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Dance Movement Therapy for Neurological Development in Ages 0-3: A Critical Review of the Literature

Anna Rupert
arupert@lesley.edu

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Anna Rupert

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Donna C. Owens, PhD

Abstract

The effects of movement on neurodevelopment have been studied by many in both the psychology and neuroscience fields. However, there is a lack of research into the specific ways in which movement is being used to affect neurodevelopment and which specific types of movement most benefit neurodevelopment. This study aims to bridge that gap in the literature by investigating how movement impacts neurological development in infants aged 0-3. Research was pulled from peer reviewed journals using Lesley Library, Syracuse University Library, and Google Scholar and synthesized into four key categories: neurodevelopment in infants aged 0-3, impacts of experience and culture on development, movement and neurodevelopment, and dance/movement therapy to facilitate neurodevelopment. The research showed that ages 0–3 are a key period for neurodevelopment across all developmental domains, and that culture and experiences in infancy play a large role in infant development in both direct and indirect ways. Researchers found exercise increases brain derived neurotrophic factor and other brain growth factors key in neurodevelopment. Although research agrees that movement positively impacts neurodevelopment, there is a debate regarding what specific types of movement most efficiently achieve this purpose. Dance therapy is a comprehensive medium for encouraging neurodevelopment through movement. Further research into which specific types of movement are most effective in increasing Brain Derived Neurotrophic Factor and other growth factors is needed.

Keywords: neurodevelopment, movement, dance movement therapy, neurological function, infant development

Author Identity Statement: The author identifies as a U.S. born, native English speaking, White cis woman, with no diagnosed neurological disorders, residing in Central New York.

Dance/Movement Therapy for Neurological Development in Ages 0-3: A Critical Review of the Literature

> I believe that the unity of mind and body is an objective reality. They are not just parts somehow related to each other, but an inseparable whole while functioning. (Feldenkrais, 1981, p. 73)

Ideas of how the body relates to the brain and the mind have been topics of high interest in research. Key foci have been how the body responds to mental trauma (Porges, 2011; Van der Kolk, 2014), connections between body development and neurological development (Dennis et al., 2013; Nelson, 1999), and the effects of movement on neural plasticity (Cotman & Berchtold, 2002; Doidge, 2007; Feldenkrais, 1980; Macedonia & Repetto, 2017[11]). It is now widely accepted that movement impacts many areas of neurological function (Cotman & Berchtold, 2002; Feldenkrais, 1981; Fredericks et al., 2006; Homann, 2020; Macedonia & Repetto, 2017; Vaynman et al., 2004). Cotman and Berchtold (2002) and Vaynman et al. (2004) produced studies showing the effects of exercise and movement on the production of brain-derived neurotrophic factor (BDNF), which plays a key role in facilitating the development and growth of new neurons in the brain in a process known as neurogenesis (Macedonia & Repetto, 2017). Their findings provided the foundation for my inquiry.

Although neurological development is a process that continues throughout the lifespan (Dennis et al., 2013), many key neurological functions develop during the ages of 0-3, and early experiences can have both positive and negative impacts on the development of these functions (Nelson, 1999). It is important now more than ever to focus on the role movement plays in

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[1]Although the data in this article is valid, the statements made by the authors regarding obesity and cognitive performance could lead people to make false generalizations.

neurological development within the age group of 0-3 because the COVID-19 pandemic has caused interruptions to children's access to developmental resources, as well as increasing the global level of children in poverty by 10% since 2019 (UNICEF, 2021, The Problem section). Dance/movement therapists will be dealing with the effects of the pandemic in every population for years to come (Deoni et al., 2021; Usher et al., 2020). Understanding the role movement plays in development as well as current strategies for using movement to foster positive development in ages 0-3 is vital, especially for mitigating the detrimental effects the pandemic is having on childhood health, wellbeing, and development.

Dance/movement therapists such as Suzi Tortora, Bonnie Bainbridge-Cohen, and Judith Kestenberg have developed key methods designed for using dance to help cognitive functioning and childhood development (Burrill, 2011; Kemble, 2019; Loman & Merman, 1996; Tortora, 2010). I have analyzed their contributions to the fields of dance therapy and early childhood development, looking for commonalities and gaps.

Although much research has been done on how movement impacts neurological function, I believe it is helpful to have a document synthesizing that research, establishing connections between existing literature and methodologies, identifying gaps in the literature, and making recommendations for future practice and research. Through a critical review of the literature, I have examined the role of movement in neurological development and the ways in which dance/movement therapy has been used to impact neurological development in children aged 0-3. What movement intervention strategies have been most effective at fostering neurological development? How can we use movement more effectively to facilitate neurological functioning in children ages 0-3? How could this translate into specific populations with neurological disorders that originate from birth? Where are the gaps in existing literature and practices? I have also offered recommendations for future research and practice.

In my review of the literature, I have explained the history of movement as it impacts neurological functioning as well as the neurological development that occurs in children aged 0-3. I discussed the impacts of language and culture on childhood development. I analyzed past and present dance/movement therapy (DMT) and other intervention methods for working with children in this age group, as well as how DMT research looks at movement for neurological development. Finally, I offered recommendations based on this review for future paths of research and practice.

