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An Examination of Working Memory in Dancers and Non-dancers

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AN EXAMINATION OF WORKING MEMORY IN DANCERS AND NON-DANCERS

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by

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ABSTRACT

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The present study examined the behavioral working memory differences between dancers and non-dancers. Previous research has indicated that dance can provide an enhancing effect on working memory, particularly in non-dancers. A Dance History Questionnaire along with the letters backward, digits backward, digits forward, letters forward, and abstract visual subtests of the Test of Learning and Memory II was used to collect data. The current study found that dancers had greater visuospatial memory than non-dancers and that dance experience may have an effect on certain working memory tests such as the letters forward subtest.

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CHAPTER I

INTRODUCTION

Dance, whether it be traditional folk dances or modern hip-hop, is a universal activity that has stretched across cultures and millennia. Dance itself is broad and can range from Zumba dance to classical ballet with different styles within those genres. Dance has yet to be concretely operationalized in the scientific literature, with many definitions of dance stemming from anthropological perspectives and more recently, neural interpretations (Basso et al., 2021; Christensen et al., 2017; Kaeppler, 2000; Reed, 1998; Hanna et al., 1979). A general definition of dance can be described as “patterned rhythmic movement in space and time” (Murrock & Graor, 2014; Pepper, 1984). Dance has been well-established as an effective activity to improve mental, emotional, and physical health (Humphries et al., 2023; Liu et al., 2022; Esmail et al., 2020, Barranco-Ruiz et al., 2020) in addition to serving as a social activity. Dance has increasingly been examined for the cognitive benefits it may have, specifically on memory.

The current scientific literature on dance and cognition has provided evidence that dance can be associated with greater working memory (Zinelabidine et al., 2022; Aguiñaga et al., 2022), inhibition (Zinelabidine et al., 2022), brain plasticity (Balazova et al., 2021; Rehfeld et al., 2018), and executive function (Zinelabidine et al., 2022; Esmail et al., 2020; Chen et al., 2016). Dance is frequently associated with memory, specifically working memory; however, there is a lack of research examining working memory in dancers and any possible differences between dancers and non-dancers. Research on working memory and dance has primarily been focused on dance interventions with non-dancers and concentrated on older adults or adolescent populations. These studies have indicated that dance serves as a beneficial activity for working memory in addition to mental, social, and physical health. The following literature review will provide further background on dance interventions on cognition, dance cognition, and working memory and dance.

CHAPTER II

LITERATURE REVIEW

Dance Interventions

Dance provides many cognitive benefits to all ages; however, it has increasingly been linked to improving cognitive decline in older adults and individuals with cognitive disorders. For example, Kosmat and Vranic (2017) found that old-old adults (75-90 years old) who danced 45 minutes a week for 10 weeks showed cognitive improvements, namely in executive function, cognitive flexibility, short-term memory, and working memory. Furthermore, these improvements were sustained at a 5-month follow-up.

Previous research on dance and neurological disorders, such as Parkinson's disease, has shown promising results. de Natale et al., (2017) examined the effects of dance on the motor and cognitive functioning of individuals diagnosed with Parkinson's disease. Patients in the dance therapy group would attend one-hour ballroom tango classes twice a week for 10 weeks, while patients in the traditional rehabilitation group (control group) were taught gait and balance exercises. Both groups were measured on motor skills (e.g., Berg Balance Scale, Timed Up-and-Go Test, 6-minutes Waking Test) and cognitive functioning (e.g., Trail Making Test, Stroop test, Frontal Assessment Battery) and were tested pre and post-test as well as at an 8-week follow up. Both groups were similar in cognitive and motor functioning before the intervention, however, at post-testing, the dance therapy group showed improvements in both motor and cognitive areas. This was sustained at the 8-week follow-up.

Whether it be for neurological disorders, mild cognitive impairment, or as a protective measure against age-related declines in cognition, dance has shown to be an effective and promising intervention for older adults. In addition to research on therapeutic dance interventions for cognitive disorders, researchers have also investigated the underlying functions of dance and the concept of dance cognition.

