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Dance and Aging: A Critical Review of Findings in Neuroscience

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Abstract Significant developments in health applications for dance have occurred over the past 40 years. While neurological changes associated with physical exercise have been well researched and documented, dance has yet to receive the same attention and represents an area of extreme interest for further study given its many reported benefits. The objective of this review is to critically examine the existing literature on observed neurological effects of dance interventions within the elderly population. A comprehensive literature search was performed using six different databases, and included dance interventions involving ballet, ballroom, tango, several cultural dances, and dance/movement therapy, with five elderly population types comprised of both healthy individuals and those exhibiting neurological impairments. The articles were critically appraised using formal research guidelines. In total, 44 appropriate and relevant studies were identified and short listed. Together, all studies examined three major domains: (1) cognition, (2) sensorimotor performance, and (3) underlying neurobiological factors. Twenty-one studies investigated the effects of dance on cognition, 27 on sensorimotor performance (gait, static and dynamic balance), and seven evaluated the effects on underlying neurobiological factors. Post-dance intervention findings showed significant

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improvements in several aspects of brain function involving cognition and sensorimotor performance; however, only a few studies were found which related the significance of dance interventions to its potential affect on various neurobiological factors. There is a need for future research investigating the direct effects of dance interventions on neurobiological changes in the elderly which this review begins to address.

Keywords Cognition · Dance · Neurobiological factors · Sensorimotor performance

Introduction

Neurological changes in the elderly associated with physical exercise have been well researched and documented. Exercises that are cardiovascular in nature such as running, walking, and aerobics have been shown to enhance cognitive plasticity and executive and motor functions producing positive effects on various neural properties—inducing neurogenesis, hippocampal hypertrophy and augmenting neurobiological factors (production of brain-derived growth factors) (Spirduso, 1983; Erickson et al., 2009; Foster, Rosenblatt, & Kuljis, 2011; Dhami, Moreno, & DeSouza, 2015).

Dance, similar to cardiovascular exercise, appears to be beneficial for the elderly, and significant developments in the applications of dance have been observed over the last 40 years. However, few studies to date have investigated the direct effects of dance on the brain in comparison to physical exercise and exercise-related changes in the brain. Dance distinguishes itself from physical exercise by providing a more enriched environment for rehabilitation and therapy (Kattenstroth, Kolankowska, Kalisch, & Dinse, 2010; Dhami et al., 2015). Dance interventions involve multiple features and are inherently multimodal as they not only comprise of physical activity or exercise but also include learning, attention, memory, emotion, rhythmic motor coordination, balance, gait, visuospatial ability, acoustic stimulation, imagination, improvisation and social interaction. Improvements in these areas have significant implications for the overall well-being of an individual (Rabinovich, 2012; Kattenstroth, Kalisch, Holt, Tegenthoff, & Dinse, 2013).

The objective of this review is a critical examination of the existing literature investigating neurological effects of dance interventions in an elderly population. This article will summarize and highlight the major findings, outcomes, and documented positive benefits of various dance interventions on brain-related functions and neurobiological factors. Finally, the strengths, limitations, and scope for future research in this field will be discussed.

Methods

Literature Search and Study Selection

A comprehensive literature search was done using six different databases including grey literature and relevant in-text references from—MEDLINE, PubMed,

PsycInfo, CINAHL, Web of Science and OAlster. The keywords used were: dance/dancing/dance therapy AND aging brains OR elderly, old, aged, seniors, geriatric; while more specific searches stated; dance AND fMRI OR brain regions OR EEG OR neurotransmitters, neurotrophins, growth factors, AND gene/genetics. Keywords that included neurological disorders such as Parkinson's disease (PD), Dementia (D), Alzheimer's disease (AD), Confusion, Disorientation, and Memory Loss (CDM), Multiple Sclerosis (MS) and Neurological Insult—Traumatic Brain Injury, Stroke (NI) were also used along with searching various dance forms such as ballet, ballroom, contemporary, jazz, polka, tango, waltz, zumba. For consistency in search and quality assurance, all searches were made using set criteria: date range, 1970—current; age range, 60 and over; article type, peer reviewed, scholarly journals.

Titles of search results were reviewed, after which the chosen abstracts were downloaded and screened further for appropriate and relevant articles. Subsequently, full text articles were downloaded and chosen for critical appraisal (see Fig. 1). Studies were selected for review if they examined the effects of dance on an elderly population, specifically in regard to brain and brain-related functions, such as cognitive performance, sensorimotor functions (balance, posture etc.), and underlying neurobiological factors. The dance interventions mentioned in the studies were composed of many different dance forms, including ballet, ballroom, tango and cultural dances (such as Irish set, traditional Greek, Turkish folklore, and Caribbean). Also included was the discipline of dance/movement therapy (DMT), and dance mixed with Reality Orientation (RO).

Critical Appraisal and Assessment Procedure

Primary research papers were chosen for critical appraisal followed by an evaluation of commentaries and other review papers. The critical appraisal involved assessment criteria that validated each study with regard to thoroughness and credibility. This involved looking at crucial elements such as the study's purpose, design, sample size and age, gender distribution, whether or not it was a randomized controlled trial (RCT), if it was conducted under Research Ethics Board (REB) approval and had a consent agreement and how all these factors justified the study's

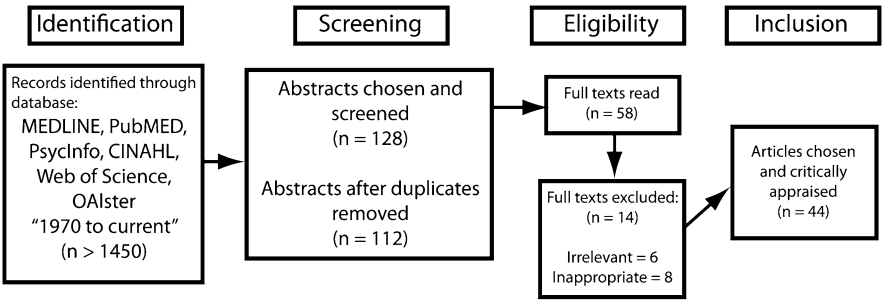

Fig. 1 Flow chart of literature review process conducted from May 14 to June 15, 2014

essential findings and outcomes across other studies. Subsequently, potential strengths and flaws of studies were evaluated by investigating biases such as selection, attrition, gender, experimenter double-blind paradigm, and credibility, etc. Significance of findings was assessed using p values or main effects indicated by the outcome measures of standardized tests, which were used in each of the studies. At all stages the relevance of the study and its impact to the real world was also evaluated.

