Rhythms of the Brain: Exploring the Intersection of Dance and Neuroscience

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Received September 29, 2024
Accepted February 16, 2025
Electronic access February 28, 2025

The effects of dance are different across different age groups. In elderly people, dance aids in preventing cognitive delays and improving quality of life. In middle-aged people, dance strengthens memory. In children, dance improves brain development in aspects such as creativity and motor memory. A systematic review is performed on the effects of dance on cognitive abilities across elderly, middle-aged, and pediatric populations. The importance of this is to analyze the differences between the populations as they are at different stages of their lives developmentally. In brain development, the repetitive aspect of dance can stunt motor cortical growth due to the procedural memory created by repetition. Some ways to improve this can be through different sequences of steps and the use of imagery to keep steps from becoming boring. This field is still new. Because of this, scientists must work through issues such as quantifying the effects of dance objectively. In the future, more memory testing should be done to truly analyze the impact that dance has on one's memory to see if it is better than the average non-dancer. When analyzing memory, there should be MRIs and participant testing in the same study to gain a better understanding of an experiment's impact. As well as further studying the impact of dance on helping with dementia-related symptoms and diseases.

Keywords: Dancing, Brain, Memory, Development, Cognition, Kinematics, Elderly, Middle-Aged, Children

Introduction

Dance is often used as a form of expression in exercise. It is a great type of aerobic exercise and can be seen as less monotonous and more engaging than other forms of exercise like walking or running. Not only is dance a great form of exercise, but it is also a way for people to improve their mental health as dancing releases endorphins [1]. Therefore, the present paper examined literature concerning how dance affects cognitive functions in populations of children, middle-aged, and elderly people. It is expected that the literature will contain evidence supporting the influence of dance on cognitive abilities over different age populations. There are many different types of cognition involved with dancing: attention, learning, and social.

Visual-spatial thinking is the ability to perceive the visual information in the environment, to represent it internally, to integrate it with other senses and experiences, to derive meaning and understanding, and to perform manipulations and transformations on those perceptions [2]. In dance, this is relevant when learning detailed choreography.

Another aspect of dance is repetition; with that, it has positives and negatives. A positive is that movements can become second nature through muscle memory leading the brain to do less work to execute the movement over time [3]. A negative is that once something is muscle memory, it takes more effort to correct it if learned improperly [4]. When a sequence of steps is repeated for an extended period, it becomes muscle memory and how it is performed is no longer of focus leaving limited room for improvement. This inhibits cognitive growth. A real-world example of this is driving; once one knows how to do it, they do not focus on how they can get better at it. Dance is analogous in that when the steps from a sequence are taken and put in a different order, it requires the brain to work and think about the steps more because it does not immediately know them. The question is: how do repetitive and varied dance movements affect cognitive function?

Other reviews [5,6] have analyzed the benefits of dance on the cardiovascular system and the nervous system together by tracking cardiovascular fitness alongside cognitive testing in perceptual speed, executive control, episodic, and long-term memory. This led to the finding that cardiovascular and cognitive fitness in dance improves the same as other forms of exercise. The current review is different because only the cognitive benefits of dance are analyzed in depth across different age populations to understand how dance can be of help to developmental processes and aging. Prior reviews also analyzed the basis of professional dancers and how they got to where they are as a result of training, performance, observation, and perception [5], whereas the present review adds to this literature by focusing on the effects of dance on ordinary people and how dancing can benefit them cognitively in the long run. These effects include improved mental health and a possibly reduced impact of age-related conditions

like dementia. This is different from professional dancers as the effects of dance to them are more extreme because they have trained significantly more than ordinary people to be professionals. The other reviews also mainly stayed on dance and did not connect much to the outside of it[6]. For example, with the connection between dance and memory that has been discussed, when analyzing ordinary people, there becomes an inquiry of whether dancing can positively impact the memory needed for routines or actions in everyday life.