Dance Cognition

Dance requires several complex cognitive skills such as attention, visuomotor integration, emotional expression, synchronization in space and time (rhythmic movements), and learning sequences of complex sensorimotor movements (Brown et al., 2006). Dance cognition utilizes several neural pathways and structures such as the posterior parietal cortex (spatial cognition), cingulate sulcus (leg control), and basal ganglia (motor movements) (Brown et al., 2006; Burzynska et al., 2017).

Recent research on the relationship between dance, brain structure and function has yielded some interesting resultsS. For instance, using functional magnetic resonance imaging (fMRI) to examine the neural differences in dancers, Burzynska et al., (2017) found that some structural differences are present in expert dancers. Specifically, expert dancers appeared to have stronger neural connections in the inferior frontal gyrus and precuneus. These regions are associated with executive function and control and visuospatial processing, respectively (Rottschy et al., 2012). Furthermore, expert dancers showed higher activity in motor regions and the basal ganglia compared to non-dancers (Burzynska et al., 2017; Wen et al., 2022). Other research has yielded similar results with dancers demonstrating greater activity in motor regions associated with foot movement (Meier et al., 2016). This suggests that dancers possess a form of sport-specific neural adaption because of their dance training. While these adaptions can be due to structural changes in the brain, research shows that dancers may also show some changes in cognition (Jean et al., 2001).

For example, a study investigating memory function in expert dancers found that expert dancers recalled unstructured dance sequences, essentially random combinations of movements, more easily and accurately than structured sequences that followed a set pattern of successive movements (Jean et al., 2001). While this effect was suggested to be due to the novelty of movement, researchers also proposed that this effect could be in part due to changes in dancers' visual working memory. This finding is supported by evidence that other artistic domains, such as music, result in changes in working memory (D'Souza et al., 2018; George & Coch, 2011). Given these findings, working memory appears to be good starting point to investigating cognitive changes in dancers. The following section will concentrate on dance and working memory.

Dance and Working Memory

Working memory is described as a multi-component cognitive system comprised of the phonological loop, visual-spatial sketchpad, central executive processing system, and an episodic buffer that works together to temporarily store and manipulate information (Baddeley, 2012; Baddeley & Hitch, 1974). Working memory allows goal-relevant information to be actively maintained while other cognitive tasks are being executed such as remembering a person's address while they give you instructions on how to get there (Rudd et al., 2021). The examination of working memory with dance has been gaining popularity with many studies finding dance to be beneficial for working memory across ages.

For instance, a study conducted by Zinelabidine and colleagues (2022) used an 8-week aerobic dance to investigate whether dance affects working memory, inhibition, and cognitive flexibility in school-aged children. The dance intervention group participated in two 45-minute aerobic dance classes a week while the control group was instructed to continue their normal routine. Both groups were measured pre and post-test for working memory, inhibition, and cognitive flexibility using the Digit Recall Test, Stroop test, and Trail-Making Test, respectively. The results suggested that dance can serve as a cognitively enhancing activity as the children in the dance intervention showed improvements in the post-test measures of working memory, inhibition, and cognitive flexibility in comparison to the children in the control group.

Norouzi et al., (2020) found similar results in middle-aged women with Fibromyalgia. Using Zumba dance as the dance intervention, there was also an aerobic exercise group (e.g., treadmill), and a control group, all of which lasted 12 weeks. Participants in the Zumba and aerobic exercise groups attended hour-long classes 3 times a week for the duration of the study. The control group attended hour-long meetings three times a week for 12 weeks and was instructed to live life as normal. Working memory, depression, and motor control were assessed pre and post-intervention using the n-back test, a Persian translation of the Beck Depression Inventory second edition (BDI-II), and the Timed Up and Go (TUG) respectively. Women in both the aerobic exercise group and Zumba group saw improvements in working memory, depression, and motor control compared to the control group. However, women in the Zumba intervention saw the greatest improvements in all 3 areas.