Method

My review of the literature includes a discussion of the research on infant neurodevelopment, how the biology of neurodevelopment interacts with other child developmental domains, and how culture and experience affect infant development. I explored how movement affects brain function and neurodevelopment in infants aged 0-3 and discuss current uses of dance and movement to impact brain functioning and neuron communication. My search terms included combinations of: (a) terms related to childhood development – infant development, development through the lifespan, neurodevelopment, developmental domains, ages 0-3; (b) terms related to the impacts of culture on development – culture and parenting, cultural practices and childhood development, culture and family functioning, cultural practices and family; (c) terms related to movement and neurobiology – neuroplasticity, movement and BDNF (brain derived neurotropic factor), exercise and neurogenesis, movement to facilitate neurogenesis, movement and neurological functioning, dance and neurological functioning; and (d) terms related to DMT for neurological functioning – DMT and neurogenesis, dance and cognitive function, DMT and child development, DMT and developmental delay, developmental dance interventions, DMT and neuroplasticity, dance and infant development.

I used Lesley Library, Google Scholar, Google, ScienceDirect, and the Syracuse University Library to search for resources. Within Google Scholar, I identified Lesley University and Syracuse University as libraries to which I have access. I also included Dartmouth University, University of Massachusetts Amherst, and Boston College as institutions to which I have access through friends or professors who were willing to help me locate a specific source within the libraries at those institutions.

I looked for sources from peer-reviewed journals, as well as narrative sources from families with different backgrounds. I included books from my personal library which discussed themes related to my topic, such as neuroplasticity and neurological functioning. I chose my sources based on the reliability and validity of studies and the publishing date (if a source was published prior to 2002 I searched for a second more recent source to either corroborate or reflect newer differing information). I made specific efforts in my searches to include research done by individuals from diverse backgrounds and to find narrative studies that included voices of the populations being studied.

I used Zotero as an organization system for my sources. I created folders labeled "Neurodevelopment 0-3," "Neurodevelopment and Movement," "Cultural Impacts," and "DMT" to organize my sources by topic. I took detailed notes on each source in a separate Word document. I also created an outline of my thesis topic and added information from each source under the appropriate subheading as I read. I kept a thesis journal on paper where I wrote down progress notes, to-do lists, and next steps for organization and planning. I also took notes of the themes appearing in the literature, organizing my thesis outline by grouping these themes together.

Literature Review

Neurodevelopment in Children Ages 0-3

In order to understand how movement affects infant neurodevelopment, it is important to know what occurs in the brain between the ages of 0-3. It is well known that during this period much neurodevelopment takes place (Broderick & Blewitt, 2020; Dennis et al., 2013; Nelson 1999). The Brighton Center for Pediatric Neurodevelopment (BCPN, 2021) defines neurodevelopment as “the brain’s development of neurological pathways that influence performance or functioning” (para. 1). In an examination of the literature on neurobiological development, Nelson (1999) identified four stages of development occurring in the first stages of infancy: the formation of the neural tube which becomes the cortex and spinal cord, the creation of specific classes of neurons, the migration of neurons from their point of creation to their final location within the cortex, and the differentiation of cells and formation of synapses, known as synaptogenesis. Sheridan and Nelson (2012) confirmed these stages in their chapter on fetal and infant neurodevelopment in the *Handbook of Infant Mental Health*.

Neurodevelopment in infancy affects functioning across all major areas of development including cognitive, motor, linguistic, and psychosocial (Evangelista & McLellan, 2004; Reinstein & Burau, 2014; Vehkavuori & Stolt, 2019; Wang et al., 2021). Childhood development across all domains is very complex, so for the purposes of this study I am only giving a brief overview of the domains of development, connecting them back to how they affect neurodevelopment.

Reinstein and Burau (2014) defined cognition as a “collection of mental processes that supports the processing of information” (p. 40). Included in these processes are visuospatial reasoning – which helps with skills such as facial recognition, spatial awareness, math skills, etc., and executive functioning – which helps with more long-term skills such as goal setting or planning, attention and memory, organization of behavior over time, and so forth. A longitudinal study in rural Western China found that cognitive development in the first three years of life was predictive of cognitive abilities and development in later childhood (Wang et al., 2021). Cognitive skill development affects functioning across domains such as motor and linguistic development (Reinstein & Burau, 2014; Vehkavuori & Stolt, 2019; Wang et al., 2021). There are two types of motor functioning: gross motor and fine motor. Gross motor skills use the large muscles in the body to perform whole body movements such as walking, balancing, sitting upright, or waving (APA, 2020). Fine motor skills use “coordination of small muscles to control small, precise movements, particularly in the hands and face” (APA, 2020, para. 1). These are skills such as writing, zipping a coat, tying shoes, and making facial expressions. Visuospatial skills from cognitive development are used in many aspects of both fine and gross motor skills, such as knowing where the body is in space to perform whole body movements or being able to space letters out adequately on a page when writing. Collective measures of ability in both gross and fine motor function are strong predictors of academic ability and behavior later in childhood (Reinstein & Burau, 2014).