This research came about due to curiosity about what happens in the brain when a dancer leaps through the air or balances on the balls of their feet for an extended time all while executing choreography via arms and steps between these specific movements. There is no single neural mechanism that allows dancers to do this, but rather a mix of neural mechanisms involved with motor control. This includes motor skill acquisition, coordination, practice, and muscle memory[4], which are all involved with repetitive vs. non-repetitive movements, and the impact that creating a procedural memory has on brain development[3]. Cognitively, dance affects people of different ages differently because the brain itself is developed at various ages.

Methods

Screening for the Systematic Review

The PRISMA Flow Method[7] was used to determine the papers studied and the exclusion criteria (see Fig 1). Two databases (PubMed and Web of Science) were used to retrieve articles for the current review. Forty-four total records were found with 5 overlapping across the two databases leaving a total of 39 unique records found. They were all screened for eligibility and 20 were excluded for various reasons. Systematic reviews (n=5) were excluded as this paper is one and should not have summarized information twice. Records discussing dance as a social event instead of a form of exercise (n=2) were excluded because the cognitive benefits in that situation were not studied. Records studying dance as a word (n=1) were excluded. Lastly, records that were not about the effect of dancing on human cognitive abilities (n=12) were excluded. No studies or reports were included as they were not found in the search results. PRISMA flow diagram[7] was used to model this method in Fig 1.

In Table 1, the 5-column structure is nonstandard and is done to look at class, separate populations of different age ranges (elderly vs. non-elderly), sex, and study methods. The class was determined by whether the paper was assessing cognitive function in an age population (class=1), repetitive movement (class=2), or both (class=1 & 2). In many of the studies, there are various methods of collecting data whether it be verbal or motor testing of participants in the study at the beginning or MRI to analyze the parts of the brain for improvement.

Literature Review

Age

The importance of studying the effect of dance across different ages is because people are at various points in their lives and development, so dance affects them all differently; it makes children more aware of their bodies[16] and fosters creativity[15], a key developmental need. In middle-aged adults, dance strengthens motor memory[4]. This can be seen through increased gray and white matter volume changes[13]. The first problems that typically arise with aging are the weakening of the connectivity in the brain[3]. Dancing for elderly people is a way for them to socialize and exercise physically during lonely times[1] while also exercising mentally by having to comprehend, execute, and retain choreography[8]. Dancing can also improve dementia-related symptoms through the cognitive challenges that it provides[3].

Elderly

Preventing Cognitive Delays: Elderly people, ages 65-90, who were involved in a dance intervention study showed an increase in gray matter volume in areas associated with working memory, long-term memory, and attention. The intervention was led by a qualified instructor over 6 months, 2 times a week for 90 minutes, and it was divided into two blocks, each lasting three months. Each block had five genres of dance: line dance, jazz dance, rock 'n' roll, Latin-American dance, and square dance. The second block was more difficult than the first with more complex choreography in a faster time. The control group was participants who performed the same exercises repeatedly (ex. bike-riding). There were also changes in white matter, significantly in the corpus callosum in the dance group. The increases help the brain with cognitive processes. The white matter increase can improve the efficiency of neurons in gray matter and the gray matter increases allow for stronger cognitive functions. These changes strengthen the connection between the two hemispheres of the brain which commonly degrade with age. While the amount of gray and white matter volume was greater in the dance group than in the repetitive exercise group from the MRIs, there were no significant differences in cognitive function in all areas[10]. Movement also activates the hippocampus which is typically the first thing to deteriorate in elderly people with dementia[11].

Quality of Life: Dance reduces stress which helps reduce the risk of depression and anxiety because elderly people, ages 65 and over, develop this due to the onset of age-related illnesses[1]. A common phenomenon in elderly people is loneliness and with dance classes or groups, they can find a community of people and form relationships. In a few studies, dance was not the best form of exercise due to certain problems with study formatting[10], but dance can still improve their overall moods leading them to live a happier and healthier life. It is a better alternative