The enhancement of working memory from dance appears to be maintained after a dance intervention as well. Aguiñaga and colleagues (2022) used a 4-month Latin dance program to examine any changes in executive function, working memory, and episodic memory in older adults. The dance intervention consisted of 1 hour classes twice a week that focused on the salsa, cha cha, bachata, and merengue dance styles and the program encouraged participants to increase their physical activity outside of classes. The control group attended two-hour meetings once a week focused on health education. Following the four-month intervention, both groups had a four-month maintenance phase. The Stroop test, Trail Making Test (TMT), Digit Span Forward, Digit Span Backward, immediate logical memory, and delayed logical memory were used to assess the three cognitive functions pre-test, post-test, and at a four-month follow-up. Post-test results showed working memory improvements in the Latin dance group, but not in the control group. Interestingly, the dance intervention did not appear to have any significant effect on episodic memory or executive function. When assessing working memory at the four-month follow-up, the older adults who were in the dance group still had greater working memory compared to those in the control group. Physical activity as promoted by the Latin dance program was found to be a mediator of this effect.

As mentioned in the Jean et al. (2001) study, it is suggested that a component of working memory could be partially responsible for the cognitive processes and mechanisms used by dancers during rehearsals. Combined with the evidence that dance can enhance working memory in non-dancers, it can be conceptualized that dancers may have greater working memory in comparison to non-dancers due to their dance background.

Research Question

The present study aimed to fill the gap in dance cognition research by examining working memory differences between dancers and non-dancers. With many studies examining how dance affects working memory, there is little published work investigating if dancers have greater cognitive abilities, particularly, in working memory. The present study will broaden the field of dance cognition and investigate the cognitive abilities of dancers and if dance training results in changes in working memory capabilities.

CHAPTER III

METHODS

Participants

Twenty-nine non-dancer participants were recruited through the SONA system at Central Washington University (CWU); however, one participant was excluded due to not meeting the criteria of being free from any substance use, neurological disorder, or medication that could have impaired memory function which left 28 non-dancer participants (*M* age = 20.89, *SD* = 8.88). The SONA system is CWU's Department of Psychology's research website that allows students to sign up to participate in psychological research. Eighteen of the non-dancer females identified as female and ten identified as male. Twenty-four dancer participants (*M* age = 19.74, *SD* = 1.79) were recruited from Central Washington University, Western Washington University, and Gonzaga University. Twenty-two dancers identified as female, and two dancers identified as male. For participants who are not from CWU, a secure sign-up link was sent out to students in the dance departments of Western Washington University and Gonzaga University. All participants had to be 18 years or older, and free from any substance use, neurological disorder, or medication that may impair memory function.

Materials

Dance History Questionnaire

A dance experience questionnaire was created for this study and was given to every participant to determine if they were a dancer or non-dancer. The dance experience questionnaire was created by the principal investigator and a dance faculty member of Central Washington University. It was modeled after a previous questionnaire about musicians and music experience. (Richardson, 2015). The questionnaire was comprised of several types of response choices (e.g., open response) and questions such as “On average, how many years have you been practicing dance? Unfortunately, the criteria of dancer is ill defined and has yet to be concretely established in the literature. For the current study, non-dancers were defined as having no dance experience or less than one year of dance experience and dancers were defined as having one or more years of dance experience and currently dancing, The principal investigator and the dance faculty member chose 1 year of dance training to be the cut-off for a dancer as many people will try a sport for a season, which for dance is about a year, before quitting or continuing the sport. For the analyses, dancers defined by the dance history questionnaire were sorted into advanced, intermediate, and novice groups based on their years of dance experience. Novice was categorized as dancers with 1 to 3 years of experience, intermediate was 4 to 6 years, and advanced was defined as having 7 or more years of dance experience. The questionnaire is shown in Appendix A.

