Comparing Executive Functions in Dancers Versus Aerobic Exercisers: A Study on Older Adults

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Abstract

Many older adults may experience cognitive decline with aging, and with a rising aging population it is important to investigate interventions that improve cognitive functions. The purpose of this study was to assess differences in executive functioning between older adult dancers and older adult aerobic exercisers. Given that dance involves the use of executive functions, in addition to engaging in aerobic exercise, older adult dancers were expected to score higher on the executive functioning tasks than the older adult aerobic exercisers. Using the Cambridge Brain Sciences Battery to assess executive functioning, this study sought to compare older adults, 50 years old and above, with 10 or more years of experience in dance or aerobic exercise and a control group with less than or equal to 1 year of experience in these activities. Because no participants were available for the aerobic exercise group, the study simply compared two older adult dancers with six older adults in the control group. A one-way between-groups analysis of variance indicated that the dance group and the control group did not differ significantly on any executive function measures. Specifically, the dance group and the control group did not differ in inhibitory control, planning, or working memory. However, these findings need to be interpreted with caution as the low sample size in both groups resulted in the study to be underpowered. Therefore, it cannot be definitively concluded that dance is not associated with higher cognitive functioning compared to the control group or the aerobic exercise group.

Keywords: Older adults, executive functions, dance, aerobic exercise

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Comparing Executive Functions in Dancers Versus Aerobic Exercisers:

A Study on Older Adults

Canada is entering uncharted territory; within the next 20 years, the older adult population, aged 65 and above, is expected to increase by 68% (Canadian Institute for Health Information, 2017). As adults age, many begin to experience cognitive difficulties, and some may develop dementia. In 2014, over 402,000 Canadians aged 65 years and older were living with dementia (Public Health Agency of Canada, 2014). The annual health care costs for 2031 are projected to double for Canadians with dementia compared to the past 20 years, from $8.3 billion to $16.6 billion.

Some of the first cognitive abilities to decline with dementia or normal aging are executive function abilities (Christensen, 2001). Executive functions are a set of general cognitive mechanisms that are responsible for goal-oriented manipulation of information in working memory, and for switching between several tasks or pieces of information (Hedden & Gabrieli, 2004). For example, managing medication or preparing meals are activities of daily living that strongly rely on executive functions (McDougall et al., 2019). Therefore, executive functions are pivotal for older adults to live independently and maintain a good quality of life.

Because of a growing aging population, there has been a recent surge of interest in examining activities that may enhance cognitive functions with aging. One of these is aerobic exercise (i.e., cardiovascular training), which has been associated with increased cognitive functioning (Christie et al., 2017; Falck et al., 2019). Another activity that has gained interest among researchers is dance. Dance involves the use of executive functions over and above aerobic exercise, thus researchers are interested in examining whether dance can enhance cognitive functions (Hwang & Braun, 2015; Meng et al., 2019). However, the specific cognitive functions that aerobic exercise or dance may improve are not well-understood. Furthermore, few studies have examined whether dance has a greater effect in improving cognitive function in older adults than aerobic exercise. The present study aims to address the above two gaps in the literature.

The following sections discuss how aerobic exercise and dance may influence cognitive function through the development of a cognitive reserve. Then, studies that have demonstrated a relationship between aerobic exercise or dance on cognitive function are introduced and critiqued. After, three studies that compared the impact of dance and aerobic exercise on cognitive function are examined. Finally, the aims of the present study will be reviewed.

Cognitive Reserve Through Aerobic Exercise and Dance

Cognitive changes are a normal component of aging, but not all cognitive abilities change the same way (Harada et al., 2013). Some cognitive abilities, such as verbal reasoning, remain intact or even improve with age. In contrast, other abilities such as memory, processing speed and executive functions, gradually decline over time. Although most older adults experience cognitive decline with normal aging, some can halt or delay their cognitive decline. According to Cognitive Reserve Theory, earlier and continued involvement in certain activities may prevent or delay age-related cognitive decline by maintaining and/or increasing cognitive functioning (Stern, 2002). This theory posits that having higher levels of education, participation in exercise, being socially engaged and having higher socioeconomic status may prevent or delay normal brain aging by building up a cognitive reserve (Fotenos et al., 2008; Scarmeas & Stern, 2003). In other words, the higher the cognitive functioning an individual has, the more cognitive reserve they are thought to exhibit. And the more cognitive reserve a person exhibits, the longer it takes to see functional deficits caused by aging or dementia.

A number of theories have been proposed to explain how aerobic exercise helps develop cognitive reserve. For instance, aerobic exercise is thought to improve brain health through its positive effects on the cardiovascular system such as increasing cerebral perfusion (i.e., blood flow to the brain) (Ainslie et al., 2008; Churchill et al., 2002; Rogers et al., 1990), which promotes neurogenesis and synaptogenesis (Bugg & Head, 2011; Kleim et al., 2002). Moreover, through increased cerebral perfusion, aerobic exercise may also increase brain-derived neurotrophic factors, which play a role in neurogenesis (Ferris et al., 2007; Vaynman et al., 2004). Neurogenesis, which is the formation of new neurons, plays an important role in maintaining cognitive function and repairing damaged brain cells caused by aging and brain pathology (Poulose et al., 2017). Synaptogenesis is the formation of connections between neurons that are important for establishing neural networks (Cohen-Cory, 2002). Thus, neurogenesis and synaptogenesis are viewed as important processes for optimal brain aging.