The assumptions made about what constitutes good research involved looking at studies that incorporated the following: a clear purpose, relevant design (RCT—an ideal design for evaluating the effectiveness of an intervention), moderate to large sample size (enough to yield significant results), minimum bias, controlled conditions, statistically significant p values, valid, reliable, and accurate quantitative measures (to help assess the magnitude of effects through formal statistical evaluations), relevant qualitative measures (that incorporate subjective meaning, personal experiences and constructs), and lastly, a study that could be relevantly and accurately related to the real world (Greenhalgh, 1997; Burls, 2009).

Results

The research has been categorized into three major domains by the variables that were tested: (1) cognition, (2) sensorimotor performance and (3) neurobiological factors. Under each of these domains the studies are further separated into four subsections in terms of the different elderly populations that were studied: (a) healthy individuals, (b) individuals with different neurological disorders i.e. Parkinson's disease (PD), (c) dementia (D) encompassing Alzheimer's disease (AD), Confusion, Disorientation and Memory Loss (CDM), and (d) neurological Insult—Traumatic Brain Injury, stroke (NI). Some studies are repeated between the three domains as they tested more than one variable and overlapped with other domains. In order to minimize the repetition, results are split and only findings related to the specific variables are highlighted.

Cognition

A total of 21 studies investigated the effects of dance on an elderly population's cognitive performance. The aspects of cognitive function examined were selective attention, concentration, memory, intelligence, learning, language, perception, executive function, and spatial and visuospatial ability. For reasons of simplicity we also included emotion (mood)—an evaluation of experience under this category.

Healthy Individuals

Six studies examined the effects of dance on a healthy elderly population with no neurological disorders. All six were REB approved and used participant consent. Age, education and other variables were matched between groups for consistency in

evaluation and as inclusion criteria. These following intervention studies looked at the effects of multi-years of amateur or expert ballroom dancing in seniors (Kattenstroth et al., 2010; Kattenstroth, Kalisch, Kolankowska, & Dinse, 2011), Agilando ballroom dancing—a special dance program for elderly people (Kattenstroth et al., 2013), social dancing (Verghese, 2006), cultural Turkish folklore dancing (Eyigor, Karapolat, Durmaz, Ibisoglu, & Cakir, 2009) and aerobic dancing (Hui, Chui, & Woo, 2009).

The first study investigated the impact of 16.5 years of amateur ballroom dancing on cognition in a sample of 62 elderly individuals above 70 years old with a female majority ($n = 49$). Twenty-four Amateur Dancers (AMD) were compared with 38 individuals in the control group (CG) who had no previous dancing experience. It was a cross-sectional study and the variables examined were selective attention, concentration (AKT test) and general/fluid intelligence (RSPM test). An 'Indices of Performance' (IP) was used to compare the overall cognitive performance across tests. Both the test results as well as the IP scores showed stronger significant p value ($p = 0.001$) for the AMD group versus the CG group, indicating improvements in all domains of cognition tested. The authors concluded that the AMD group showed superior performance over the CG group (Kattenstroth et al., 2010).

The second study investigated the impact of more extensive ($\approx$25 years) ballroom dancing experience on cognition in a sample of 49 elderly individuals above 70 years old with a female majority ($n = 35$). Eleven individuals who had competitive experience (4 h/week training) were called Expert Dancers (ED) and were compared with 38 individuals in the CG, who consisted of sedentary individuals with no dancing experience. The ED group was extensively experienced in several ballroom dances such as slow waltz, Viennese waltz, tango, slow foxtrot, quickstep, samba, rumba, cha–cha–cha, paso doble and jive. This was also a cross-sectional study, where the experimenters used similar standardized quantitative measures as in Kattenstroth et al. (2010). Both AKT and RSPM tests were used to measure attention, concentration, and intelligence. Statistically significant results were found—better cognitive performance in the ED group compared to the CG group; AKT ($p < 0.001$) and RSPM ($p = 0.06$) (Kattenstroth et al., 2011).

The third study investigated the impact of a 6-month (1 h/week for 24 weeks) Agilando ballroom dance intervention program in a sample of 35 individuals above 65 years old with a female majority ($n = 24$), 25 of whom were randomly assigned into the Intervention group (IG) versus 10 individuals who were assigned to the control 'non-dancers' group. A pre/post-test administration design was used (tests were conducted at baseline prior to the study/intervention and after the conclusion of the study/intervention) and the experimenters conducted the tests with experimenter double-blind paradigm (experimenters' lack of knowledge about which groups the tests were being administered to) not accounted for. Apart from examining attention, concentration (AKT/FAIR) and intelligence (RSPM) using standardized quantitative measures, two other cognitive variables were tested. These were immediate and delayed memory (RBANS) and non-verbal learning (NVLT). A significant improvement in all domains of cognitive functions including the IP score ($p < 0.001$) was found. However, fluid intelligence measured by the RSPM

test did not show a significant improvement here. The authors stated that this was most likely because, unlike crystallized intelligence, fluid intelligence needs explicit training and due to the shorter intervention time period in this study (6 months) compared to the previous studies (Kattenstroth et al., 2010, 2011), fluid intelligence did not show improvements, suggesting that a higher intensity and longer period of intervention could help improve one's fluid intelligence (Kattenstroth et al., 2013).

All three studies conducted by Kattenstroth group showed significant improvements in attention, concentration, memory, and learning as a result of ballroom dancing (p values <0.05). The majority of participants in these studies were female, with an approximate age range of 60–94 years. Standardized tests were administered by the experimenters to examine general/fluid intelligence (Raven Standard Progressive Matrices—RSPM), selective attention and concentration (non-verbal geriatric concentration test—AKT and Frankfurt Attention Inventory—FAIR), memory (Repeated battery of neuropsychological status—RBANS) and non-verbal learning (non-verbal learning test—NVLT) (Kattenstroth et al., 2010, 2011, 2013).