Table 1

Descriptive data for dancer subgroups and non-dancers

	Age Mean (SD)	Years of Dance Experience Mean (SD)
Dancer (Novice) *N* = 2	19.50 (0.71)	1.50 (0.71)
Dancer (Intermediate) *N* = 4	21.50 (2.89)	5.50 (0.58)
Dancer (Advanced) *N* = 18	19.35 (1.37)	14.17 (2.94)
Non-Dancer *N* = 28	20.89 (8.88)	1.00 (2.45)

Test of Memory and Learning – II (TOMAL – II)

The Test of Memory and Learning – II (TOMAL – II) is a nationally standardized test for assessing general and specific memory functions such as working memory (Reynolds & Voress, 2007). The TOMAL – II is made up of eight core subtests, six supplementary subtests, and two delayed recall tasks The proposed study used the following subtests: digits backward (DB), letters backward (LB), digits forward (DF), letters forward (LF), and abstract visual (AV). Letters forward and digits forward measure phonological memory, letters backward and digits backward measure working memory, and abstract visual memory measures visuospatial memory. The subtests were all scored manually and took approximately 55 minutes to administer.

Procedure

Participants were seated at a desk across from the principal investigator and were given the consent form. If participants signed the consent form and agreed to be in the study, they were given the participant history questionnaire which contains general demographic information, and the dance history questionnaire to determine if they are a dancer or non-dancer. If the participant met all the criteria to participate such as no substance use or a neurological disorder, the TOMAL – II tests were administered. The tests were administered in the order of digits forward, digits backward, letters forward, letters forward, and abstract visual. The instructions for the LF/DF and LB/DB tests are similar: the principal investigator would say a string of letters/digits at a rate of one letter/digit per second and participants would be asked to verbally recall the string either forward or backward. For the abstract visual test, participants were shown a symbol for five seconds and then shown a series of six symbols. The participants were asked to select the symbol that they had previously seen. Instructions were given before each subtest and the tests would not continue until the participant understood the instructions. Once all the tests were administered, the participants were debriefed and thanked for their participation and the study was complete.

Experimental Design and Variables

This study used an independent *t* test to measure differences between dancers and non-dancers and a one-way analysis of variance (ANOVA) was used to measure differences between years of dance experience. The subject variables of interest are dancers and non-dancers, and the dependent variable was the TOMAL – II scores.

Hypotheses

H(1): Dancers will perform better on working memory tests than non-dancers.

H(2): Dancers will perform better on phonological memory tests than non-dancers.

H(3): Dancers will have a greater visuospatial memory than non-dancers.

H(4): Dancers with more years of experience will perform better on working memory tests than dancers will fewer years of experience.