Language development occurs largely within the first 24 months of life (Vehkavuori &Stolt, 2019), although our understanding and use of language continues to grow more complex as we age. There are two branches of language development: receptive language (the ability to perceive and process language; APA, 2020) develops first (Broderick & Blewitt, 2020; Reinstein

& Burau, 2014; Vehkavuori & Stolt, 2019) and expressive language (ability to produce written or spoken language; APA, 2020) develops shortly after (Broderick & Blewitt, 2020; Reinstein & Burau, 2014; Vehkavuori & Stolt, 2019). Linguistic development across both expressive and receptive domains is related to later success across all areas of development, including socioemotional development (Evangelista & McLellan, 2004; Reinstein & Burau, 2014; Vehkavuori & Stolt, 2019). The rate of communication disorders comorbid with emotional and/or behavioral difficulties is estimated at between 50-60% (Evangelista & McLellan, 2004). Academic success is also dependent on having both receptive and expressive language abilities (Reinstein & Burau, 2014). Psychosocial development is similarly influenced by development in other domains. Children with developmental delays have a higher rate of behavioral difficulties in school as reported by Evangelista and McLellan (2004). There are many theories surrounding psychosocial development in infancy and throughout the lifespan (Broderick & Blewitt, 2020; Chilton et al., 2007). These theories highlight both the internal and external influences on psychosocial development, including the need for expressive and receptive language skills for emotional processing and relationship building, cognitive skills for self-regulation abilities, and visuospatial reasoning and motor skills for recognizing nonverbal communication in others (Broderick & Blewitt, 2020; Reinstein & Burau, 2014). Visuospatial reasoning is also required for using nonverbal communication oneself (Reinstein & Burau, 2014; Vehkavuori & Stolt, 2019). Early childhood development is filled with complex processes and many domains which influence each other.

Due to the high level of neurodevelopment and neurogenesis (creation of neurons; Queensland Brain Institute, 2021) occurring in infancy, the infant brain is thought to have the most plasticity, or ability to change and adapt (Dennis et al., 2013). One aspect of plasticity that is particularly relevant to my current research is Hebbian plasticity. Hebbian plasticity comes from Hebbian theory created by Donald Hebb and refers to the change in strength of synapses and connections as a response to changes in stimuli occurring outside the mechanism of the brain (Dennis et al., 2013; Park et al., 2014). Hebbian plasticity can be thought of as the "use it or lose it" concept, where synapses grow in strength when use is more frequent (long-term potentiation) and decrease in strength or die off when their use is less frequent or ceases all together (long-term depression; Dennis et al., 2013; Park et al., 2014). For example, if someone figure skated as a child but had since stopped, returning to the ice would feel less natural than it used to (long-term depression), but with continued practice, those movements would begin to feel more natural again (long-term potentiation). Plasticity affects development in both adaptive and maladaptive ways throughout the lifespan (Dennis et al., 2013). Dr. Norman Doidge (2007) provides many case examples of how plasticity can be wonderfully adaptive; however, plasticity is a side effect of experiences and genetics working together, not an intentional result. Therefore, plasticity does not always benefit brain functioning or development (Dennis et al., 2013; Doidge, 2007).

Although plasticity is thought to be highest in infancy and childhood, with the creation of new synapses peaking between 2 and 4 months of age (Nelson, 1999), Dennis et al. (2013) argued that the plasticity privilege of youth is inflated in research and common thought. This is because there is some evidence that with brain injuries, younger age at injury results in greater/longer-lasting damage to brain function. However, a longitudinal study on functional impairments post traumatic brain injury (TBI) in preschool aged children found that ability level pre-injury and severity of injury, not age at injury, had the highest effect on post-injury outcomes (Anderson et al., 2006). Additionally, Dennis et al. (2013) demonstrated the "mechanisms that facilitate developmental plasticity may exacerbate damage resulting from brain injury during development" (p. 2765). I understand this argument to mean that when the brain is injured during key developmental periods, the high level of plasticity causes it to develop in accordance with the injury, potentially creating maladaptive patterns that have long-term effects on the infant's neurological functioning. My examination of the literature hopes to point towards intervention strategies to mitigate some of these effects.

Impacts of Experience and Culture on Development

While genetics and biology affect neurodevelopment and plasticity, experience also plays a large role in the development of the brain (Chilton et al., 2007; Mills-Koonce et al., 2021; Muir & Bohr, 2019; Nelson, 1999; Sheridan & Nelson, 2012; Wang et al., 2021). Nelson (1999) explained how "experience takes advantage of the brain's ability to form new connections or alter existing ones" (p. 421), allowing them to alter the function and structure of the brain. Experiences such as exposure to the infant's native language (Nelson, 1999; Vehkavuori & Stolt, 2019), and to the visual world (Nelson, 1999) are necessary for the development of visual as well as receptive and expressive language skills. The grammar, syntax, vocabulary, and communication style of a person's native language influences the ways in which they think (van As et al., 2020) further compounding how the experience of language influences development.