The next study investigated the impact of social dancing on cognition in individuals age 70 and older. This study used a cross-sectional survey with two group comparison design. It investigated the effects of social dancing by comparing 24 social dancers (SD) with 84 non-dancers (ND). The majority sample size was female ($\approx$70 %) (Verghese, 2006). Research assistants administered standardized quantitative measures with a double-blind paradigm not accounted for. Episodic memory was examined using Free and Cued Selective Reminding test (FCSRT), executive functions examined using Wechsler Adult Intelligence test (WAIT), verbal fluency test (VF) and Trail Making tests (TMT), concentration examined using Blessed Information-Memory-Concentration Test, and general cognitive function examined using a neuropsychological test battery, which were all valid and reliable tests. However, the outcomes examined in this study did not show significant differences between the SD and ND groups. The author stated that this could have been due to the variability between the SD's dancing experiences. The mean duration of dancing was 36.6 $\pm$ 26.5 years and each SD self-identified as being of a different level (i.e. expert, intermediate, beginner). Another reason for the non-significant outcome as stated in the study was because both groups had a comparable level of participation in other leisure activities apart from dancing which minimized the cognitive differences. An equal number of individuals compared between the two groups and equal dancing experience in the SD group would have set a clearer and more consistent baseline for comparison and rise of significant p values. This study demonstrates the importance of control over extraneous variables when evaluating the singular effects of dance.

The final two studies looked at the effects of Turkish folkloric dance (8 week program: 60 min/thrice/week) (Eyigor et al., 2009) and aerobic dance (12-week program: 50 min/twice/week for 6 weeks $\rightarrow$ 60 min/twice/week for 6 weeks) (Hui et al., 2009) on the cognitive function of emotion. Both used a pre/post-test administration design with 19 participants in the Turkish Folklore dance intervention group and 52 participants in the aerobic dance intervention group. All the participants were above age 60 with a full female sample in the first study and a high female majority in the second. Both studies used a standardized subjective QOL

measure (SF-36 questionnaire) and found significant higher scores post-study for the intervention groups over the control groups (who did not undergo the dance interventions). The studies stated that the participants felt happier with an enhanced mood post-dance interventions.

Parkinson's Disease (PD)

Seven studies examined the effects of dance on an elderly population with Parkinson's disease. All were REB approved and used participant consent. They were age, disease, and extraneous variables matched between groups for consistency in evaluation and as inclusion criteria. These studies looked at the effects of an Argentine tango and American ballroom dance intervention (Hackney & Earhart, 2009b), a partnered and non-partnered Argentine tango dance intervention (Hackney & Earhart, 2010), a community-based Argentine tango dance intervention (Foster, Golden, Duncan, & Earhart, 2013), an Argentine tango dance intervention (Rabinovich, 2012), an adapted tango dance intervention (McKee & Hackney, 2013), dance/movement therapy (DMT) (Westbrook & McKibben, 1989) and a free form dance sequence intervention involving ballet, square dancing, and jazz steps (Westheimer, 2007).

The first study investigated the impact of a 13-week (2 h/week) Argentine tango versus American ballroom (Waltz/Foxtrot) dance intervention program in a sample of 58 participants above age 60, with a male majority (60 %). It was a randomized, between-subjects, prospective, repeated-measures design with pre/post-test administration conducted by the experimenters who maintained the double-blind paradigm for test ratings. A subjective exit questionnaire and a qualitative videotape analysis were used to assess participants' moods. Participants who underwent dance interventions involving Argentine tango and American ballroom both showed an overall improvement in mood and reported increased enjoyment compared to the CG (no intervention) who did not show these outcomes. This indicated that both Argentine tango and American ballroom dancing had a positive impact on mood (Hackney & Earhart, 2009b).

In the same way, improvement in mood was also observed with a 10-week (2 h/week) partnered versus non-partnered Argentine tango dance intervention program in a sample size of 31 participants involving both genders above age 60, with a male majority ($n = 26$). The participants were randomly assigned into partnered versus non-partnered groups. It was a between-subjects design with a pre/post-test administration conducted by certified experts who maintained a double-blind paradigm for test ratings. A subjective exit questionnaire and a qualitative videotape analysis were performed. Higher enjoyment and enhancement of mood was reported by the partnered Argentine tango group which showed that Argentine tango dancing was even more beneficial when done with a partner, highlighting the importance of social interaction. This study shows how dance in its multifaceted forms naturally helps cultivate a positive social climate (Hackney & Earhart, 2010).

Another study reported similar enhancement in mood and enjoyment following a 12-month (2 h/week) community-based Argentine tango dance intervention program. Participants showed a willingness to participate in future dance programs.

This was a single blind RCT with 52 participants above age 60 involving an almost equal distribution of both genders in the tango group versus control (no intervention). A subjective standardized measure known as the Activity Card Sort was used (Foster et al., 2013). The findings from this study supported Hackney and Earhart's (2009b, 2010) previous studies.

In addition, a study conducted by Rabinovich (2012) investigated the benefits and meanings that a 16-week (90 min/week) Argentine Tango intervention had in the healing process of a sample of six participants above age 60, with a higher female sample size ($n = 4$). It was a qualitative study that used post-intervention test design in the form of in-depth interviews to capture the participants' mood and qualitative responses—experiences and perception—to the program. A clinical psychologist conducted these interviews but a double-blind paradigm was not employed. There was no CG in this study. Participants showed very positive perceptions of the program, an enhanced mood and stated that they highly enjoyed it. It had an extremely high self-reported impact in adherence, continuity and desire to use tango movements as a strategy to be applied in activities of daily living. They found a peer support group that prompted bonding and togetherness, promoting better coping with Parkinson's disease. The findings from this study also support the qualitative findings from the studies mentioned above (Rabinovich, 2012).

A study done by McKee and Hackney (2013) examined the effects of a 12-week (90 min/twice/week) community based adapted tango dance intervention program on spatial cognition and executive function in a sample size of 33 elderly individuals above age 60 with an equal gender distribution. It was a RCT with a between subjects design, which used a pre/post-test administration, conducted by trained raters who maintained a double-blind paradigm for test ratings. Significant improvements in spatial cognition and executive functions were found for individuals with PD who underwent the intervention (p values $= 0.021,\ 0.012$). These factors were measured using two valid, reliable and standardized quantitative tests—The Brooks Spatial Task for Spatial cognition and MoCA (Montreal Cognitive Assessment) for executive function (McKee & Hackney, 2013). This study showed that adapted tango had positive effects on both spatial cognition and executive functions in the elderly.