CHAPTER IV

RESULTS

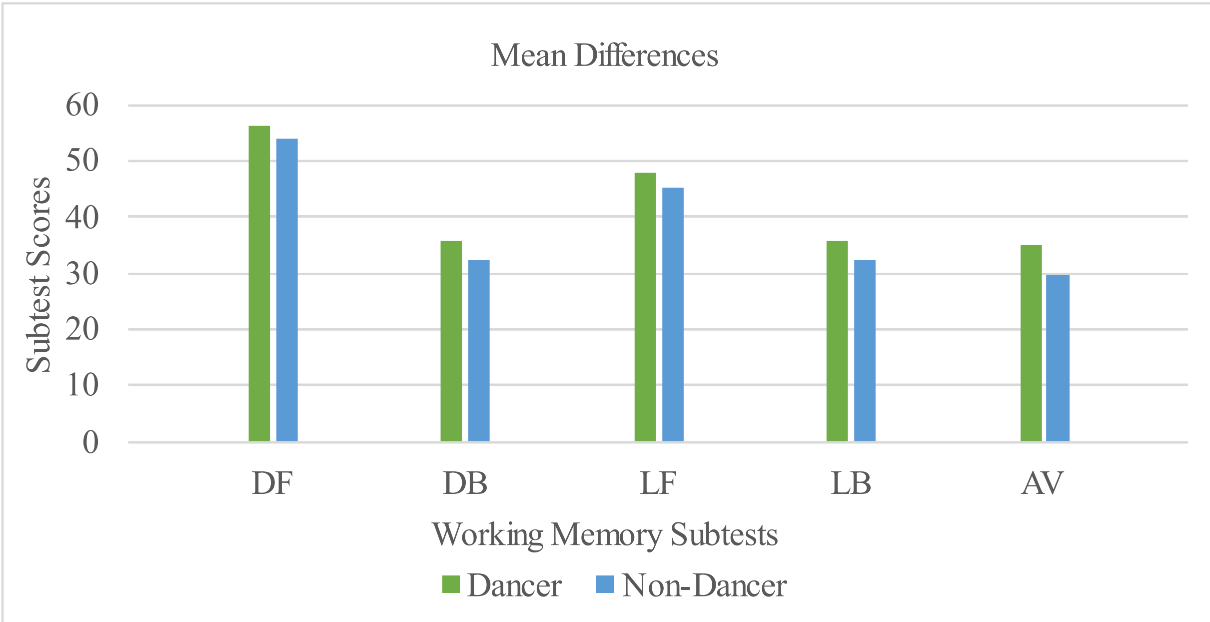
Behavioral Data

The scores from the TOMAL–II were measured on a ratio scale and were manually recorded by the principal investigator during the testing process using scoring sheets provided by the TOMAL–II. The highest possible score for the DF/LF subtests was 81, 64 for the DB/LB subtests, and 39 points for the abstract visual subtest. An independent-sample *t* test was run for each of the subtests to assess any behavioral differences between dancers and non-dancers. The digits forward ($t(50) = 0.82$, $p = .41$), digits backward ($t(50) = 0.95$, $p = .35$), letters forward ($t(50) = 0.80$, $p = .43$), and letters backward ($t(50) = 0.98$, $p = .33$) all had non-significant results. The abstract visual subtest was significant, $t(50) = 2.92$, $p < .01$, suggesting that there is a difference between dancers and non-dancers' visuospatial memory. Specifically, dancers scored higher on the abstract visual subtest ($M = 34.92$, $SD = 4.25$) than non-dancer participants ($M = 28.78$, $SD = 7.62$). The effect size for this difference was large, Cohen’s $d = .81$.

Examining the descriptive data of the subtests, there are some notable, but non-significant trends. Generally, the dancer participants scored higher on the digits forward ($M = 56.13$, $SD = 10.31$) than non-dancer participants ($M = 53.96$, $SD = 8.60$). On the digits backward subtest, dancers had higher scores ($M = 35.71$, $SD = 12.71$) compared to non-dancers ($M = 32.18$, $SD = 13.98$). Dancers also had higher scores on the letters forward ($M = 47.96$, $SD = 10.91$) and letters backward ($M = 35.92$, $SD = 10.78$) subtests compared to non-dancer participants on the letters forward ($M = 45.18$, $SD = 13.71$) and letters backward ($M = 32.43$, $SD = 14.38$). Although dancers tended to score higher on these working memory and phonological tests, the only significant finding was visuospatial memory.

Figure 1

Mean differences for working memory subtests.



Note. DF = digits forward, DB = digits backward, LF = letters forward, LB = letters backward, AV = abstract visual.

A one-way ANOVA was run to assess differences between dancer participants. For the digits forward subtest, there were no significant differences between more experienced dancers and novice dancers, $F(2, 21) = 0.12$, $p = .90$. No statistically significant differences were found for the digits backward, $F(2, 21) = 0.47$, $p = .63$, abstract visual, $F(2, 21) = 0.18$, $p = .84$, and letters backward, $F(2, 21) = 0.05$, $p = .95$. The difference between levels of dance experience on the letters forward subtest approached significance, $F(2, 21) = 3.32$, $p = .056$, however, there was only a small effect size, $\eta^2 = .24$. Tukey's HSD post hoc test was run to assess group differences and revealed that dancers with more years of dance experience (e.g., more than 10 years) performed better on the letter forward subtest than dancers with fewer years of experience (e.g., less than two years), $p < .05$. Based on self-report, participants in the "Dancer" group, reported dancing an average of 5-10 hours per week with years of experience being $M = 11.67$, $SD = 5.19$ and a range of 18.