Similar to aerobic exercise, dance is also believed to play a role in healthy cognition (Muller et al., 2017). Not only can dance impart the same benefits as aerobic exercise, but it may also confer unique cognitive stimulation. For example, dance requires an individual to hold multiple complex movements in working memory, and then plan a movement to occur at a specific time. It also requires an individual to direct their attention to the dance instructor while navigating various other sensory information, such as music and body movements. Thus, dance involves using executive functions (i.e., directed attention, working memory and planning), in combination with aerobic exercise, which is expected to provide a rich environment for the brain and promote neuroplasticity (Muller et al., 2017). Neuroplasticity, the brain's ability to rewire itself, can help an individual recover from injury and adapt to new environments (Kays et al., 2012). Thus, neuroplasticity may allow an individual to efficiently allocate their cognitive resources to meet new challenges and/or compensate for deficits in cognitive functioning.

Because dance involves the use of executive functions over and above aerobic exercise, dance may be more promising than aerobic exercise for improving cognitive health. In summary, aerobic exercise and dance may confer positive physiological benefits, which may increase cognitive functioning, and in turn may lead to a higher cognitive reserve. However, the majority of the studies on the effects of aerobic exercise or dance on cognitive function have employed global cognitive measures or mainly focused on physical improvements. Furthermore, there is a lack of comparison between dance versus aerobic exercise; of the studies that have compared dance and aerobic exercise, many were short-term.

The Impact of Aerobic Exercise on Cognitive Function

Many longitudinal and randomized control trials have supported the idea that participation in aerobic exercise may enhance cognitive health for older adults (Flack et al., 2019). For instance, a longitudinal study conducted by Yaffe et al. (2001) followed 5,925 community-dwelling women for 6-8 years. They found that women with higher daily levels of walking were less likely to display cognitive decline, as measured with the Mini-Mental State Examination (MMSE). Another longitudinal study conducted by Dik et al. (2003) measured the processing speed of older adults using the Alphabet Coding Task-15 and compared it with their activity levels when they were between 15 and 25 years old. Participants who reported higher levels of physical activity earlier in life showed greater current levels of processing speed. Moreover, a study by van Gelder et al. (2004) reported the benefits of physical activity later in life. Older adults who increased or maintained their physical activity later in life were approximately four times less likely to experience cognitive decline when assessed through the

MMSE. Although these studies demonstrate that engaging in physical activity throughout the lifespan may help in providing a cognitive reserve in older adults, they heavily rely on global measures of cognitive function. For example, a majority of these studies employed the MMSE, a global measure of cognition, which is specifically used to diagnose if one has mild cognitive impairment. It may be more worthwhile to use specific cognitive measures, such as executive function measures, because they are more sensitive in detecting whether older adults can perform their activities of daily living (McDougall et al., 2019).

The Impact of Dance on Cognitive Function

While much of the literature on aerobic exercise administered global cognitive measures rather than specific measures, most of the research conducted on dance examines whether it improves physical function, such as balance and proprioception. There is limited research that examines whether dance can improve cognitive function in older adults, but a few studies show some promise. For example, Kattenstroth et al. (2013) conducted a randomized control trial for six months with 25 older adults in a dance group and 10 older adults in a non-active control group. In the dance group, participants were taught Agilando — a special dance program developed for older adults – for 1 hr per week. The participants in the dance group showed greater improvement in attention and memory (i.e., immediate and delayed recall) than those in the control group. Another study by Wang et al. (2020) examined the effect of Chinese square dancing on the cognitive function of older adults with mild cognitive impairment using the MMSE. The study was a non-randomized control trial with 33 older adults in the dance group and 33 older adults in the control group, and it took place over 3 months. The participants in the Chinese square-dancing group showed significant improvements in their cognitive function compared to those in the control group. Additionally, Coubard et al. (2011) compared a contemporary dance group (*n* = 16), a fall-prevention group (*n* = 67) and a tai chi group (*n* = 27) on attentional control using the Stroop and Wisconsin Card Sort Task. Training in each group lasted for 5.7 months. The results indicated that only older adults in the contemporary dance group exhibited improvements in attentional set-shifting.

Taken together, the above findings suggest that dance may be an encouraging intervention that could be used to improve cognitive function in older adults. In addition, it may be appealing to older adults because it can be performed in relaxed or pleasant settings (e.g., a park) and has the potential for social engagement (Meng et al., 2019). Interestingly, the majority of the studies that examined the effect of dance on cognitive function in older adults did not assess whether dance produced a greater effect on cognitive function than aerobic exercise. Instead, they simply compared results from a dance group with those from a passive control group.

Comparing the Impact of Dance and Aerobic Exercise on Cognitive Function

Because dance is a complex physical activity that involves the use of executive functions more than aerobic exercise, it may have a greater potential for improving cognitive function than aerobic exercise. Understanding which activities offer the most benefits can be relevant for health promotion and preventative efforts. However, to date, only three studies have directly compared dance with aerobic exercise.

One was a randomized control trial conducted by Muller et al. (2017) in which healthy older adults were assigned to a dance group (*n* = 12) and a sports group (*n* = 10) for 18 months. The dance group involved doing a combination of dance styles, such as line dancing, jazz, rock and roll, and square dancing, while the sports group engaged in strength training and aerobic exercise. The researchers ensured that the amount of aerobic exercise between the two conditions was equivalent. With regard to outcome measures, the researchers examined gray matter volume changes and administered cognitive tests, including a verbal short-term and long-term memory test and an attention battery. After 18 months, it was found that the older adults in the dance group displayed gray matter volume increases in the parahippocampal gyrus. However, no differences in cognitive function emerged between the two groups, potentially because of the low sample size. Notably, both groups displayed improvements in attention after 6 months and in verbal memory after 18 months. It appears promising that older adults in the dance group displayed a larger gray matter volume than those in the sports group in a region generally associated with memory. Nevertheless, the researchers missed an opportunity to administer executive function measures for the cognitive tasks, as dance involves the use of many executive functions. Executive function measures are highly predictive of older adults performing their activities of daily living and are thus favourable measures for assessing their cognitive function (McDougall et al., 2019).