Experiences with poverty impact infant development in both positive and negative ways (Chilton et al., 2007; Mills-Koonce et al., 2021). The influences of poverty on development are extremely complex, and so for the purposes of this paper I am only offering a broader picture of the issues related to poverty and infant development. Access to nutrition plays a major role in infant development (Chilton et al., 2007). In 2020, 584,000 children in the United States lived in households where their nutrition was disrupted (Economic Research Service [ERS], 2021), and 15.3% of households with children under the age of 6 experienced food insecurity. Sustained lack of nutrition during the ages of 0-3 can cause lasting damage to childhood development (Chilton et al., 2007). Poor child development can begin in utero if the pregnant person is malnourished (Chilton et al., 2007). Poverty and lack of access to resources not only contributes to food insecurity leading to malnutrition and developmental delays, but also contributes to the parents'/guardians' abilities to provide uninterrupted quality care for their infant (Chilton et al., 2007; Mills-Koonce et al., 2021). Household disorganization, characterized as "high levels of noise, excessive crowding, clutter, lack of structure, chaotic home environment" (Sameroff, 2010, p. 258) is associated with maladaptive development.

Access to resources is required to maintain a home environment without the above-mentioned characteristics. Low-income households frequently do not have access to the money, free time, and other resources required to avoid household disorganization, putting their children disproportionately at risk for developmental delays across all areas of functioning (Chilton et al., 2007; Mills-Koonce et al., 2021; Wang et al., 2021). Studies on how family functioning relates to infant/childhood development found that children born to older mothers, mothers with higher education, and/or families with higher income and lower needs showed the least risk for developmental issues (Chilton et al., 2007; Mills-Koonce et al., 2021; Wang et al., 2021). This can be attributed to the absence of certain environmental contributors to poor child development.

The manner in which children experience familial relationships also impacts childhood development. Maternal depression, poor parent-child relationships/interactions, and poor parent-to-parent interactions that involve the child can all negatively impact childhood development (Beebe, 2010; Chilton et al., 2007; Evangelista & McLellan, 2004; Mills-Koonce et al., 2021; Muir & Bohr, 2019; Wang et al., 2021). Similarly, exposure to domestic abuse and violence negatively impact development (Chilton, 2007; Mills-Koonce et al., 2021; Muir & Bohr, 2019).

Exposure to enriching environments and families that are emotionally connected and supportive have positive developmental impacts (Dennis et al., 2013; Mills-Koonce et al., 2021). The research on familial impacts on childhood development was mainly focused on maternal influences. Paternal influences on childhood development require further study.

Neurodevelopment and neuroplasticity are similarly influenced by cultural experiences (van As et al., 2020; Doidge, 2007; Evangelista & McLellan, 2004; Mills-Koonce et al., 2021; Muir & Bohr, 2019; Wang et al., 2021). Doidge (2007) pointed out that any sustained activity, including daily living within a particular culture, changes the brain and the mind. Every culture has distinctive child-rearing practices (Muir & Bohr, 2019). However, every parent/family will have a different definition of their own culture (van As et al., 2020). An individual’s experience of culture is shaped by many external factors and lived experiences, so it is important to understand that “while cultural norms may be shared by a group of people, the interpretation thereof differs for each individual” (van As et al., 2020, p. 3).

The topic of how each culture impacts family relationships, child rearing, and child development is too complex to assess comprehensively within this thesis. However, I would like to highlight some studies which show relevant connections between culture and neurodevelopment. A qualitative study on the impact of culture on early intervention programs in South Africa found that not nurturing children’s cultural identity can adversely influence both social and personal development (Fredericks et al., 2006). Muir and Bohr (2019) conducted a review of Canadian Aboriginal child development and parenting practices to see how the culture, development, and parenting practices were interrelated. They discovered what can be categorized as two different, distinct ways culture is interrelated with parenting style and childhood development: the cultural practices themselves and the societal privileges and/or prejudices that come from being a part of that culture. In the Aboriginal community being studied, the cultural practices had shifted and changed as a consequence of colonialism and forced enrollment in residential schools. Not only did the residential schools attempt to erase any traces of Aboriginal culture, but they also taught by corporal punishment and abuse tactics, meaning the children raised in these schools did not have positive role models for how to parent their own children. Aboriginal children today continue to be affected by the impacts of the generational trauma caused by these schools. Although the residential schools were unsuccessful in erasing Aboriginal culture entirely, they had a significant impact on how that culture is experienced by Aboriginal people today.

These studies raise questions for researchers studying neurodevelopment in the United States. This country has a long history of colonialist practices which have damaged, and in some cases, erased the sociocultural identities of marginalized people. It is, therefore, reasonable to hypothesize that many families within marginalized communities experience a similar intergenerational trauma affecting child-rearing in the U.S., which subsequently affects childhood development.

The example of the Aboriginal parents suggests that the impacts of culture on childhood development and neuroplasticity would not always be direct and explicit (Muir & Bohr, 2019). Culture has significant effects on infant development, but culture is a living process (plastic) and evolves in response to circumstances in the world around it. As a result, the manners in which culture impacts infant development evolve as well.