Another study evaluated the effect of DMT sessions with elderly individuals with Parkinson's disease. Dance/movement therapy is distinct in its emphasis on mind–body connections through dance/movement, and the interventions focused on individual movement vocabularies over learned movement sequences or a particular style as in other dance forms. The intervention was conducted by trained dance/movement therapists and done over a 6-week period (1 h/week) in a sample of 30 individuals above age 60 using a crossover design where both genders participated. The DMT group was called the therapy group and compared to the CG undergoing an exercise program. It was hypothesized that DMT would have a greater impact on mood and movement initiation than exercise, as dance/movement therapists are trained to address the psychological symptoms which accompany a loss of movement potential. A pre/post-test administration design was used for certain measurements with a qualitative assessment (videotaping) done by professional photographers while a neurologist was hired to keep a check on the

PD symptoms. Subjective improvements in mood were apparent through qualitative assessments such as family members' and authors' observations, and participants' self-reports (Westbrook & McKibben, 1989).

Finally, a study looked at the effect of a 17-month (1 h/15 min/week) dance intervention which employed free form dance sequences involving ballet, square dancing, and jazz steps, conducted at the barre, in the center, and moving across-the-floor, specifically designed by the Mark Morris Dance Group (MMDG) and the Brooklyn Parkinson Group (BPG) for 15 individuals with PD. During the across the floor part, a memorized, choreographed sequence was taught which usually included ballet, modern, square dancing, Broadway and jazz steps and/or repertoire. The researchers administered the Oregon Health and Sciences University version of the Quality of Life Scale (QOLS) post-intervention (an experimenter double-blind paradigm was not employed) to investigate the participants' perceived effects of dance and what the participants appreciated most about their experiences. They found that the second item of the Questionnaire—'Health—being physically fit and vigorous' received the highest response. The author concluded that this was because feeling better physically stemmed from a combination of both physical activity and a heightened mental activity engaging imagination and emotions, all offered through the dance program (Westheimer, 2007).

Dementia (D)

Seven studies examined the effects of dance in elderly individuals with dementia, which also included subjects with Alzheimer's disease (AD) and those with confusion, disorientation, and memory loss (CDM). These studies were REB approved and used participant consent. They were age, disease, and extraneous variables matched between groups for consistency in evaluation and as inclusion criteria.

The studies looked at the effects of dance as a leisure activity (Verghese et al., 2003), the effects of DMT intervention (Hokkanen et al., 2008), social dancing (Palo-Bengtsson & Ekman, 2002), circle dancing (Hamill, Smith, & Röhricht, 2012), Latin ballroom—Danzon dancing (Guzmán-García, Mukaetova-Ladinska, & James, 2013), waltz ballroom dancing (Rösler et al., 2002) and dance combined with Reality Orientation (RO) intervention (Bumanis & Yoder, 1987).

The first study investigated the association between leisure activities (dancing, reading, playing board games, playing musical instruments etc.), cognitive function and the risk of dementia in a sample of 469 subjects above age 70, with a female majority (64 %). Subjects with dementia at baseline were ruled out in order to obtain a clearer association between cognitive activity and risk of dementia. It was a correlation study that ran for 21 years and used a cox proportional-hazards analysis with pre/post-test administrations done by study clinicians who maintained an experimenter double-blind paradigm for ratings. Concentration, executive function and episodic memory were all measured using standardized measures; Blessed Information-Memory-Concentration test, Wechsler Adult Intelligence Scale and Fluid Object Memory Evaluation (which were seen to be used in the previous studies as well). Significant p values were produced for subjects in whom dementia

did not develop. The most important finding was that among all other leisure activities, dancing was the only physical activity that showed a significant association with a lower risk of dementia. This study did not mention which form of dancing was investigated (Verghese et al., 2003). Overall, it was a strong study that examined a large population for 21 years using standardized variables, test/retest reliability and studied both male and female populations, controlling for accretion bias and using a double-blind paradigm.

The second study investigated the effects of a 9-week (30–45 min/week) DMT intervention in a sample of 29 participants with dementia, above age 70 with a female majority (76 %). It was a RCT where the control group did not undergo the 9-week DMT intervention. The DMT sessions composed of a consistent structure involving warm-up, theme development, and closure. The researchers conducted a pre/post-test administration but experimenter double-blind paradigm was not accounted for. A standardized quantitative Mini Mental State Examination (MMSE) was used to investigate cognitive impairment at baseline, week 5, week 9 and week 13 (follow up) and a standardized cognitive based test known as the Clock Drawing test showed significant improved scores post intervention indicating improvements in visuospatial ability and planning (Hokkanen et al., 2008).

The third study investigated the effects of social dancing (45 min/month) in six individuals with dementia who were above age 80 and admitted at a nursing home in Sweden; four males and two females. The study does not state how long (duration) this intervention lasted. It was a qualitative study that recorded observational data using videotaping and cameras to study body engagement, subjects' moods and emotions in a social dancing condition versus walking condition (20–45 min organized walks). The study was mainly conducted to evaluate the subject's emotional response to social dancing, which was analyzed by the researchers using a descriptive phenomenological method. The findings showed an improved and higher emotional reaction to social dancing compared with walks (Palo-Bengtsson & Ekman, 2002).

The fourth study was conducted to investigate the effects of a 10-week (45 min/week) circle dancing intervention in a sample of 18 subjects with dementia, with a female majority ($n = 72$ %) who were above age 70. Only ten subjects attended the intervention while the rest were used as the control group for data comparisons. The study used a pre/post-test administration design conducted by the researchers with an experimenter double-blind paradigm not accounted for. Standardized quantitative assessments such as the Mini Mental State Examination (MMSE), Quality of Life Scale in Alzheimer's disease (QOL-AD) and General Health Questionnaire (GHQ-12) were used to measure cognitive function and subjective qualitative assessments such as progressive monitoring sheets, interviews and general observations were performed to assess the change in mood over the duration of the intervention. The findings showed an improvement in cognitive function and mood (Hamill et al., 2012).