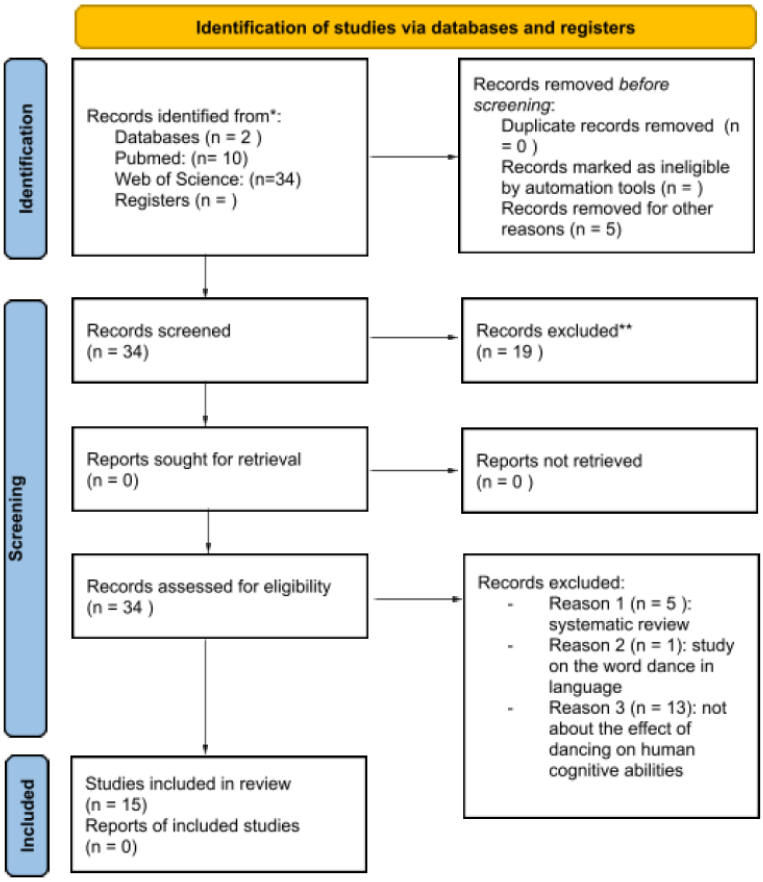

Fig. 1 Prisma Flow Diagram

than elderly people doing nothing or simply not knowing what to do with their time. Many times, excercises like walking or running are boring and it is hard to find a variety within that type of exercise[3]. With dance, there are many different levels and styles to choose from making it difficult to get bored leading to a longer commitment to exercise from people in general, but more specifically the elderly due to proneness to loneliness[1].

Middle-Aged

Memory: One aspect of middle-aged individuals, ages 20-28, impacted by dance is motor memory. It has been demonstrated that professional contemporary dancers were tested on how well they knew dances from decades ago. The goal was to remember the dance fully with all the details and have the steps in the correct sequential order. Music was purposefully left out of the study, so the dancers would not have audio cues to trigger their memory. The type of piece with the greatest recall was duets fitting with the hypothesis that the presence and actions of other dancers provide social cues for recall[4]. Social cognition, the perception of the behaviors of others, is very strong in dancers and often helpful and necessary to them when remembering choreography because they have to be able to play off their peers' emotions and movements when performing in a group setting. Even in middle-aged non-dancers, aged 23-32, social cognition is strong with a beat, a study found that participants, in a club environment, pick up on each other's movement cues when the music is popularly known among the group[14]. The hippocampal formation (HF) is involved with various aspects of memory. In a study with professional dancers and slackliners, ages 17-33, HF-dependent configural learning was better in the trained subjects than in the controls (leisure activity group). This means that the spatial memory within the professionals was better because they had to perform in groups on small stages without bumping into each other[13]. Later on, in the lives of these adults when they become elderly, the question could be asked because of their strong memory due to dancing, could these dancers be less likely to contract dementia or have issues with memory loss?