Movement and Neurodevelopment

There is considerable research establishing a multitude of connections between the body and the mind (Cotman & Berchtold, 2002; Doidge, 2007; Feldenkrais, 1981; Fredericks et al., 2006; Heinze et al., 2021; Homann, 2010, 2020; Macedonia & Repetto, 2017; Nay et al., 2021; Porges, 2011; Van der Kolk, 2014; Vaynman et al., 2004; Won et al., 2021). In the 80s and early 90s there was an explosion of research on how the body and mind are connected (Fredericks et al., 2006). Moshe Feldenkrais (1981) looked at how movement impacts the way we think and live. Piaget theorized that children develop through movement in the sensorimotor stage (Faber, 2017). The work of Porges (2011) and van der Kolk (2014) established the effect psychological traumas have on the body. Fredericks et al. (2006) states that our understanding of the world derives from movement, and that "movement is an integral part of all mental processes" (p. 30). This literature review specifically explores how movement connects to development, and how we can use physical movement and exercise to enhance neurological processes. Current research summarizing connections between exercise and brain communication states that adequate exercise can be an effective strategy to help combat neurological decline and mood disorders due to the crosstalk between the brain, muscles, liver, and gut (Nay et al., 2021).

Reinstein and Burau (2014) provide examples of how we function in daily life using a combination of executive function skills and gross motor movement skills. As previously discussed, movement is frequently broken down into two types: gross motor (using large muscle groups to achieve skills such as sitting, standing, balancing, walking, and so forth; Esposito & Vivanti, 2013, para. 1) and fine motor (using the small muscles of the body to achieve tasks such as grasping, writing, pinching, finger articulation, and more; Rodil, 2020, para. 1). The development of both sets of movement skills provides the foundations for neural development starting in early infancy (Kemble, 2019). Linguistic development starts with movements in infancy, specifically gestures such as reaching up towards a caregiver (Faber, 2017; Kemble, 2019). These gestures and our caregiver's responses create the basis for our understanding of communication and language. Movement facilitates the development of attention, balance, and coordination (Fredericks et al., 2006), which provide the foundations for future learning (Blythe, 2000). Movement is integral to the development of focus, concentration, memory, and logical problem-solving skills (Faber, 2017). These skills are necessary to carry out activities of daily living as well as succeed in an academic environment.

The film *The Moving Child III* (Kemble, 2017) mentioned a Yale Child Study Center research report stating the use of movement is a stimulus to the development of the brain. I was unable to find that specific report, however much of my research corroborates that point. A study in South Africa found that a targeted developmental movement program significantly enhanced first graders' performance in spatial, reading, and mathematical skills (Fredericks et al., 2006). The study pointed toward movement as "providing the stimulation to neurological systems that is necessary for their development and optimal functioning" (Fredericks et al., 2006, p. 29). Fredericks et al. (2006) also highlight research done by Changeaux and Conic (1987), whose findings suggest that neural growth is dependent on movement.

The impact of movement on neurological development has been proven in the above studies. Next, it is important to look at the specifics of how movement affects neurological structure, functioning, and processes. Movement stimulates several neurological processes that aide in brain function (Cotman & Berchtold, 2002; Heinze et al., 2020; Macedonia & Repetto, 2017; Nay et al., 2021; Vaynman et al., 2004; Won et al., 2021). Movement prompts neurogenesis through triggering the release of BDNF (Macedonia & Repetto, 2017). BDNF is a protein encoded by the BDNF gene (MedLine Plus, 2020), which is most highly expressed in the cerebellar and hippocampal regions of the brain (Camusso et al., 2022). BDNF is imperative for neurological functioning as it supports many neurological growth processes. Studies have connected BDNF and learning performance, providing evidence that BDNF promotes communication between neurons, synaptic connectivity and plasticity, learning, and working memory (Camuso et al., 2022; Cotman & Berchtold, 2002; Macedonia & Repetto, 2017; Nay et al., 2021; Vaynman et al., 2004).

Two studies on the relationship between exercise, BDNF, and cognition in rats showed promising results that could be applicable to human neurological functioning (Cotman & Berchtold, 2002; Vaynman et al., 2004). Cotman and Berchtold (2002) studied the potential benefits of exercise on BDNF, to see if it increased brain health and plasticity. They used "voluntary wheel running" (Cotman & Berchtold, 2002, p. 295) to avoid variables such as stress from forced exercise and designed the study to parallel human exercise studies. They discovered that after multiple days of exercise through voluntary wheel running BDNF levels increased in the hippocampus. The hippocampus is the area of the brain normally connected to cognitive function, as opposed to motor activity. This is important because it provides a direct connection between exercise and cognitive function. The results of Cotman and Berchtold's study suggest that the enhanced learning effects of exercise on the brain are most likely caused by BDNF as opposed to other neurotrophins. Vaynman et al. (2004) used a binding agent to block BDNF in the hippocampus of a group of rats and then measured them against an exercise group and a sedentary control group. They then gave the exercise group and the binding-agent group 1 week of voluntary exercise and measured the cognitive abilities of all three groups using the Morris water maze (MWM) test. Vaynman et al. (2004) discovered that the rats who had been given the BDNF binding agent performed similarly to the sedentary control rats on the MWM. The exercise group of rats found the platform faster, showing improved performance. These findings are novel because they show direct evidence of exercise enhancing cognitive function by increasing BDNF. These studies indicate “mechanisms that induce BDNF gene expression, such as exercise, can enhance learning” (Cotman & Berchtold, 2002, p.296). Since movement triggers BDNF, which enhances learning performance, one can conclude that movement enhances learning performance.