Another study that compared dance and aerobic exercise directly was a randomized control trial done by Merom et al. (2016), who assigned healthy older adults to a ballroom dance group (n = 60) and a home walking program (n = 55) for 8 months. The researchers administered executive function measures such as the Stroop Colour Word Task to assess inhibitory control. Contrary to predictions, no differences between the groups emerged on the cognitive tests. The researchers suggested that this could have resulted from attrition in the dance group or that the dance intervention was too short-lived. Similar results were found by Esmail et al. (2020) who conducted a randomized control trial in which healthy older adults were assigned to a dance/movement training group, an aerobic exercise group, and a non-active control group for 12 weeks. The dance group involved doing expressive movements and guided gestures while the aerobic exercise group trained on a seated bicycle (i.e., three times per week and 1 hr per session). For the cognitive outcome measures, Esmail et al. (2020) assessed executive functioning using the Dual-Task, the N-back Task, and the Digit Stroop Task. The researchers found no significant differences between the groups. Most dance intervention studies, like the studies above, are limited to approximately 1 year of intervention; thus, it may have been difficult to detect any significant improvements in cognitive function. Given these findings, the question of whether dance can bolster cognitive function in older adults remains equivocal.

Present Study

As mentioned above, few studies have examined which specific cognitive functions are affected by aerobic exercise or dance, and also few studies have tested whether dance is associated with higher cognitive functioning than aerobic exercise. In light of these limitations, the present study aims to compare long-time older adult dancers with long-time older adult athletes (e.g., runners, rowers, swimmers, and bikers) who still currently engage in these activities. This aligns with the testing of the cognitive reserve hypothesis which states that earlier and continued involvement in some activities is associated with greater cognitive functioning. In this study, randomly assigning individuals to a dancing condition versus an aerobic exercise condition for several years is not practical. Therefore, dancers and participants from physical activity groups with over 10 years of experience and who are over 50 years of age were recruited. Furthermore, individuals with no more than 1 year of experience in either activity were included in the control group. Because the majority of previous studies on dance are limited to approximately 1 year of intervention, I was interested in understanding whether an advanced dancer would display enhanced executive function when compared to an advanced athlete who engages in aerobic exercise (e.g., runners, rowers, swimmers and bikers).

To measure specific, rather than global cognitive functions, the Cambridge Brain Sciences battery was used (Hampshire et al., 2012). The Cambridge Brain Sciences battery, a web-based neurocognitive assessment, measures cognitive functions such as executive functions, which are an accurate predictor of seniors performing their activities of daily living (McDougall et al., 2019).

Finally, because dance involves the use of executive functions, in addition to engaging in aerobic exercise, it may have a greater potential for improving cognitive function than traditional physical activity training (e.g., running). Thus, the present study examined the following research question: Is dance associated with better executive function than aerobic physical activity in older adults? The present study predicted that long-time older adult dancers would be associated with greater executive functioning than long-time older adult athletes who engaged in aerobic exercise.

Methods

Participants

Eight English-speaking healthy older adults, 50 years old and above, with normal or corrected to normal vision were recruited from the local London community (e.g., community centres and dance studios). There were six females and two males, ranging in age from 52 to 72 years old (M_{age} = 61.63, SD = 6.35), and they were compensated with $5 for their participation.

The dance group consisted of two female participants (M_{age} = 62, SD = 1.41); one participant only had training in ballroom dancing and the other participant had training in both ballroom and hip-hop dance styles. The participant with only ballroom dance training had 21 years of experience and trained for 6-15 hrs per week while the participant with both hip-hop and ballroom dance training had 20 years of experience and trained for 2-5 hrs per week. Moreover, the ballroom-only dance participant had completed high school education while the hip-hop and ballroom dance participant had completed an undergraduate degree.

Unfortunately, no participants had aerobic exercise training in rhythmic sports (i.e., running, cycling, swimming, or rowing). Rhythmic sports are activities which involve a consistent rhythm that does not change with music. Participation was restricted to individuals with rhythmic sports training because dance training involves varying rhythm, and this may have controlled for the effect that rhythm has on cognitive functioning (Schwanz, 2020, personal communication, February 9, 2021).

The control group consisted of six individuals (two males and four females) who had less than 1 year of experience and training in dance and rhythmic sports (M_{age} = 61.50, *SD* = 7.48). Three of the control participants had a college level of education, one participant completed an undergraduate degree, and two participants had completed graduate studies.

Inclusion and Exclusion Criteria

To be included in either of the dance or aerobic exercise groups, participants needed to have training in dance or rhythmic sports. Training included either engaging in professional or recreational classes (a minimum of 1 hr class per week), taking private lessons, training individually, training with team members, and/or performing in competitions at a beginner or advanced level. One year or less of participation in dance or aerobic exercise training, such as training in a physical education class, was not considered relevant experience and these participants were included in the control group.

Participants who self-reported less than 1 year of experience in dance or aerobic exercise training were included in the control group. Also, participants who reported being part of a class that was not focused on one activity (e.g., an elementary or high school physical education class), were not considered as having relevant training and so, they were also included in the control group.

Participants who self-reported having neurological (e.g., Parkinson's disease, Alzheimer's disease, a concussion, stroke, brain tumours), or psychiatric conditions (e.g., major depression, attention deficit/hyperactivity disorder, schizophrenia, somatoform disorder) were excluded. Participants were also excluded if they reported using psychoactive medication that affected mental performance. The study was approved by Western University's Research Ethics Board (see Appendix A).