Class	Study	Population	Sex	Study Method	Summary
1	Banio, Adrianna (2020)[1]	Elderly (>65)	M & F	Survey containing questions about the influence of dance on participants' lives	How Latin dance can improve the quality of life for the elderly. Many chose dance because it was a fun social activity to stay fit and combat loneliness.
1	Godde et al. (2016)[8]	Elderly (65-82)	F	6-month dance program with cognitive and respiratory testing afterward	Dance may not be superior to other physical activities if the relative fitness level is the same, but it can be an attractive and fun way to exercise when compared to walking and stretching.
1	Fanning et al. (2021)[9]	Elderly (∼65)	M & F	MRI (T1 weighted images, which detect subtle changes more easily to deduce white matter integrity) and cognitive assessment	White matter plasticity measured as a change in the T1w/T2w signal is relevant for episodic memory processes in the dance and walking group.
1 & 2	Brigadski et al. (2018)[3]	Elderly (63-80)	M & F	MRI (T1 weighted image & Voxel-Based Morphometry) made it possible to directly compare the effects of one intervention vs the other (dance vs sport) on gray and white matter structures.	Dancing can intensify the connection between both cerebral hemispheres which is commonly degraded with age because it uses more cognitive resources than a procedural memory associated with biking or walking. This was found through a dance intervention program focused on learning new movements and choreographies versus a sports group.
1	Cooke et al. (2018)[10]	Elderly (60-80)	M & F	Brain Modularity- testing the hemispheres of the brain and their connectivity to each other	Inconsistent dance intervention program led to no cognitive improvement.
1	Chan et al. (2015)[11]	Elderly (65-90)	M & F	Cortisol levels, neuropsychiatric, cognitive, and daily functioning testing	A clinical trial using a dance movement intervention program to investigate different types of exercise's effect on dementia. It is expected to find an association between cortisol levels and neuropsychiatric, cognitive, and daily functioning, in addition to psychosocial measures. (lacked published results)
2	Karin, J (2016)[12]	Middle-Aged Adults (N/A)	M & F	N/A	Ballet dancers do not fully understand their bodily anatomy making it difficult for them to apply corrections to improve stunting their motor learning. The use of imagery can be used to develop a stronger understanding of the task.
1	Binetti et al. (2011)[13]	Middle-Aged Adults (17-33)	F	MRI (Voxel-Based Morphometry, VBM)	A VBM was performed and there was found to be smaller gray matter volume in the anterior HF and insular cortex in trained subjects (dancers & slackliners) vs the control (minimally active).
2	Old et al. (2019)[4]	Middle-Aged Adults (20-28)	F	Motor memory assessment	Long-term memory is strongest in dancers when they have a partner to remember the routine with.
2	Berson et al. (2016)[14]	Middle-Aged Adults (23-32)	M & F	Cluster Phase: measuring individual movement over time vs. average movement of the group in time measuring the degree of movement synchrony across the whole group	Used a running belt with a mobile phone on individuals in a club environment to analyze group synchrony of movement resulting in more synchronous torso movement with popular songs and songs with a pulsation of 100-150 bpm.
1	Petrenko, N.B. (2016)[15]	Children (4-6)	M & F	Classes and then assessing improvement after	Children can learn to move to music rhythmically, developing memory and attention.
1	Boccia et al. (2019)[16]	Children (6-10)	M & F	Execute different cognitive tasks (ex. Make a topological map)	Dancers have more body awareness improving motor divergent thinking.

Table 1 Study Details

Children

Development: Children who dance learn to become more aware of their bodies improving motor-divergent thinking. In a study about visuospatial thinking and motor benefits of dance, the children, ages 6-10, were asked to execute different tasks using their bodies such as performing different stances (e.g., football, cleaning, athletics) and creating a topological map of the body. The results showed that the dancer group was more aware of their body defending the hypothesis that dance improves motor divergent thinking and body awareness, but does not significantly improve visuospatial thinking [16]. Through dance and learning choreography, children with speech disorders, ages 4-6, can improve upon them by using the right side of their brain in these classes to be able to feel the musical rhythm and work their short-term and long-term memory through the memorization of dance moves and the terminology involved with dance. They do this by developing the nervous structures and improving the psycho-physiological properties and cognitive functions. Moving to music helps to develop memory, attention, thinking, and imagination [15].