Some research has identified the mechanisms by which this effect is produced. In addition to increasing production of BDNF in the brain, physical exercise triggers a higher release of the neurotransmitter glutamate (Macedonia & Repetto, 2017). Glutamate is thought of as the foundation of the learning process, as it is essential to neuron communication (Heinze et al., 2020). Exercise increases growth in volume of two brain structures thought to be responsible for short-term memory and cognitive functions: the hippocampus and the entorhinal cortex (Macedonia & Repetto, 2017). Exercise also can increase brain tissue in the prefrontal cortex areas, which are connected to increased cognitive control and executive functioning. Increased exercise and cardiorespiratory fitness lead to cognitive function improvements, which Won et al. (2021) hypothesized could be due to increased integrity of the structural networks in the brain.

There is consensus among researchers that physical exercise and movement benefit brain functioning, facilitate neurological development, and increase cognitive performance (Cotman & Berchtold, 2002; Doidge, 2007; Feldenkrais, 1981; Fredericks et al., 2006; Heinze et al., 2021; Homann, 2010; Homann, 2020; Macedonia & Repetto, 2017; Porges, 2011; van der Kolk, 2014; Vaynman et al., 2005; Won et al., 2021). However, there seems to be disagreement regarding what specific types of movement most benefit neurological functioning and development. Won et al. (2021) evidence acute exercise (a single session of exercise, p. 925), cardiorespiratory fitness (CRF, defined as the body’s ability to send oxygen to large muscle groups during long-term exercise, p. 925), and resistance training as all having cognitive benefits. They also highlight recent studies which suggest diversifying the types of movement and exercise used in training has the highest cognitive impact. Heinze et al. (2020) compiled a literature review investigating connections between longer-term physical activity and cognitive performance. In the studies they reviewed, long-term exercise programs showed more benefit than short-term exercise programs because BDNF only increased when people were training at medium to high intensity levels, and it did not increase with the low intensity and stretching control groups. Heinze et al.'s (2020) findings in combination with those of Won et al. (2021) seem to suggest that diverse types of movement are best for increasing cognitive function, but medium-to-high intensity workouts should be a part of the diverse training program. A study within the literature review discovered that another growth factor called insulin-like growth factor (IGF-1) only increased with high intensity exercise. Heinze et al. also reference a study where 11-year-old children completed a 16-week Taekwondo training program and exhibited higher levels of BDNF and IGF-1. This information further evidences that high intensity exercise should be a part of the diverse training program mentioned above.

Fredericks et al. (2006) highlight a study done in 2002 which found that a "regular physical education programme" (p. 30) did not have a statistically significant effect on cognitive function. When children participated in a specifically designed sensory-perceptual movement program, there were statistically significant increases to cognitive function. Fredericks et al. (2006) cite a contradictory study by Corrie and Barrat-Pugh done in 1997 which yielded the opposite results. Corrie and Barrat-Pugh found that some perceptual-motor programs did not significantly improve cognitive function in any domain. The contrasting results in these studies points towards a need for further research into the specific types of movement and exercise programs will have the most effect on cognitive function and neurological development. In their own study, Fredericks et al. (2006) used four first grade classes and divided them into groups of experimental (developmental movement; a DMT concept surrounding natural developmental movement patterns) group, control group, free play group, and educational toys group. The results of their study provide evidence that developmental movement has a statistically significant impact on cognitive performance. Macedonia and Repetto (2017) point to many studies which find strong correlations between gestural movements and stronger cognitive performance.

Finally, there is some evidence that cognitive enrichment along with movement is important for enhancing cognitive function and neurological development. Dennis et al. (2014) discuss how exposure to cognitively enriching environments can help slow the rate of decline in individuals with degenerative brain damage (p. 2764). Kshtriya et al. (2015) look at the differences between how dance versus physical exercise impact cognitive plasticity in older adults. One of the key differences they discuss is that dance interventions provide more enrichment due to the inherent multi-modal nature of dance. Dance involves not just movement, but thought processes, creativity, coordination, balance, visuospatial skills, cognitive skills, memory skills, and much more. They completed a comprehensive review of the literature, and the results of their study showed improvement in cognitive functioning when individuals took part in dance programs; however, fluid intelligence only increased when individuals had several years of dance experience. Kshitrya et al.'s (2015) results allow researchers to infer that the combination of cognitive enrichment with movement is what makes dance so impactful on neurological development.

