understand and apply current research findings with the hope that it may eventually be possible to identify selected teaching approaches to support specific types of brain activation. Teachers need to have a knowledge base and understanding of how the brain works and develops as the child progresses through school. Additionally, teachers must become critical evaluators of research on brain-based interventions in order to discriminate between those interventions that are truly evidence based and those that the research does not support.

Research in neuroscience, cognitive science and neuropsychology has intensified in recent years. Additionally, research in neurodevelopment and neurobiology indicate that a child's brain development between the ages of birth to five years is a critical period of brain development because it lays the foundation on which all later learning occurs. Unfortunately, much of the neuroimaging research that might benefit early childhood education comes from adult populations. Because the developing brain of a child is quite different from that of an adult, research findings cannot be applied across the age spectrum. Therefore, caution should be heeded because much of the research compiled today does not have the potential to benefit the field of early childhood special education directly, but what we can hypothesize how this information may affect the design of intervention practices in the future (Frey & Fisher, 2010). There is an essential need for more neuroimaging research to be conducted with the pediatric population; which is now possible due to advances in noninvasive neuroimaging. Once the field has further explored these constructs with the pediatric population, the scientific results can be utilized to develop interventions that are more effective in meeting individual student needs. However, not only is this initial research critical, but we also need to then test the derived hypotheses and proposed interventions to ensure that the evidence supports their use. As noted earlier, the statistical analysis utilized to analyze neuroimaging only implies a correlational relationship. Therefore, we must only use the neuroimaging information as a tool to develop hypotheses about how the brain functions. It will then be the responsibility of neuropsychologists and school psychologists to evaluate the effectiveness of interventions derived from neuroimaging research as applied in school settings to determine what is appropriate for educational instruction.

Future studies will add to our understanding of how memory, perception and intelligence are represented in the brain (Peiffer, Laurienti, Koch, & Timmerman, 2014). Neuroimaging results addressing the association of cognition and intelligence testing may indicate if human cognition is a modular or global process in the brain. Additional findings may yield consensus on how to determine the extent to which intervention theories and instructional methods support the research findings of neuroimaging (Koch, Timmerman, Pieffer, & Laurienti, 2013). Already we know that neural circuitry differences exist in dyslexic readers. The left occipito-temporal word form area has been identified as a possible area responsive to effective reading interventions (Shaywitz et al., 2008). The fields of neuroscience, neuropsychology and early intervention should be challenged to offer teachers training in biologically based systems of diagnosis and intervention. Additional forays should address the question of whether individual differences in learning and intelligence are mirrored by observable differences in brain structure and function. Once answered, this neuropsychological information may become a critical component in the early identification of developmentally delayed children and in the design of early childhood intervention approaches.

An analysis of the literature has made it evident that more traditional interventions, which historically have not been based on neuropsychology, may not be as successful as once thought. Numerous empirically based studies have shown specific differences in brain functions utilizing fMRI; this allows for school neuropsychologists "to develop individualized interventions that are more efficacious in children with atypical neurodevelopment in relation to their functional needs and deficits" (Miller & Defina, 2009, pp. 144). Neuroimaging will be used in the future to monitor the effectiveness of interventions. It is conceivable that school neuropsychologists will assume major responsibility for designing and evaluating inventions specifically for children at risk for neurodevelopmental disorders (Miller & Defina, 2009). Awareness of differences in neural activation patterns can benefit early childhood special education by emphasizing the importance of teaching different strategies to help students develop the skills necessary for learning new concepts. The use of neuropsychological assessments that examine sensory-motor functions, cognitive processing, and environmental factors along with effective partnerships among schools, service providers and parents will enable early childhood special education teachers to maintain realistic expectations for learners with special needs. It will be critical that early interventionists must gain a working understanding of how specific brain functions contribute to various behaviors observed in a child in a classroom setting (Wolfe, 2001).

Today, school psychologists, early interventionists and special education teachers are dealing with a broader array of educational and behavioral problems exhibited by young children in school classrooms than ever. More specifically, children at risk of developmental delay may exhibit deficits in one or more areas to include cognitive, physical, communication, social-emotional, or adaptive development. School psychologists have the responsibility to design and assist in interventions of those children that have either a diagnosed physical or mental condition that results in a high probability of developmental delay. In recognition of these concerns, during the reauthorization process the President of the United States requested an increase of $20 million for IDEA Part C bringing the total funding amount to over $460 million in the 2013 fiscal year. Because the responsibility is left up to the states to create coordinated service delivery for children with developmental disabilities aged birth through three years, services are inconsistent due to how states define who are considered at risk for developmental delay and how many areas of delay must be involved for children to qualify for services under Part C. Due to the inconsistencies among individual states' definition of developmental delay, a student who receives services in one state may not qualify for services in another state that has a more narrow definition and service delivery model (Hadadian & Koch, 2013). Therefore, national legislation needs to develop a more comprehensive and consistent definition of the developmental delay and at-risk categories in order to provide reliable services across state lines. Additionally, the federal government needs to pass legislation for permanent funding to ensure appropriate allocation of resources on a continual and more stable basis. In conjunction with more effective and comprehension legislative funding, individual states, at the urging of the No Child Left Behind legislative act, must adhere to best practices which promote evidence based interventions that possesses robust construct validity.

In conclusion, it is evident that the developing brain is highly vulnerable to both genetic and environmental factors that can result in childhood learning disorders. With an ever growing body of research showing how behavior and neurology are interlinked, the importance of investigating brain functioning as a means for the early identification and treatment of specific disabilities will become paramount. It is recognized that there are differences among adults and children due to variability in learning among adult and pediatric populations. These inconsistencies between the need of the pediatric population and the available research makes it difficult to determine appropriate evidence based interventions for children at risk of developmental delay. It is critical that children receive individualized evidence-based interventions as early in life as possible. Understanding the implications and applications of recent brain research promises to enlighten the design and development of future best practices. The development of best practices can improve the quality of care (prenatal and postnatal) and later the early childhood services (assessment, treatment and intervention) received by young children. In order to apply the initial findings of overall brain development we need to establish a sound foundation of understanding across disciplines which allows neuroscientists to quantify what theorists and practitioners within the field of early childhood special education have advocated for years.

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