Repetitive Movements vs. Different Sequence of Movements

Repetitive movements or activities are difficult to improve when the same sequence of steps or moves is done consistently. In the sports group of the superiority dance training study, the routines did not require subjects to be in conscious control. They could perform the tasks automatically creating a procedural memory requiring less cognitive resources because it is the same thing [3]. For example, in ballet dance, class starts with a warmup at the bar, and dancers do the same sequence of pliés in 1st, 2nd, 4th, and 5th positions with the same arms. After a while, one no longer has to think about what they are doing. The use of imagery can aid in fueling focus when dancing. For example, a dancer can think of jumping over a puddle to give meaning to a step [12]. When the sequence of steps is still the same, but in a different order, or a slight detail like an arm is changed, the brain has something to think about improving and making sure it is correct in the sequence of steps [4].

Discussion

This paper reviewed the cognitive benefits of dance across different ages and analyzed the effects of repetitive movement vs. non-repetitive movement. There were varying results due to the developing field making it difficult to synthesize results. As a systematic review paper, the studies included in the present review reported correlations, and therefore causal mechanisms of cognitive effects of age populations on dance remain unclear. While some studies have shown positive effects, it is important to note that these effects may vary depending on factors such as age, dance experience, and individual differences [10]. Some studies may not adequately control for confounding variables, such as differences in lifestyle, diet, and stress levels, which could influence cognitive function. Many of the papers did not set up their experiments to cater solely to cognitive abilities and because of this, it makes it difficult to analyze results that were not looking for connections to memory specifically. Because many of the sample sizes reported in the studies presented are small, their findings may not generalize to larger samples. A lot of things were not as concrete as commonly found in research. For example, in the clinical trial, it was discussed that dance could help the symptoms of dementia [11], but not necessarily fully proven which is understandable as this is a newer field of study with complex connections. In the Senior Dance Experience, there were certain benefits such as attentional performance, stronger balance, and motor fitness were better in long-term dancing, but the study did not include tasks that could further test that objectively instead of subjectively [8]. There were inconsistent results across studies because of the differences in the number of groups [3,10]. They found varying amounts of brain hemisphere connectivity between dancers and non-dancers. They split the groups on different criteria as well which could be an explanation for the varying results. One paper [8] divided the population between a dance and a sports group that did repetitive exercises with weights. The other paper [10] divided the population between dance, walk, walk and supplement, and stretch, strength, and stability. These papers compare dance to two different types of repetitive exercise which explains the varying results (walking to dancing vs. gym exercises to dancing). It was also difficult for researchers to streamline the dance group to be at the same level of exercise or quantity of people as the other exercise groups included in the studies. This skewed the dance group to have unfavorable outcomes [10]. Dance may not be superior to other physical activities if the relative fitness level is the same, but it can be an attractive and fun way to exercise [8]. In the future, there could be more focus on the cognitive aspects of dance in testing memory skills. Many methods used in the studies mentioned analyzed the cognitive aspect of dance through MRIs and gray and white matter increases inferring that these could be a result of dancing while only one study with trained professional dancers tested their memory and retention [4]. There needs to be more studies analyzing this motor memory and retention process learned in dance on normal people that participated in the dance intervention study. When analyzing the memory, combining MRIs and participant testing in the same study could be used to gain a better understanding of a study's impact. There should also be studies conditioned to analyze the long-term cognitive effects of dance as individuals age. The longest studies analyzed here were 6 months long. As well as further studying the impact of dance on helping with dementia-related symptoms and diseases. Dance is a powerful form of exercise with many benefits such as strengthening the

connection between brain hemispheres and creating more body awareness. With additional research on this topic, insights can be gained as to how dance can create positive changes. Some of these may include increased exercise due to dance being enjoyable and easier day-to-day activities in people's lives such as playing with family and climbing stairs. Overall, Dance has the potential to cognitively improve the lives of many people of all different ages.

Acknowledgments

Thank you to my mentor Kazutaka Takahashi and Lumiere Research Program for their patience and guidance when writing this paper.

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