Materials

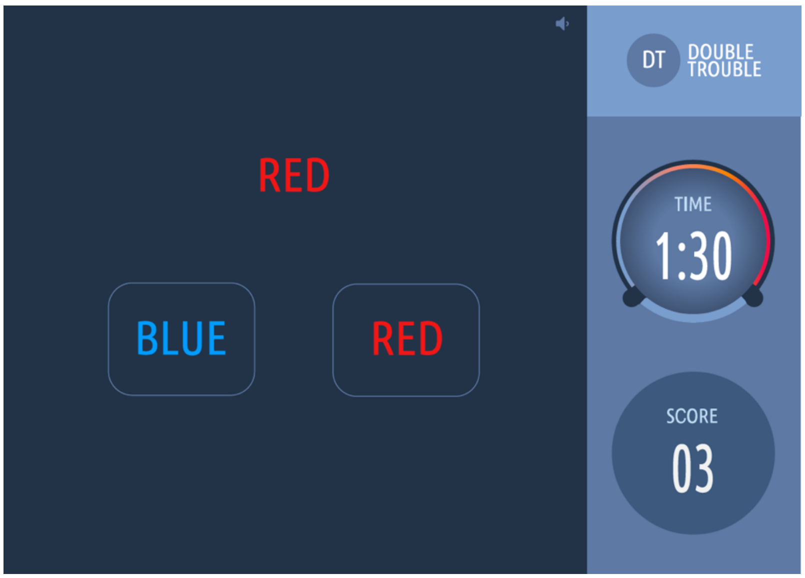
Cambridge Brain Sciences Battery

The Cambridge Brain Sciences Battery (CBSB), a web-based neurocognitive assessment, was developed from well-validated psychological measures (Hampshire et al., 2012). Four tasks from the CBSB, each measuring a different facet of executive functioning, were used for this study. The details regarding the four tasks and the executive function constructs they measure (i.e., inhibitory control, working memory, planning) are described below.

Double Trouble Task. This task is a modified version of the Stroop test, which is used to measure inhibitory control (i.e., participants inhibiting the natural tendency of reading the written words versus stating the font colour of the words) (Stroop, 1935). In this task, three coloured words are shown on the screen (i.e., one at the top and two at the bottom). Participants had to correctly choose which of the two words displayed on the bottom of the screen described the colour of the font of the word written at the top of the screen, regardless of their own font colour. The trials included congruent, incongruent, or doubly incongruent colour word mappings based on whether the font colour of the top word matched the written word and whether the font colour of the two choice words matched the written words. The scores of the participants were calculated based on how many problems they solved within 90 s. A sample trial from Double Trouble is presented in Figure 1.

Figure 1

A Sample Trial from the Double Trouble Task.



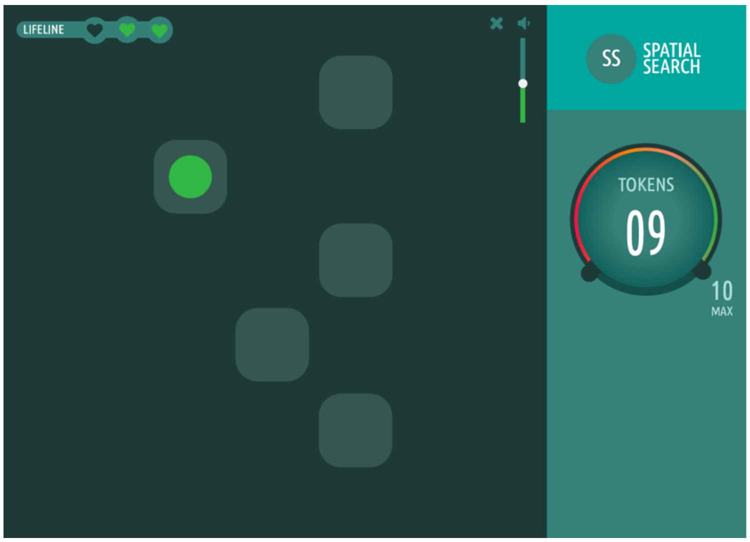
Note. The correct answer is the word on the right-hand side. This is a congruent trial.

Spatial Search Task. This task is adapted from a test that is used to measure strategy during search behaviours and working memory (i.e., a participant's ability to hold onto new information and manipulate information to perform a task) (Collins et al., 1998). Participants were shown a set of boxes at random locations on the screen and were required to click the boxes one at a time until they found the hidden "token". After the token was found, it was hidden again in another box. During each trial, the token was not concealed in the same box twice; participants had to search the boxes until the token was found once within each box. The trial ended if a participant searched the same box twice or a box where the token was previously found. The task difficulty was adjusted by increasing the number of boxes by one if the previous trial was done correctly, or decreasing the number of boxes by one if the previous trial was done incorrectly.

The task was ended after three errors. A participant's score was based on the highest number of boxes on the screen when all the tokens were found without error. A sample trial from the Spatial Search Task is presented in Figure 2.

Figure 2

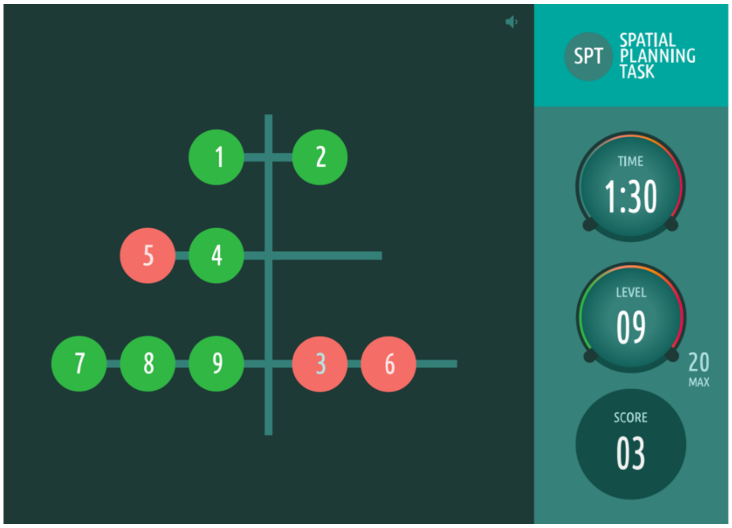
A Sample Trial from the Spatial Search Task.