The fifth study involved the investigation of a 6-week (35 min/twice/week) Latin ballroom (Danzon) dance intervention in 13 elderly individuals above age 70, with a higher female sample size ($n = 10$). It was a qualitative study with a grounded theory methodology led by post intervention interviews, conducted by the

experimenters. The findings showed an improvement in mood and an enhancement in the group's positive emotional states (Guzmán-García et al., 2013). The study's qualitative results could have been enhanced with quantitative analysis for a more robust evaluation of the effects of Latin ballroom dancing in participants with dementia.

The sixth study investigated the effect of a 12-day (30 min) waltz ballroom dance intervention in five participants with Alzheimer's disease who were above age 70. Gender distribution was not mentioned. It was a qualitative study where an independent filmmaker videotaped sessions and individual, certified dance therapists who were blinded of the participant's conditions rated the video clips. The Alzheimer's group was compared with another group (five age-matched participants with depression). The Alzheimer's group made substantial progress in their dancing scores and significant improvements were found in procedural learning—an important aspect of cognitive function (Rösler et al., 2002).

The last study examined the effects of a 2-week (30 min/5 days/week) dance combined with Reality Orientation therapy (RO) intervention in a sample of 15 participants above age 60, with a female majority ($n = 13$). These participants were diagnosed with confusion, disorientation, and memory loss (CDM). It was a RCT with a pre/post-test administration design conducted by the experimenters and an experimenter double-blind paradigm was not accounted for. The standardized Goldfarb Rating Scale test was used which included a subjective Mental Status Questionnaire. A large number of reduced errors on this scale were seen for the intervention group than the CG who did not undergo the intervention. The findings from subjective, descriptive narratives showed an overall improvement in mood and emotions (Bumanis & Yoder, 1987). A major weakness of this study was that it examined the effects of dance mixed with RO therapy and therefore the findings cannot be claimed to be due to dance alone. This study does not help identify what dance in its entirety achieved and whether the effects were solely due to dance or Reality Orientation.

Neurological Insult: Traumatic Brain Injury, Stroke (NI)

Only one study examined the effects of dance on an elderly population with TBI and stroke. This study was REB approved and used participant consent. It investigated the impact of a 5-month (45 min/week) DMT intervention in a sample size of 107 elderly individuals above age 60, with a slightly higher female majority (62.9 %). It was a RCT with a pre/post-test administration design conducted by trained and experienced dance/movement therapists who were not involved in the intervention in order to minimize experimenter bias. Participants were of mixed ethnicities, a similar distribution of both genders in the intervention as well as the control group and controlled for attrition, a double-blind paradigm and confounding variables. Valid and standardized quantitative assessments such as Cognitive performance scale (CPS) and two mood scales; Geriatric Depression Scale (GDS) and Minimum Data Set (MDS) were used. Cognitive Performance Scale results were significant for the intervention group over the CG who did not undergo the DMT intervention ($p = 0.0006$). A qualitative videotaped review was also conducted to support the

quantitative findings and showed an enhancement in mood and positive emotion. However, the other quantitative measure (GDS) did not show a significant improvement from the control group. The study stated that this was most likely because the GDS cut off points disclosed that participants were not depressed at baseline levels and so statistical significant improvement in mood was altogether ruled out to be an expected outcome (Berrol, Ooi, & Katz, 1997).

Overall this was a strong study that supported the positive effects of DMT on NI participants as it minimized biases such as selection (mixed ethnicities were considered), gender (there wasn't an extreme majority of females or males being studied), attrition (subjects who did not complete the program were eliminated from the study and their data wasn't used), experimenter (experimenter double-blind paradigm maintained) and used a control group for a clear comparison between intervention and control settings.

Sensorimotor Performance

A total of twenty-seven studies were found that investigated the effects of dance on an elderly population's sensorimotor performance—static and dynamic balance, posture and gait, tactile performance, motor performance—mobility, speed, steadiness, aiming, pin plugging, tapping, freezing and reaction times.

Healthy Individuals

Fifteen studies examined the effects of dance on a healthy elderly population with no neurological disorders. All were REB approved and used participant consent. They were age, education and extraneous variables matched between groups for consistency in evaluation and as inclusion criteria.

These studies looked at the effects of multiple years of amateur and expert ballroom dancing (Kattenstroth et al., 2010, 2011, 2013), Latin ballroom—Danzon dance intervention (Guzman-Garcia, Johannsen, & Wing, 2011), aerobic dance interventions (Hopkins, Murrah, & Hoeger, 1990; Shigematsu et al., 2002; Hui et al., 2009), cultural dance interventions—traditional Greek (Sofianidis, Hatzitaki, Douka, & Grouios, 2009), Argentine tango (McKinley et al., 2008), Caribbean (Federici, Bellagamba, & Rocchi, 2005), Turkish folkloric (Eyigor et al., 2009), and others—social dance intervention (Verghese, 2006), contemporary dance intervention (Keogh, Kilding, Pidgeon, Ashley, & Gillis, 2009) and jazz dance interventions (Alpert et al., 2009; Wallmann, Gillis, Alpert, & Miller, 2009).

Among the above, the studies conducted by Eyigor et al. (2009), Hui et al. (2009), Kattenstroth et al. (2010, 2011, 2013), and Verghese (2006) were described earlier under the 'Cognition' domain. These studies examined the effects of the dance interventions on both cognitive functions in healthy elderly individuals as well as 'Sensorimotor performance.' Due to the overlap, only the findings relevant to this domain will be described; these studies will not be introduced again under this section.

Kattenstroth et al. (2013) intervention study looked at the participants' sensorimotor functions—posture and balance (using force platform, assessing

subject's centre of pressure—COP), tactile performance (using touch threshold and two-point displacement threshold, haptic object recognition), motor performance—steadiness, aiming, pin plugging and tapping (using computer based test battery for all), reaction time (using finger selection reaction time task) in a pre/post-test administration design. All assessments were standardized, valid, and had test/retest reliability. Results showed that the intervention group significantly improved in all domains ($p = 0.001$), unlike the control group. Overall, indices of performance i.e. Individual Performance (IP) across all tests was measured (1 = best IP and 0 = worst IP). Subjects in the intervention group showed a significant IP > 0.5 (Kattenstroth et al., 2013). Similar significant findings were also found in Kattenstroth et al. (2010, 2011) studies.