Nelson (1999) further evidences the connection between cognitive enrichment paired with movement and increased impact on neurological development by mentioning a study by

James Black and William Greenough on “acrobatic” (p. 423) rats. In this study, some rats were taught complex motor coordination tasks, some were given motor tasks that did not involve cognitive enrichment (wheel running, treadmill), and some were inactive controls. The acrobatic rats showed increased synapses per neuron in the cerebellum, where the inactive control rats and the repetitive motor task rats showed no such increase. Additionally, the acrobatic rats demonstrated significantly increased density of blood vessels in the cerebellum. Taken together, the results of Black and Greenough’s study show that cognitive enrichment paired with movement or exercise facilitates synaptogenesis to a significantly higher degree than simply repetitive exercise with no cognitive components.

DMT to Facilitate Neurodevelopment

Studies have shown that creativity in all forms supports cognitive processes (Beaty et al., 2016; Kounios & Beeman, 2009). Beaty et al. (2016) define creative cognition as “a set of cognitive processes that support the generation of new and useful ideas” (p. 87). In generating and evaluating creative ideas, people practice the cognitive skills needed for goal-directed, self-generated tasks required in daily life (2016). Homann (2010) confirms that creative exploration engages many levels of neurological functioning. Given this evidence, it is reasonable to infer, using the “neurons that fire together wire together” (Doidge, 2007, p. 63) concept, that creative exploration facilitates cognitive and neurological development.

Dance/movement therapy (DMT) is an excellent avenue for using movement to facilitate neurodevelopment and cognition because it combines creativity, movement, and a cognitively enriching environment, all of which benefit brain functioning. The American Dance Therapy Association (ADTA, 2020) defines DMT as “the psychotherapeutic use of movement to promote emotional, social, genitive, and physical integration of the individual, for the purpose of improving health and well-being" (para. 1). Dance and dance therapy promote neurological integration, support perceptual processing, and help coordinate neurological communication across the corpus callosum ("the network of fibers that facilitates communication between the right and left hemispheres of the brain" Faber, 2017, p. 175; Homann, 2010, 2020). Additionally, neurological development requires emotional regulation (Evangelista & McLellan, 2004) which is a key benefit of DMT (Homann, 2020). Finally, the key tenet of DMT is engaging the client at their level of readiness and capability (Levy, 2005) by finding the underlying needs and causes of issues clients are having and working with them on their level, targeting an intervention towards those needs. This approach reflects recommendations made by Fredericks (2006) that any movement program focus on root causes of developmental difficulties.

Developmental movement as defined by Susan Aposhyan is "the movement that naturally occurs in all humans as we develop toward maturity" (Kemble, 2019, 1:15). In recognizing these movement patterns, we are provided information on where an infant is developmentally, and how to facilitate further development (Burrill, 2011; Kemble, 2019; Loman & Merman, 1996). Each developmental movement pattern provides scaffolding for the next, solidifying the patterns and connections in the brain with each repetition. *The Moving Child III*, directed by Helen Kemble (2019), follows dance therapist Bonnie Bainbridge Cohen and others who practice her methods as they work with developmental movement in infants. Bonnie Bainbridge Cohen (2022) developed the Body-Mind Centering (BMC) method which integrates "the embodiment and application of anatomical, physiological, psychophysical, and developmental principles, utilizing movement, touch, voice, and mind" (para. 1). When using BMC in infants, the goal is to guide the infant towards reaching their fullest potential as who they are. Bonnie and the other BMC therapists do this by watching the infants move, looking to see if there is a movement pattern missing. Once those missing movement patterns are identified, the therapist plans interventions based on how they can support or encourage those missing patterns to facilitate development as is appropriate for each child. This is done by integrating earlier developmental patterns into intervention strategies to provide the proper scaffolding for the missing movement pattern. For example, if a baby isn't reaching then the therapist would work on the patterns of yield and push which are both skills used in reaching. All these developmental movement patterns build on each other, eventually leading to skills such as walking, and have a large impact on future learning patterns.

Ways of Seeing is another method for working with infants and children, which was developed by Suzi Tortora (2010). This method is based in attachment theory and uses dance, movement, and music, as well as Laban Movement Analysis (LMA) to foster appropriate individualized development. Tortora's method is based on how early experiences form memories within our somatic, sensory, and kinesthetic systems. These memories shape human development, learning processes, and cognitive processes. Tortora works with infants/children and their parents to facilitate matching communication styles between parents and their infants, thereby creating more healthy developmental experiences for the infant. Those healthy developmental experiences directly impact the infant's developmental trajectory, facilitating individualized appropriate neurodevelopment. This approach is echoed in a 2010 study researching mother/infant communication styles (Beebe, 2010). Beebe's (2010) study looked at infant responses to maternal communication and found that infants demonstrate more positive development when caregivers (in this instance, mothers) match their communication style to that of the infant.

The Kestenberg Movement Profile (KMP) is a method that uses movement patterns that match developmental stages to support developmental progress (Burrill, 2011, Loman & Merman, 1996). This method was developed by Judith Kestenberg over 30 years of work. Similar to Bonnie Bainbridge-Cohen's work with developmental movement, therapists using the KMP observe an infant's movement patterns to gain information on their unique development and apply specific rhythms, called tension-flow rhythms, to support appropriate development. Knowledge of these rhythms can show where developmental challenges lie and can assist the therapist in addressing those challenges.