Spatial Planning Task. This task is a modified version of the Tower of London Task, which is used to measure planning ability (Shallice, 1982). Participants were shown numbered beads placed on a tree-shaped frame. Participants had to reposition the beads to achieve ascending numerical order from left to right and top to bottom on the tree frame in the fewest moves possible. The difficulty of the trials was increased by increasing the total number of moves on each trial. A trial ended if the participant used more than twice the number of moves required to complete it. Participants had to solve as many problems as possible within 3 min. The participant's score was based on the number of moves required to complete the trial correctly. A sample trial from the Spatial Planning Task is presented in Figure 3.

Figure 3

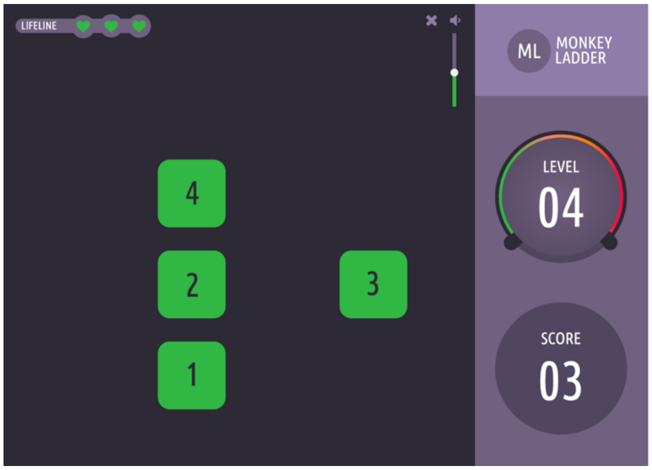
A Sample Trial from the Spatial Planning Task.



Monkey Ladder Task. This task is a modified version of a task taken from the non-human primate literature, which measures working memory (Inoue & Matsuzawa, 2007). Participants were shown a set of numbered squares situated at random locations on the screen. After a variable amount of time, the numbers on the squares disappeared and participants had to click the squares in ascending numerical order by remembering where the numbers had previously appeared. The task difficulty was automatically adjusted by increasing the number of boxes by one if the previous trial was done correctly, or decreasing the number of boxes by one if the previous trial was done incorrectly. The task was ended after three errors. A participant's score was based on the largest number of squares on the screen when the participant solved the trial correctly. A sample trial from the Monkey Ladder Task is presented in Figure 4.

Figure 4

A Sample Trial from the Monkey Ladder Task.



Demographic Questionnaire

Participants completed a demographic questionnaire (see Appendix B) to gather information regarding their age, sex, education level, medical history, dance and aerobic exercise experience.

Procedure

Testing took place online via a Qualtrics survey. Prior to testing, participants read the Letter of Information for the study and provided consent (see Appendix C). Then, participants were directed to a demographic questionnaire and later underwent cognitive testing via the CBSB. The four aforementioned CBSB tasks were presented in a random order. The entire study required approximately 40 min to complete.

Results

A one-way between-groups analysis of variance (ANOVA) was conducted to compare the dance group and the control group on the following executive function tasks: Double Trouble Task, Spatial Search Task, Spatial Planning Task, and the Monkey Ladder Task.

Double Trouble Task

Prior to conducting the one-way between-groups ANOVA, the assumption of homogeneity of variance was tested and was satisfied based on Levene's *F* test, $F(1, 6) = 2.26$, $p = .183$. The one-way between-groups ANOVA indicated that there was no significant difference between the dance group ($M_{score} = 3.00$, $SD = 2.83$) and the control group ($M_{score} = 5.50$, $SD = 10.04$) on the Double Trouble Task (i.e., $F(1, 6) = 0.110$, $p = .751$).

Spatial Search Task

Again, prior to conducting the one-way between-groups ANOVA, the assumption of homogeneity of variance was tested and was satisfied based on Levene's *F* test, $F(1, 6) = 0.02$, $p = .904$. Similar to the Double Trouble Task, there was no significant difference between the dance group ($M_{score} = 5.00$, $SD = 1.70$) and the control group ($M_{score} = 4.68$, $SD = 1.51$) on the Spatial Search Task (i.e., $F(1, 6) = 0.063$, $p = .810$).

Spatial Planning Task

The assumption of homogeneity of variance was tested and was satisfied based on Levene's *F* test, $F(1, 6) = 2.07$, $p = .107$. Like the Double Trouble Task and the Spatial Search Task, no significant difference was found between the dance group ($M_{score} = 26.50$, $SD = 2.12$) and the control group ($M_{score} = 15.00$, $SD = 11.14$) on the Spatial Planning Task (i.e., $F(1, 6) = 1.906$, $p = .217$).

Monkey Ladder Task

The assumption of homogeneity of variance was tested and was satisfied based on Levene's *F* test, $F(1, 6) = 3.58$, $p = .183$. Similar to the three aforementioned tasks, no significant difference was found between the dance group ($M_{score} = 5.00$, $SD = 0.14$) and the control group (M_{score} = 4.52, *SD* = 0.73) on the Monkey Ladder Task (i.e., $F(1, 6) = 0.794$, p = .407).