CHAPTER V

DISCUSSION

The purpose of this study was to assess working memory differences between dancers and non-dancers, as well as to determine if varying levels of dance experience influence working memory. As shown in the results, dancers showed greater visuospatial memory compared to non-dancers, which supports H(3). These findings are supported by previous research that found that expert dancers (e.g., at least 10 years of dance experience or dancing 10 or more hours a week for 3 years) had greater connectivity in brain regions involved in the processing of visuospatial information such as the precuneus (Burzynska et al., 2017; Rottschy et al., 2012; Brown et al., 2006). For instance, Jean and colleagues (2006) suggested that dancers may possess greater visual working memory due to their ability to recall unstructured sequences of movement more accurately than structured combinations. While the current study did not examine the memory of movement sequences, the present results do support the previous idea of dancers having an enhanced visual working memory.

In addition to the visuospatial working memory finding, there were several interesting (although non-statistically significant) trends between dancers and non-dancers. For example, the dancer participants generally scored higher than the non-dancer participants on the digits forward, digits backward, letters forward, and letters backward subtests. These results partially support previous findings examining how dance may improve working memory, specifically using digit span tests, in non-dancers (Zinelabidine et al., 2022; Aguiñaga et al., 2022).

Regarding within-group differences, there was a significant difference between dancers of different levels of dance experience in terms of the letters forward subtest. This finding partially supports H(4) and suggests that the amount of dance experience a person has may affect their working memory capabilities. Specifically, post hoc testing showed a significant difference between more experienced dancers (*N* = 18, *M* dance experience = 14.20 years) and beginner dancers (*N* = 2, *M* dance experience = 1.50), with more experienced dancers scoring higher on the letters forward subtest. However, this finding contained a skewed sample size and small effect size which could indicate that this significance may be due to a type I error (false positive) or the unequal sample sizes.

While the current study did not find many significant results based on dance experience, previous research suggests that dance experience can influence cognition. Past research has demonstrated that more experienced dancers (*M* experience = 7.2 years) have an enhanced motor recall of movements compared to novice dancers (*M* experience = 24 hours) (Starkes et al., 1990). Furthermore, research looking specifically at expert dancers has shown that a high level of dance expertise can have both neural and cognitive enhancements such as greater activation in motor regions of the brain and enhanced mental representations of dance movements (Meier et al., 2016; Bläsing et al 2009; Jean et al., 2001). Although the current study showed some interesting findings in terms of working memory differences, there are a few limitations that warrant consideration.

Limitations

This study had a low sample size for both the dancer population and non-dancer population which could have led to insufficient data for analysis. This could have particularly affected the results for the examination of dance experience within the dancer group. While there were enough participants in each population to find at least one significant result, the dancer group may have been too small to fully assess if various levels of dance experience (e.g., advanced versus novice) affected working memory capabilities. There could also be no effect of dance experience within dancers, however, the sample size was too small to accurately make that assessment.

Another limitation of this study is the validity of the dance experience questionnaire and the working criteria of a dancer. The questionnaire and criteria were created by the principal investigator and a CWU dance faculty member as a universal dance experience questionnaire has not been developed yet. However, the current questionnaire may have been either too broad, too specific, or both, especially with the determination of what a dancer is. The criteria for a dancer used in this study was the participant must be currently dancing and have been dancing for at least one year. The inconsistent criterion of dancer is seen throughout previous research as some studies described expert dancers as having a range of 5 to 25 years of dance experience (Smyth & Pendleton, 1994) while other studies had expert dancers where the average years of dance training were closer to 19 years (Bar & DeSouza, 2016). This definitional issue is a prevalent problem in the literature and as it stands, there is no agreed-upon definition of what a dancer is. This problem can be seen in related fields such as music as there is not a general consensus on the definition of a musician (D'Souza et al., 2018; George & Coch, 2011). The current criteria were purposely left broad to be more inclusive in hopes of increasing sample size, however, this vagueness may have led to less substantive results.

