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Neuroplastic Properties of Dance: Exploring the Potential in Parkinson's Disease Rehabilitation

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It may be said: the brain that dances is changed by it. Although all types of human movement are complex, dance is possibly the most complex form of movement that humans engage in. The brain allows for this unique function by coordinating an intricate set of interconnected neurological structures. When activated through dance, these structures have the ability to change and become more efficient in their functions; referred to as neuroplasticity. In this way, dance has the potential to be used therapeutically to aid those suffering from various neurological disorders affecting similar areas of the brain, including Parkinson's disease: a degenerative disorder compromising the functions of the motor system. Engaging the damaged motor system through dance may aid in re-establishing its connections and movement related functions impaired by Parkinson's. This paper discusses the neuroplastic properties of dance training and rehearsal, and the potential it holds in rehabilitation of select damage to the motor system. It would be invaluable to explore how this form of rehabilitation may be applied to neurodegenerative diseases such as Parkinson's.

Dance is a universal human behaviour that has become an influential part of human life across cultures (Brown, Martinez, & Parsons, 2006). As an instinctive, rhythmic bodily movement, it is reflected in humans' ability to unconsciously move to the beat of music (Brown & Parsons, 2008). The brain allows for this unique function by coordinating a complex set of neurological structures. When activated through dance, these structures have the ability to change and become more efficient in their functions; referred to as neuroplasticity (Hanna, 2014). In this way, dance has the potential to be used therapeutically to aid those suffering from various neurological disorders including Parkinson's disease, which is a disorder compromising the functions of the motor system. This degenerative disease affects brain regions involved in the motor system including the motor cortex, substantia nigra, and basal ganglia. Neuronal loss and unorganized neural connections and firing in these areas induce the common symptoms seen in Parkinson's disease (Farrer, 2006). These symptoms include impairments in movement and mobility such as tremors, flexed posture, trouble with balance, shuffling steps and difficulty with stride, increased cadence, difficulty turning while walking, and moments of freezing or immobility (Hackney, Kantorovich, Levin, & Earhart, 2007). Engaging the damaged motor system through dance may aid in re-establishing its connections and movement related functions that are impaired by Parkinson's.

From the standpoint of cognitive neuroscience, dance is comprised of a fascinating set of features. These include complex movement, rhythmic synchronization, motor learning, and imitation (Brown, 2011). Those trained in dance come to possess an exceptional skill set including; high coordination, proper posture, balance, flexibility, perception, and patterned movement abilities (Hanna, 2014), skills that are often impaired in Parkinson's disease. These basic skills are also involved in many other aspects of life and may be significantly influenced by the detriments of Parkinson's, which include daily activities that require mobility such as walking, running, completing errands and chores, and self care. All of which may benefit from the complex nature of dance training.

Although all types of human movement are complex, dance is possibly the most complex form of movement humans engage in

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(Brown, 2011). Due to its complexity in cognitive and neurological features and acquired skill set, dance is poised to be the next wave in cognitive neuroscience (Brown, 2011). Researchers are turning to dance because it is a versatile activity that can aid in understanding which parts of the brain coordinate the body to perform intricate movements to music, and how their functions hold therapeutic potential in those who have been affected by brain damage (e.g., Bar & DeSouza, 2016; Hackney et al., 2007; Hänggi, Koeneke, Bezzola, & Jäncke, 2010).

As dancing is so complex, it engages a wide variety of interconnected brain structures. First, movement planning occurs in the frontal lobe, which includes the premotor cortex and the supplementary motor area (SMA). These structures also provide information about positioning in space and memories of movement (Hänggi et al., 2010). The sensorimotor network is responsible for the initiation of voluntary movement and houses the putamen and caudate nucleus of the basal ganglia (Hänggi et al., 2010). Signals from each of these areas are sent to the primary motor cortex, which then sends instructions to the appropriate muscles through the corticospinal tracts (Brown & Parsons, 2008; Hänggi et al., 2010). Finally, the cerebellum uses feedback from the body to refine specific movements (Brown & Parsons, 2008), which is partially how motor learning and training occur, among more complicated processes. Evidence suggests that this form of training directly modulates the brain structures involved (Hänggi et al., 2010). Through dance training, damaged connections within the motor pathways may be re-established and functions restored.

In order for the brain to change, there must be individual units capable of change. These units are referred to as neurons, which transmit information through voltage spikes that are converted into chemical signals (Hanna, 2014). All of movement, thought, and sensations emanate from these electrical and chemical impulses travelling through the brain's interconnected neurons. The brain is comprised of approximately 100 billion neurons, each connected to tens of thousands of neighboring neurons through synapses (Hanna, 2014), which act as relay sites for information. When these neurons fire electrical and chemical impulses together in a repetitive sequence, the connections between them grow stronger, which in turn impacts perception, comprehension, and memory consolidation and retrieval (Hanna, 2014). In this way, neurons can improve intellect, memory, and a wide variety of learning functions (Hanna, 2014).

Modifications to the brain such as these occur throughout life, and are especially influenced by the effects of early experience on brain development and damage through neural reorganization. Neuroplasticity is greatest early in life peaking at 2-years-old, where infants have 50% more synapses than mature adults, and are better able to either replace lost neurons or modify existing connections in response to damage (Hoshooley, 2015). However, in the adult brain, surviving neurons from damage still have the capability to reorganize, only at a slower, less efficient rate (Hoshooley, 2015). More efficient changes through neuroplasticity may be inferred from repetitive behaviours and rehearsal, such as dance training.