In the 2010 study, the control group had more subjects with poor performance in the tested domains than the experienced amateur dancers group (Kattenstroth et al., 2010). For both of the 2010 and 2011 studies better posture, balance, motor performance and reaction times were observed in the amateur and expert dancers group. However, tactile performance did not show a significant difference from the control group. The authors stated that this could have been because tactile abilities are a non-expertise related domain. Therefore, poor performers were present in both the intervention and control groups that caused a lack of significant difference between the groups. The study stated that non-expertise related tasks such as tactile performance show a decline in performance with age. Thus, in order to counteract this, optimum level of dance training is needed that is tailored to achieve maximum benefits in all domains of sensorimotor performance (Kattenstroth et al., 2011).

A study by Guzmán-García et al. (2011) examined the effects of another form of ballroom dancing on the sensorimotor performance—balance in the elderly. It investigated the effects of a 30-minute Latin ballroom dancing (Danzon) intervention on functional balance in a sample of ten participants, with a female majority ($n = 9$) above age 60. Participants were recruited in five pairs and a pre/post-test administration was done. There was no CG used in this study. An optoelectronic motion tracking system was used by the experimenters to capture the participants' body sway kinematics. An experimenter double-blind paradigm was not mentioned. Findings showed a significant reduction in body sway ($p < 0.05$) after the Danzon class, indicating the beneficial effect of Danzon training for improving balance in the elderly (Guzmán-García et al., 2011).

Apart from investigating the effects of different types of ballroom dancing interventions, some studies were found that examined the impact of aerobic dance interventions on healthy elderly individuals' sensorimotor performance.

Hopkins et al. (1990) investigated the effects of a 12-week (50 min/thrice/week) low impact aerobic dance intervention on balance and motor control in a sample of 65 elderly women above age 60. It was a RCT with pre/post-test administration conducted by the experimenters where 35 participants were randomly assigned to the experimental group who underwent the intervention while the remaining 30 were assigned to the CG who did not undergo the intervention. This study did not account for experimenter double-blind paradigm. Standardized quantitative measures were used—balance was assessed using the 1-foot stand test while motor control was assessed using the soda pop test—a test where three standard 12-ounce

cans of soda pop are placed in circles and told to be placed upside down on the adjacent circles then back again. A significant improvement in balance was seen in the experimental group ($p < 0.01$) unlike the control group. However, motor control and coordination did not show a significant difference between the groups. The study stated that this could have been because the intervention program did not conduct activities that specifically trained for motor control and coordination with hands (Hopkins et al., 1990). The outcome was similar to the Kattenstroth et al. (2010, 2011) study where the authors suggested a special tailored or optimum level of dance training for improvement in tactile-based performance for the elderly. This seems to show that regardless of dance type, be it ballroom or aerobic, tactile-based training needs to be incorporated in dance intervention programs for an improved motor control, coordination with hands and tactile-based performance in the elderly.

Similar findings were seen replicated in another study which investigated the effects of a 12-week (60 min/thrice/week) dance based aerobic exercise intervention on balance, locomotion/agility and motor processing in 38 elderly women above age 60. This was a sample of Japanese participants versus the American participant sample used in the study above. It was also a RCT with pre/post-test administration conducted by the experimenters (experimenter double-blind paradigm not considered) where participants were randomly assigned into experimental and control groups. Standardized quantitative tests such as single leg balance and 3-min walk tests were used to assess balance and motor performance. Post study results showed significant improvements in balance and locomotion/agility ($p < 0.05$). However, changes in motor processing "i.e. hand reaction time and foot tapping" were not statistically significant. The authors suggested the same explanation as seen before, which was linked to the dance program itself that did not specifically train to improve motor performance (Shigematsu et al., 2002). The different cultural samples are important because they show similarity in findings and reinforce study outcomes across cultures.

In contrast, a third study investigated the effects of a 12-week (50 min/twice/week for 6 weeks → 60 min/twice/week for 6 weeks) low impact aerobic dance program on balance and motor performance in a sample of 111 participants above age 60 with a female majority (96.2 %). This study was conducted in China and participants were recruited from the social centers for seniors located in Hong Kong. It was a RCT which consisted of an intervention group and a control group and used a pre/post-test administration design that was conducted by the experimenters who maintained experimenter double-blind paradigm for test ratings. They used standardized, valid, and reliable quantitative tests such as TUG (Timed Up and Go), Sit and Stand test, 6MWT (6 min walk test) and obtained significant p values post study ($p = 0.01$, $p < 0.001$, $p < 0.001$). A significant improvement was not only found in dynamic balance but also in motor performance. This difference could have been due to the fact that this study used a large sample size, much larger than the other studies and was overall a strong study that controlled for attrition bias, confounding variables, experimenter double-blind paradigm and credibility of dance instructor and test administrators, which were all considered and maintained. Standardized tests were also used (Hui et al., 2009).

Apart from ballroom and aerobic type dance interventions, some studies also investigated the impact of cultural dance interventions—traditional Greek, Argentine tango, Caribbean, Turkish folkloric on healthy elderly individuals' sensorimotor performance. Mostly balance and motor performance variables were tested.

Sofianidis et al. (2009) investigated the effects of a 10-week (60 min/twice/week) traditional Greek dance intervention program on static and dynamic balance in a sample of 26 participants above age 60, with a female majority ($n = 20$). This RCT incorporated both intervention ($n = 14$) and control groups ($n = 12$) and used a pre/post-test administration design conducted by the experimenters with experimenter double-blind paradigm not mentioned. Standardized quantitative Romberg test was administered for assessing static balance while a weight shifting task was carried out to assess dynamic balance. A significant improvement was seen ($p < 0.05$) on both variables at the end of the study indicating that Greek dance was an effective intervention for improving balance in the elderly (Sofianidis et al., 2009).

In the same way, a study investigated the effects of a 10-week (2 h/twice/week) Argentine tango dance intervention program on functional balance in a sample of 30 elderly participants above age 60. It was a RCT with an intervention group ($n = 14$, underwent the intervention) and a control group ($n = 10$, walk group who did not undergo the intervention) with genders equally distributed between the groups, minimizing gender bias. Pre/post-test administrations were conducted by a physical therapist that was blind to the participants' treatment status, minimizing experimenter bias. Standardized and valid physical performance tests were conducted and showed a significant improvement on functional balance post study for the intervention group ($p < 0.001$), indicating the positive effects of Argentine tango on functional balance in the elderly (McKinley et al., 2008).