Directions for Future Research

This current study opens the door to many new research avenues. Firstly, future researchers should strive to expand and clarify the dance experience questionnaire and criteria for dancers. Altering the questions to be more open-ended and having a more rigorous definition of what a dancer is may allow for more substantive data in future studies. Dance experience is difficult to operationalize into a singular questionnaire and a universal questionnaire has not yet been developed so the development of a more universal questionnaire should be a future focus.

Moreover, future studies should focus more on the level of dance experience and different genres of dance. As noted, the sample size of dancers was too small to adequately surmise if dancers with more dance experience had greater working memory compared to dancers with less experience. Previous studies such as Bar and DeSouza (2016), Smyth and Pendleton (1994), and Starkes and colleagues (1990) have broached this topic with the use of professional dance companies and dance academies; however, more rigorous work should be done to examine cognitive differences outside of motor recall. Furthermore, future studies should examine if genre differences have an effect on working memory in dancers. Although genre data was collected in this study, it was not fully assessed and many of the dancers had training in the same genres (e.g., contemporary/modern and ballet). which made it difficult to make any assumptions. Much of the literature has focused on ballet dancers (Meier et al., 2016; Bläsing et al., 2009; Jean et al., 2001; Smyth & Pendleton, 1994) with an occasional study done on contemporary/modern dancers (Starkes et al., 1990), therefore, future research should explore if there are genre specific effects in tap dance, hip-hop, or jazz.

Conclusion

From Viennese balls to dancing in college clubs, dance is a beloved and widely practiced art form that has been integrated into human cultures for millennia. The healing act of dance extends beyond the freeing experiences it provides and stretches into neural and cognitive health. The current study aimed to explore a seemingly unexplored area of dance cognition; the working memory capabilities of dancers compared to non-dancers. Dancers appear to have greater visuospatial memory than non-dancers but did not show any other significant differences in phonological memory or working memory. However, dancer participants did tend to score higher on all of the working memory tests. Overall, the findings of the current study suggest that while dancers do seem to possess an enhanced visuospatial memory, further research will need to be done to fully assess whether dance impacts other aspects of working memory and cognition.

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APPENDIXES

Appendix A

Measures and Materials

Brain Dynamics & Cognitive Neuroscience Lab

Central Washington University

Dance Experience Questionnaire

1. On average, how many years have you been practicing dance? _______
2. On average, how many hours per week do you dedicate to dance class or rehearsal? Please select one.
    - 0
    - 1 – 4
    - 5 – 10
    - 11 – 15
    - Other (specify below)
3. At what age did you start dancing persistently? ________
4. Choose any of the following that categorize your dance training of most experience.
    - Ballet
    - Jazz
    - Contemporary/Modern
    - Hip-Hop

- Other (specify)

5. Are you currently and regularly dancing? If so, please specify which style you practice in order of time spent practicing, greatest to least.

____

____

6. What is your major? __________________

7. Do you participate in any other sports? If so, please indicate which sport and how many years you have been practicing.

____

____

Brain Dynamics & Cognitive Neuroscience Lab

Central Washington University

Participant History Questionnaire

1. What is your age? ___________

2. What is your biological sex?
   - ❑ Male
   - ❑ Female
   - ❑ Prefer not to answer

3. What is your race/ethnicity? ____

4. Have you ever had a concussion, stroke, seizure, or any other traumatic brain injury?
   - ❑ Yes
   - ❑ No

   If yes, please explain the injury and when this occurred.

   ____

5. Do you have a vision impairment that cannot be corrected for with lenses or glasses?
   - ❑ Yes
   - ❑ No

6. Do you have a hearing impairment that cannot be corrected for with a cochlear implant or hearing aids?
   - ❑ Yes
   - ❑ No

7. Have you taken any pharmaceutical or nonpharmaceutical drugs within the past two weeks?
   - ❑ Yes
   - ❑ No

   If yes, please specify.

   ____

8. Do you have a learning disorder or disability?
   - ❑ Yes
   - ❑ No