Discussion

The present study hypothesized that long-time older adult dancers would be associated with greater executive functioning than long-time older adult aerobic exercisers. Unfortunately, this hypothesis could not be tested because no participants were available for the aerobic exercise group. Because of this limitation, the study simply compared the dance group and the control group on four executive function measures. The results indicated that no differences between the groups were found across the four executive function measures (i.e., Double Trouble Task, Spatial Search Task, Spatial Planning Task and the Monkey Ladder Task). In other words, the groups did not differ in inhibitory control, planning, or working memory. However, these findings need to be interpreted with caution as the study is severely underpowered because of the low sample size in both groups.

Consistent with the findings of the present study, a meta-analysis conducted by Meng et al. (2019) found that dance compared to non-active control groups demonstrated no differences in executive functioning. However, the studies included in the meta-analysis only employed the Trail Making Test Part B, which measures set-shifting ability. None of the tasks used in the present study have measured the set-shifting component of executive functioning and given the small sample size in the present study, it is difficult to definitively suggest that dance is not associated with greater executive functioning. Furthermore, systematic reviews conducted by Hwang et al. (2015) and Predovan et al. (2019) have suggested that dance may offer greater cognitive functioning than a non-active control group. Thus, it is too early to conclude that dance may offer no benefits for cognitive functioning compared to engaging in no activity.

If the participant groups were larger in the present study and the results showed that the dance group had greater executive functioning than the aerobic exercise group and the control group, those results may be related to the complex nature of dance. Dance involves the use of executive functions as well as aerobic exercise. This added complexity over and above aerobic exercise may be responsible for differences in executive functions between dancers, aerobic exercisers and controls (Hwang et al., 2015). I also expect the aerobic exercise group to be associated with higher executive functioning than the control group because past research consistently suggests that engaging in aerobic exercise is associated with enhanced cognitive functioning compared to individuals with no aerobic exercise experience (Falck, 2019).

Alternatively, even with enough participants in each of the groups, I may have found no differences in executive functioning between the dance group and the aerobic exercise group. To date, two randomized control trials have compared dance with aerobic exercise and found no performance differences between the groups on executive functioning (Esmail et al., 2020; Merom et al., 2016). However, both of these interventions only lasted for 3-8 months, leaving the possibility that a longer duration of dance experience could enhance executive functioning. In regard to the control group, I would expect the dance group and aerobic exercise group to be associated with higher executive function than a passive control group based on past research. A number of studies have shown that dance or aerobic exercise is associated with higher cognitive functioning when compared to a passive control group (Coubard et al., 2011; Falck, 2019; Kattenstroth et al., 2013; Wang et al., 2020).

Limitations

Given the cross-sectional design of this study, there is concern for selection bias, which precludes causal conclusions. It could be that participants who have higher executive functioning may be choosing to engage in dance or aerobic exercise, and therefore, the activities themselves may not be improving executive functions. Furthermore, participants' experience (e.g., intensity of experience, years of experience) in dance or aerobic exercise may not be uniform between the groups, so whether or not differences are found between the groups need to be interpreted in the light of this experience difference. Finally, higher levels of education, socioeconomic status, and social engagement are also other potential variables that are associated with higher cognitive functioning (Fotenos et al., 2008; Scarmeas & Stern, 2003). The present study found no differences between the dance group and the control group on executive functioning, and this could potentially be because the control group participants had higher levels of education than the dance group which may have counteracted the benefits of dance. However, the present study had a small sample size, so this greatly underpowered the study in finding any differences between the groups.

Future Directions

Because of the limitations associated with cross-sectional studies, it may be worthwhile to conduct a longitudinal experimental study that compares participants with long-time experience in dance and participants with long-time experience in aerobic exercise. Care should be taken to match individuals on these other potential confounding variables (e.g., socio-economic status, social engagement) so that causal inferences can be made about the findings from the study. To address the issue of selection bias, prospective researchers may want to randomly assign participants to a dance group or an aerobic exercise group and examine these participants' executive functioning longitudinally. Finally, to control for the non-uniform intensity of dance or aerobic exercise, researchers may want to have different levels of intensity within each group (e.g., 1-2 hrs per week, 2 to 5 hrs per week etc.). Although randomly assigning participants to a dance group and an aerobic exercise group and examining them over a 50-year period is ideal, this may not be practically feasible. Therefore, future researchers may want to assign older adult participants with no experience in dance or aerobic exercise and examine how their executive functioning changes over a 5 to 10-year period.

Conclusion

The association of long-time dancers with greater executive functioning than long-time aerobic exercisers was not tested in this study because of the small sample sizes. Within the data collected, participation of older adults in dance was not associated with greater executive functioning than compared to older adults who did not engage in dance or aerobic exercise. However, caution must be taken when interpreting these results as the study was largely underpowered because of the low sample size in both groups. If future cross-sectional studies do find that long-time older adult dancers are associated with greater executive functioning than long-time older adult aerobic exercisers, they may want to causally evaluate this conclusion with longitudinal experimental studies.

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Appendix A

Western Research

Date: 29 October 2019

To: Dr. Jessica Grahn

Project ID: 114440

Study Title: Dance Against the Cognitive and Physical Declines Associated with Aging

Application Type: HSREB Initial Application

Review Type: Delegated

Full Board Reporting Date: November 19,2019

Date Approval Issued: 29/Oct/2019

REB Approval Expiry Date: 29/Oct/2020

Dear Dr. Jessica Grahn

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above mentioned study as described in the WREM application form, as of the HSREB Initial Approval Date noted above. This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Documents Approved:

Document Name	Document Type	Document Date	Document Version
BrainsCAN Recruitment Script	Recruitment Materials	11/Oct/2019	2
Data Collection Form	Other Data Collection Instruments	09/Aug/2019	1
Letter of Information	Written Consent/Assent	18/Oct/2019	2
Recruitment Poster	Recruitment Materials	11/Oct/2019	2
Research Protocol	Protocol	18/Oct/2019	2
The Demographics Screening Questionnaire	Paper Survey	17/May/2019	1
Website Ad	Recruitment Materials	11/Oct/2019	2

No deviations from, or changes to, the protocol or WREM application should be initiated without prior written approval of an appropriate amendment from Western HSREB , except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University HSREB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Karen Gopaul, Ethics Officer on behalf of Dr. Philip Jones, HSREB Vice-Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Appendix B

Screening and Demographics Questionnaire

Cognitive Functioning of Dancers and Athletes

Please complete the following questions. Any information that you provide will remain confidential and accessible only to the investigators of this study.