A study investigated the effects of a 3-month (60 min/twice/week) Caribbean dance intervention program on balance in a sample of 40 elderly individuals above age 60 with a female majority ($n = 26$). It was a RCT with 20 participants in each group—intervention group versus control group and used a pre/post-test administration design conducted by researchers who maintained experimenter double-blind paradigm when testing. Four standardized balance tests were incorporated: Tinneti, Romberg, Improved Romberg, Sit-up-and-Go, all of which showed a p value <0.001, which demonstrated a significant improvement in balance for the intervention group versus the control group, which did not show any significant changes. This study showed that Caribbean dancing was also an effective intervention for improving balance (Federici et al., 2005).

Another study investigated the effects of an 8-week (60 min/thrice/week) group-based Turkish folkloric dance intervention on balance and motor performance in a sample of 40 elderly women above age 65. It was a RCT with sample equally divided between the intervention and control groups. Certified physicians who maintained experimenter double-blind paradigm when testing conducted a pre/post-test administration. Standardized quantitative measures such as the Berg's Balance Scale (BBS), motor performance based tests—6 min walk test (6MWT), stair climbing test and chair rise tests were administered to measure changes in balance and motor performance. A statistically significant improvement ($p < 0.05$) was seen

in balance and motor performance post study for the intervention group over the control group where no statistically significant changes were found in these variables. This study showed the beneficial effects of Turkish folkloric dancing on sensorimotor performance—balance and motor performance, in the elderly (Eyigor et al., 2009).

Other forms of dance interventions were also studied—social dancing, modern contemporary dancing and jazz dancing. The Verghese (2006) study, which was introduced under the 'Cognition' domain, also investigated sensorimotor performance in the healthy elderly participants—balance, gait and motor performance was evaluated. The 24 experienced social dancers (SD) had significantly better balance ($p = 0.08$), gait and motor performance—reduced stance time, longer swing time and shorter double support time (reflection of a more stable walking pattern), compared to the non-dancer (ND) group. Both balance and gait were measured using standardized, valid, and reliable quantitative measures as well as an objective assessment tool—GAITRite (computerized gait mat) and a physical performance battery tests (PPB) (Verghese, 2006). The results of this study showed that social dance can positively impact aspects of sensorimotor performance in the elderly population who have social dancing experience compared to a sample with no social dancing experience.

Keogh et al. (2009) investigated the effects of a 6 month (50 min/twice/week) modern contemporary dance intervention program on balance and motor performance in a sample of 60 elderly participants above age 70, with a female majority (93.7 %). It used a crossover design where the participants were divided into three groups—intervention, crossover control group (12 weeks dance followed by no dance) and control group. The researchers conducted a pre/post-test administration design and experimenter double-blind paradigm was not mentioned in the study. Due to inconsistency in attendance during the program, effects of the dance intervention were compared between those who attended once a week versus twice a week. Participants who underwent the dance intervention program showed improved balance and motor performance ($p = 0.037$) using Four Square Step test (FSST). However, the two other balance and motor performance tests—Timed Up and Go (TUG) and Repeated Chair Raise (RCR) did not yield statistically significant values. All the tests used were standard, valid and reliable quantitative measures. However, only FSST ended up showing a significant improvement (Keogh et al., 2009). This was due to the inconsistency in settings used—participants were given more rest period before conducting FSST assessment than TUG and RCR, which could have affected the result. This calls for caution in future studies where the researcher must maintain consistency in order to yield accurate and consistent results.

Wallmann et al. (2009) investigated the impact of a 15-week (90 min/week) jazz dance intervention on static balance in a sample of 12 elderly women, eleven of whom were above age 60. All women underwent the intervention and no CG was used. A pre/post-test administration design was conducted by a certified physical therapist and experimenter double-blind paradigm was not mentioned in the study. Balance was measured using Smart Balance Master System's Sensory Organization Test (SOT) protocol, a computerized objective, and quantitative test unlike the

subjective clinical assessments used in most studies. The participants showed a statistically significant improvement post study ($p < 0.05$), indicating the positive effects of jazz dancing on static balance in the elderly (Wallmann et al., 2009).

The findings from the above study were supported by Alpert et al. (2009), which investigated the effects of a 15-week (details per week and for time were not mentioned) jazz dance intervention in 13 elderly women above age 60. All 13 women underwent the intervention and no CG was used in this study as well. The researchers conducted a pre/post-test administration design and experimenter double-blind paradigm was not mentioned. This study also used SOT to measure balance and found a significant increasing trend from baseline to post study ($p < 0.001$) showing improved static balance as a result of jazz dancing (Alpert et al., 2009).

Parkinson's Disease (PD)

Ten studies were found that examined the effects of dance on an elderly population with PD. All were REB approved and used participant consent. They were age, disease, and extraneous variables matched between groups for consistency in evaluation and as inclusion criteria.

A series of five studies conducted by Hackney et al. (2007), Hackney and Earhart (2009a, 2009b, 2010), McKee and Hackney (2013) investigated different forms of tango dance interventions on PD participants' sensorimotor performance. Other studies investigated the effects DMT intervention (Westbrook & McKibben, 1989), mixed dance routine intervention (Heiberger et al., 2011), modern dance interventions (Batson, 2010; Marchant et al., 2010) and cultural dance—Irish set dance intervention (Volpe, Signorini, Marchetto, Lynch, & Morris, 2013).

Among these, three of Hackney and Earhart studies (2009b, 2010) and one Westbrook and McKibben (1989) study were introduced and discussed earlier under the "Cognition" and "PD" domain. Hence, only their relevant findings will be discussed in this section. The studies overlap with this section due to their investigation on sensorimotor performance variables.