Discussion

The purpose of this thesis was to take stock of the literature on how movement impacts neurological development, connecting existing literature and providing future recommendations for practice/study. I did this by completing an extensive review of the literature, focusing on infants aged 0-3. My findings indicate that movement paired with cognitive enrichment facilitates neurological development by increasing BDNF and other brain growth factors, increasing neurological integration between hemispheres, and providing the skill practice needed to advance to the next developmental stages. Additionally, movement can be used to scaffold developmental stages of infants, to help them progress successfully to the next appropriate stage. Taken together, this evidence strongly implies that dance therapy and movement can be used to facilitate neurological development across all domains in infants aged 0-3.

Infant development is an especially complex event, occurring across multiple interconnected domains (Dennis et al., 2013; Evangelista & McLellan, 2004; Nelson, 1999; Vehkavuori & Stolt, 2019; Wang et al., 2021). Neurodevelopment in infancy lays the foundation for all future development across all domains (Dennis et al., 2013; Nelson et al. 1999;

Vehkavuori & Stolt, 2019; Wang et al., 2021). Although the brain is plastic (Cotman & Berchtold, 2002; Dennis et al., 2013; Heinze et al., Macedonia & Repetto, 2017; 2020; Porges, 2007; Vaynman et al., 2004), it is important to provide infants with a strong developmental foundation so they can reach their developmentally appropriate goals.

Experience and culture play a heavy role in shaping an individual's neurodevelopment, starting before birth, and continuing throughout the lifespan (As et al., 2020; Chilton et al., 2007; Mills-Koonce et al., 2021; Muir & Bohr, 2019; Porges, 2007). As clinicians, when our goal is to facilitate individually appropriate development for our clients, it is important to not only recognize and examine the biological impacts on neurodevelopment, but the cultural, experiential, and societal impacts as well.

Movement facilitates neurodevelopment by increasing brain growth factors, increasing communication between hemispheres, and integrating multiple skills foundational for development (Cotman & Berchtold, 2002; Faber, 2017; Heinze et al., 2020; Macedonia & Repetto, 2017; Vaynman et al., 2004; Won et al., 2021). Movement paired with cognitive enrichment has the potential to have the highest effects on neurodevelopment and increasing brain growth factors, as evidenced by the acrobatic rats study detailed in Nelson (1999) and the study linking cognitive enrichment to decreased cognitive decline detailed in Dennis et al. (2013).

Dance/movement therapists have developed many methodologies for working with movement to facilitate development, including the Body-Mind Centering method (Kemble, 2019), the Ways of Seeing method (Tortora, 2010), and the Kestenberg Movement Profile (Burrill, 2011; Loman & Merman, 1996). Homann (2010; 2020) details how DMT integrates many modalities including verbal, cognitive, motor, and emotional into intervention strategies and increases cerebral functionality across hemispheres, facilitating appropriate developmental goals. Dance therapy's focus on working with individuals within their capacity (Levy, 2005) allows for highly adaptable interventions that can meet all needs and abilities.

Although the present results clearly support the use of movement and DMT to facilitate neurological development in infants aged 0-3, it is appropriate to recognize several potential limitations. Primarily, although there is a general consensus that movement positively impacts neurological development and functioning, there is disagreement about what types of movement most achieve this goal (Fredericks et al., 2006). That movement is essential is not disputed; it is how it is essential. Much work remains to be done before there is full understanding of which specific types of movement and exercise across which populations is most beneficial to neurodevelopment.

Additional limitations include that the focus of this study was on the broad population of infants aged 0-3 and did not look in detail into the nuances and variables that can exist within that population that may affect how movement would impact neurological development. Finally, while there is much research on the effects of exercise for neurological function in adults and older adults, there is less research regarding these effects in infants and children (Heinze, 2020). An interesting area of future study would be looking at movement level in infants and how varying levels of activity impact neurological function and development.

My final recommendation for future research would be to look at how dance and movement affect neurogenesis, neurodevelopment, and synaptic connections in individuals with neurological disorders affecting neural communication. Fredericks et al. (2006) point out the lack of studies using movement interventions to ameliorate learning difficulties and the conflicting results provided by the few studies that do exist. A particular area of interest for me is how movement would affect neural communication across brain hemispheres in individuals with partial or complete agenesis of the corpus callosum. During my research, I was unable to find any studies on this. If I were to do further research, that is a direction I would be very interested in following.

Despite these limitations, this study has enhanced my understanding of how movement impacts neurodevelopment, and how movement could be used to facilitate neurodevelopment in infants. I hope that current research will continue these important areas of investigation and will further enhance our understanding of these topics.

Conclusion

This literature review provided evidence of the connection between movement and neurological development, pointing towards the use of dance therapy with infants as a successful intervention to facilitate neurological development. DMT combines the neurological benefits of movement with cognitive enrichment and emotional regulation to create the prime conditions for neurological development. These exciting results lead to future research questions surrounding the use of DMT to help make up deficits brought on by neurological disorders affecting communication in the brain.

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In the judgment of the following signatory this thesis meets the academic standards that have been established for the above degree.

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