DEMOGRAPHIC INFORMATION:

1. Sex (please circle your response):

   MALE FEMALE OTHER

2. Age:

   ____

3. Handedness (please circle your response):

   LEFT-HANDED RIGHT-HANDED

4. What is the highest level of education you have completed? (Please check one)

   □ Elementary School
   □ Less than Grade 12
   □ High school diploma
   □ Some university undergraduate schooling
   □ Other (please specify): __________________
   □ College Degree (2 years)
   □ Bachelor's degree
   □ Postgraduate degree

5. Are you multilingual? (please circle your response)

   YES NO

   7.1 If yes, besides English, what other languages are you fluent in?

   ____

   7.2 What is your dominant language?

   ____

6. Do you currently live in your own home? (excluding residential care)

   YES NO

7. What is your country of origin?

   ____

MEDICAL INFORMATION:

8. Do you have normal or corrected-to-normal (i.e. glasses, contact lenses) vision? (please circle your response)

   NORMAL CORRECTED-TO-NORMAL NO

9. Are you currently taking any medications that could alter how you perform mentally or physically? (please circle your response)

   YES NO

10. Have you been diagnosed with any of the following neurological conditions? (please check any that apply)

    □ Parkinson's disease
    □ Stroke
    □ Alzheimer's disease
    □ Brain tumor
    □ Dementia
    □ Concussion (within last 12 months)
    □ Other (please specify): _______________

11. Have you been diagnosed with any of the following psychiatric conditions? (please check any that apply)

    □ Major depression
    □ Somatoform disorder
    □ Attention deficit/hyperactivity disorder
    □ Schizophrenia
    □ Other (please specify): _______________

12. Do you have any of the following physical limitations? (please check all that apply)

    □ Osteoarthritis
    □ Musculoskeletal or joint disease

□ Currently using a mobility aid (cane, walker, wheelchair, or scooter)

□ Have undergone surgery within the last 3 months

DANCE TRAINING:

13. Do you have any formal dance training? (please circle your response). If NO, please go
directly to the next section: ATHLETIC TRAINING (Question 14).

YES NO

13.1 If yes, what style(s) have/do you train or perform in? (please check all that apply)

□ Ballet
□ Contemporary
□ Modern
□ Jazz
□ Other (please specify): ___________
□ Ballroom
□ Tap
□ Hip-hop
□ Folk

13.2 How long have you been training or performing?

____

Please provide details if the length of training has differed for different dance styles.

____

13.3 What type of training did/do you receive? (i.e. self-taught, school dance class, small group/dance studio, private, competitive, training at a professional level etc.) Please describe.

____

13.4 Do you currently dance? (please circle your response)

YES NO

13.4.1 If yes, approximately how many hours per week do you spend dancing? (please circle your response)

0 to 1 2 to 5 6 to 15 16 to 20 20+

13.4.1 If no, please describe when your training began and ended.

____

ATHLETIC TRAINING:

14. Do you have any training as an athlete (recreational or professional)? (please circle your response). If NO, you have finished the questionnaire.

YES NO

14.1 If yes, which of the following sports have/do you train or compete in? (please check all that apply)

- ☐ Running
- ☐ Cycling
- ☐ Swimming
- ☐ Rowing
- ☐ None of these

14.2 Do you train or compete in any other sports or athletic activities? Please describe.

____

14.3 How long have you been training or competing?

____

Please provide details if the length of training has differed for different sports.

____

14.4 What type of training did/do you receive? (i.e. individual (on your own), school

team, recreational team/club, competitive team/club, training at a professional
level etc.) Please describe.

____

14.5 Do you currently train in running, cycling, swimming, or rowing? (please circle
your response)

YES NO

14.5.1 If yes, approximately how many hours per week do you spend training or competing? (please circle your response)

0 to 1 2 to 5 6 to 15 16 to 20 20+

14.5.1 If no, please describe when your training began and ended.

____

15. Do you listen to music while you are training? (please circle your response)

YES NO

Appendix C
Letter of Information
Dance Against the Cognitive and Physical Declines in Aging

Research Investigators:

Sarah Schwanz, BA Student Researcher Email: sschwanz@uwo.ca	Dr. Jessica Grahn Principal Investigator Brain and Mind Institute Western Interdisciplinary Research Building, 5th Floor University of Western Ontario London, Ontario N6A 5B7 Email: jgrahn@uwo.ca Phone: 519-661-2111 ext. 84804	Dr. Jeffrey Holmes Co-Investigator Health and Human Performance Lab Elborn College, Room 2529 University of Western Ontario London, Ontario N6A 5B7 Email: jeff.holmes@uwo.ca Phone: 519-661-2111 ext. 88967

Introduction:
You are being invited to participate in this student research study investigating the cognitive and physical performance differences between dancers and athletes, and how this might relate to functioning in older age; because you either are a dancer, athlete, or a non-dancer/athlete. The purpose of this study is to explore whether dance uniquely preserves cognitive and physical function, compared to other activities such as exercise training. More specifically, this study hopes to determine if dance training provides significant benefits to the areas that most often experience decline due to aging, including executive function, processing speed, memory, attention, visuospatial abilities, strength, balance, gait, and fine motor movement.