It may be said, "the brain that dances is changed by it" (Hanna, 2014). Recent research investigating the neuroplastic changes associated with motor tasks has shown that rehearsal results in an alteration of neural activity in several specific brain regions (Bar & DeSouza, 2016; Page, Szaflarski, Eliassen, Pan, & Cramer, 2009; Boyke, Driemeyer, Gaser, Büchel, & May, 2008). Generally speaking, during the learning process, neural activation follows an inverted 'U' pattern; beginning at a slow pace, accelerating to a peak at the midpoint, and finally returning to the original level once the task has been mastered (Bar & DeSouza, 2016). Demonstrating this concept, researchers Bar and DeSouza (2016) conducted a study measuring long-term neural changes that occur as one transfers from learning a motor sequence to becoming an expert. Professional ballet dancers' brain activity was measured at four time points over 34 weeks as they learned and perfected their choreography. The findings show that the rehearsal of the complex motor sequence initially increased activity within the sensorimotor cortex; only to have it decrease once the task had been mastered (Bar & DeSouza, 2016). This clearly demonstrates the inverted 'U' pattern of neural activation. However, this does not necessarily indicate that the region is no longer significantly involved in the process, but suggests that neurons within the required region have become more efficient by changing their connections.

In a similar study, Hänggi et al. (2010) investigated the neural structural correlates of intensive ballet training. In order to measure this, grey matter (GM) and white matter (WM) volumes were taken and compared between professional female ballet dancers and non-dancers. In trained dancers, decreased GM volumes were observed in the left premotor cortex, SMA, and putamen. Decreased WM volumes were also found in both corticospinal tracts (Hänggi et al., 2010). These findings complement the idea that experts in a particular motor task show reduced neural activity. These reductions in brain activity are accompanied by decreases in GM and WM volumes. Together, these studies paint a vivid picture of how dance may shape the brain's activity and structure. Neuroplastcity in the brain is associated with training and is learning dependent. Therefore, select damage to the motor system has the potential to benefit greatly from motor movement training in rehabilitation such as dance.

The ultimate goal in rehabilitation is to reacquire the ability to produce behaviours lost after trauma. In order to accomplish this, the remaining neuronal connections must be utilized (Bar & DeSouza, 2016). This is where neuroplasticity plays a large role in recovery. The basic rules governing how neural circuits adapt to learn new behaviours do not change after injury, as the brain will use the same processes it used to acquire those behaviours initially (Bar & DeSouza, 2016). Therefore, the neuroplastic effects seen in regular dance training may also enable motor improvement in therapy if these brain areas experienced trauma.

An example of such brain trauma and motor impairment is Parkinson's disease. This neurodegenerative disorder is partially caused by a loss and misfiring of neurons in the basal ganglia, responsible for the initiation of voluntary movement, and interrupts messages sent to the motor cortex. This loss of communication results in patients experiencing tremors, rigidity, and difficulty initiating planned movements (Brown & Parsons, 2008). Parkinson's is the most widely studied neural disorder for dance-based movement rehabilitation programs. A study conducted by Hackney et al. (2007) demonstrated how tango dancing improved mobility in those with Parkinson's disease. After 20 tango classes, patients had fewer moments of immobility or freezing, better balance, and a lower risk of falling as recorded by the researchers (Hackney et al., 2007). Although this study did not explore neuroplastic changes, it can be assumed that the brain was using the original learning mechanisms in order for the patients to execute, practice, and relearn movements. These learning mechanisms involve changing the structure and function of related neurons; which is a demonstration of neuroplasticity.

Another neuroplastic strategy used in dance rehabilitation for Parkinson's patients is the activation of mirror neurons. These specialized neurons are activated when watching a movement performed by another person that is perceived as familiar and executable by the individual (Berrol, 2006; Brown, 2011). These neurons behave as if the movement was actually being performed. This phenomenon is highly present in dance, as dancers often learn by imitating experts, which would imply that the neural circuits involved are well engaged. Thus in dancers, observation alone can stimulate the motor system (Brown, 2011). A study exploring this effect in those with Parkinson’s disease suggested that the basal ganglia may be involved in action observation as it showed similar activity to that of the same movement being executed (Alegre et al., 2010). Activating mirror neurons in the motor areas through dance observation may follow the basic principles of neuroplasticity by continuously activating the neural circuits, making them stronger. Using dance therapeutically provides an environment for the mirroring processes to take place (Payne, 2006), and allows for the potential neuroplastic benefits, including recovering lost or damaged behaviours such as initiation of movement.

Understanding what happens in the brain during both the learning and practicing processes involved with motor movement has provided insight into potential therapeutic strategies using dance, to assist those who have been affected by Parkinson’s disease (Bar & DeSouza, 2016). Dance is perhaps the most complex form of human movement, engaging many interconnected brain structures mainly in the motor areas of the brain. Movement training is able to modify these structures through neuroplasticity by employing repeated actions such as dance training. In rehabilitation, the brain relies on the same neuron modifying, learning mechanisms it originally used to learn the lost or damaged behavior. This is how dance therapy may aid those with Parkinson’s disease. By actively moving to music, following or watching an instructor may stimulate areas within the motor cortex, strengthening and improving connections and consequently motor functions. It would be invaluable to explore how this may also be expanded to other illnesses affecting both the body and the brain.

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