The purpose of this letter is to provide you with information required for you to make an informed decision regarding participation in this research. It is important for you to understand why the study is being conducted and what it will involve. Please take the time to read this carefully, and feel free to ask questions if anything is unclear or if there are words or phrases you do not understand.

Inclusion and Exclusion Criteria:
Individuals who are 50 years of age or above and are either a dancer, musician, or athlete may participate in this study, or individuals who lack experience in all three activities. Dancers, musicians, and athletes must all have at least 10 years of experience and must be currently training or practicing. Individuals will be considered to have no experience if they have less than one-year experience in dance, music, or the selected sports. Accepted styles of dance include: ballet, ballroom, modern, jazz, tap, hip-hop and related styles. Accepted styles of music include: piano, percussion, brass, wind, and string. Accepted sports include: running, swimming, cycling, and rowing. Those with experience in more than one of the three activities will be excluded from the study. Lastly, individuals must have normal or corrected-to-normal vision, no cognitive or neurological impairments, and no physical impairments or limitations.

Research Procedures:

If you agree to participate, you will be asked to participate in the following tasks. Participants will have the option to complete the online cognitive tasks only or complete both the cognitive tasks and in-person assessments.

Online Cognitive Tasks:
For these tasks, participants will play a variety of short computer games that are designed to engage attention, executive functioning, and memory. You will be asked to create an account on Cambridge Brain Sciences (CBS) using your personal email address. CBS will store this email address and no further personal information will be collected.

It is also important to note that Cambridge Brain Sciences (CBS) will also record your internet protocol (IP) addresses. Storage of your IP address runs the risk of additional privacy breaches that is associated with your IP address for example your network, device or service. Your IP address also provides information on the following areas, online services for which an individual has registered; personal interests, based on websites visited; and organizational affiliations.

These tasks will be completed online. It is anticipated that all tasks will take no more than 1 hour to complete.

Optional In-Person Tasks:
Screening Tests
These tests are standardized to asses general cognitive and physical status, and may ask participants to identify objects, remember a list of words or numbers, perform simple math problems, write or draw, and independently or verbally respond to questionnaire items.

Grip Strength Task
For this task, participants will be asked to squeeze a handheld dynamometer as hard as they can with both their dominant, and non-dominant hand.

Walking Task
For this task, participants will walk at a comfortable pace for 10 meters, turn around, and walk back to the starting position for a total of 20 meters.

Balance Task
For this task, participants will be asked to balance in a variety of conditions including: on a firm surface, on a soft surface, eyes open, eyes closed, two feet together, and single foot.

Nine Hole Peg Task
For this task, participants will pick up and place pegs into holes on a peg board and take them out as fast as they can with both their dominant and non-dominant hand.

If the participant chooses to complete the optional in-person tasks, they will be conducted in the Health and Human Performance Lab in Elborn College at Western University in London, Ontario, Canada. It is anticipated that all tasks will take no more than 1.5 hours to complete.

Risks:
There are no known risks for participating in the online cognitive tasks. For participants who choose to participate in the in-person tasks and who may be unsteady walking or standing, there is a potential risk of falling during gait and balance tests. Participants will be asked to walk 20 meters, as well as balance for three 20-second intervals in a variety of conditions such as eyes open and eyes closed. During gait and balance tests, participants will be monitored at a close distance by the researcher in the event of a potential fall.

Benefits:
Although you may not directly benefit from participating in this study, the information gathered may provide benefits to society as a whole which include enhancing our scientific understanding of the benefits of dance, music, and athletic training, leading to potential advancements in medical care. Results from this study may be used in further research to understand how dance training may influence the aging process or how dance may be used in interventions or therapies.

Compensation:
Online participation through MTurk will be compensated with $5.00 for your participation.

Voluntary Participation:
Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time without loss of promised compensation. You may also withdraw your data if you withdraw consent.

Confidentiality:
All data from this study will remain confidential and will be accessible only to the investigators of this study. In the event of publication, any data resulting from your participation will be identified only by case number, without any reference to your name or personal information. The data will be stored on a secure computer in a locked room. Both the computer and the room will be accessible only to the investigators. After completion of the experiment, data will be archived on storage disks and stored in a locked room. Any documents identifying you by name will be kept separately from your data and will be destroyed after 7 years. Representatives of the University of Western Ontario Health Sciences Research Ethics Board may require access to your study-related records or may follow up with you to monitor the conduct of the study.

All users will remain anonymous and researchers of this study will not have access to any identifying information other than your amazon-allocated “user id’. If a participant chooses to also participate in the optional in-person visit, their name and chosen form of contact will be made available to investigators of this study and will remain confidential as described above.

Contacts for Further Information:
If you would like to receive a copy of the overall results of the study, or if you require any further information regarding this research project or your participation in the study you may contact: Sarah Schwanz at sschwanz@uwo.ca or Dr. Jessica Grahn at jgrahn@uwo.ca.

If you have any questions about your rights as a research participant or the conduct of the study you may contact:

The Office of Research Ethics
The University of Western Ontario
519-661-3036
E-mail: ethics@uwo.ca

<u>Consent Form</u>
Project Title: Dance Against the Cognitive and Physical Declines in Aging
Study Investigator's Name: Sarah Schwanz

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

Participant's Name (please print): ____

Participant's Signature: ____

Date: ____

I would like to be contacted to participate in a follow-up in-person session to complete the physical tasks:

Please initial:

___ yes, the researcher may contact me to participate in a follow-up session at ______________

___ no, I do not wish to be contacted to participate in a follow-up session.