The first study (Hackney et al., 2007) investigated the impact of a 13-week (60 min/twice/week) Argentine tango dance intervention versus regular exercise intervention program on the motor performance, balance, and freezing of gait in a sample of 19 elderly participants with PD above age 60, involving a distribution of both genders with a male majority ($n = 12$). It was a RCT with the exercise group used as control ($n = 10$) and compared with the intervention group ($n = 9$). A pre/post-test administration design was used where tests and ratings were conducted by certified professionals such as a physical therapist who was blinded to the treatment conditions. Standardized, valid and reliable quantitative measures were used—Unified Parkinson's Disease Rating Scale (UPDRS), Timed Up & Go test (TUG), Berg's Balance Scale (BBS), and Freezing of gait self-reported questionnaire to measure motor performance, balance, gait and freezing. Post study results showed significant improvements on the UPDRS motor subscale ($p < 0.001$) for both groups. However, only the tango group showed an upward trend for the TUG scores and a significant improvement in balance (BBS scale yielded a significant

main effect $p = 0.01$), unlike the exercise group. Both groups showed a reducing trend in freezing of gait but this wasn't statistically significant. This could have been because it was a self-reported subjective measure. Complementing this questionnaire with a clinician rated assessment would have helped yield consistency in ratings (controlling for bias and experimenter double-blind paradigm) and a statistically significant value. Overall, this study showed the positive benefits of one type of dance intervention over regular physical exercise intervention in elderly with PD.

The second study (Hackney & Earhart, 2009a) investigated the effects of a 2 week (1.5 h/5 days/week) short duration intensive Argentine tango dance intervention program on the balance, motor performance and gait in a sample of 12 elderly participants with PD, above age 60 with a high male majority (67 %). It was a within subjects, prospective, repeated measures design with a pre/post-test administration conducted by the experimenters with experimenter double-blind paradigm not considered as there was only an intervention group and no control group. Similar standardized measures were used as in the previous studies except an extra objective based measure was added—instrumented, computerized GAITRite walkway for measuring gait. Post study results showed significant improvements in balance (BBS score $p = 0.021$) and mobility (UPDRS score $p = 0.029$). An upward trend and improvement was found in gait (forward and backward) but for the TUG and 6MWT scores, it was non-significant. This shows that an intensive Argentine tango intervention is beneficial for balance and mobility, however not enough to show a significant improvement in TUG, 6MWT and gait. Perhaps a longer intervention could help improve on these variables, as in Hackney et al. (2007) and Hackney and Earhart (2009b). Also, as stated in the study there were certain limitations in the research design such as absence of a CG (this led to a selection bias for the intervention group) and lack of a larger sample size. Controlling for these limitations could help yield more accurate results (Hackney & Earhart, 2009a). Overall, this study showed that Argentine tango intervention was feasible as a short duration therapy for improving balance and mobility in the elderly but was found to be less useful for motor speed and functional motor capacity.

The next three studies conducted by Hackney and Earhart (2009a, 2010) and a fourth study conducted by Westbrook and McKibben (1989) were described earlier under 'Cognition'.

The Hackney and Earhart (2009b) study found similar findings as the (2007) study above. Of the Argentine tango intervention group and the American ballroom (Waltz/Foxtrot) group, both improved post dance intervention in balance and motor performance as seen by BBS and 6MWT tests. However, the Argentine tango group was found to improve more on these measures compared to the American ballroom group, showing that Argentine tango might better address deficits associated with PD.

The Hackney and Earhart (2010) study which investigated the effects of partnered versus non-partnered Argentine tango dance intervention also found significant improvements in BBS and 6MWT scores as well as comfortable and fast-as-possible walking velocity. The study showed that both partnered and non-

partnered tango helps positively benefit an elderly individual's balance, motor performance and gait. The added benefit of partnered tango was that it had the social aspect included which increased motivation in the elderly for participating in such dance interventions. Overall, this study showed that both forms of dance intervention are equally beneficial in terms of improving elderly with PD's sensorimotor performance.

McKee and Hackney (2013) study which examined the effects of a slightly different form of tango—this community based adapted tango dance intervention program investigated balance and mobility in a sample of 33 elderly individuals above age 60 with an equal gender distribution. Statistically significant improvements were found post intervention for balance and motor performance using standardized assessments—BBS and UPDRS. This study included an equal number of male and female participants preventing gender bias, showing that the beneficial effects of adapted tango can be generalized to both male and female elderly populations with PD.

The next study conducted by Westbrook and McKibben (1989) investigated the effects of DMT intervention in individuals with PD. A significant improvement in motor performance—walking speed, for the intervention group ($p < 0.001$) was found. This was assessed by a subjective standardized neurological assessment—Hoehn & Yahr's method for staging of Parkinson's disease, and yielded a statistically significant improvement (Westbrook & McKibben, 1989).

The next three studies investigated either short term effects or short duration interventions. In the first, Heiberger et al. (2011) conducted a study that investigated the short term effects of an 8 month (once/week) mixed dance routine intervention (involving ballet, jazz steps, contemporary dance, and dance theatre) on the sensorimotor and motor performance in 11 elderly participants, ten out of whom were above age 60 with 6 females and 5 males. The short-term effects involved testing participants' immediately after each dance class. This study was not a RCT and there was no CG used. Pre/post-test administration was conducted by the experimenters and certified neurologist who maintained experimenter double-blind paradigm for test ratings. Standardized quantitative measures—UPDRSIII, TUG and SeTa (Semitandem) were used for measuring motor performance, speed, balance and posture, backed up with a qualitative measure—videotaping for motor evaluation. Significant results were found in UPDRS motor scores ($p = 0.001$) with strongest positive effects seen in rigidity scores ($p = 0.002$), hand movements ($p = 0.002$), finger taps ($p = 0.02$) and facial expressions ($p = 0.01$). A trend towards improvement was found for TUG but it did not yield significant results just like the results seen for the SeTa scores. This shows that the mixed dance routine which incorporated various dance forms—ballet, jazz steps, contemporary dance and dance theatre improved participants' motor performance significantly but not speed, balance, and posture. The study states the non-significant results for the speed, balance, and posture could have been due to the tiredness felt immediately after class which could have affected these variables (Heiberger et al., 2011). This is an interesting observation as it shows the importance of test administration times—post dance class versus after a dance intervention program. Therefore, researchers

must be cautious about the times when assessments are administered before making robust conclusions about their research findings.

The second study of short duration intervention, by Batson (2010), investigated the effects of a 3-week (85 min/thrice/week) intensive modern dance intervention on balance and motor performance—speed in a sample of 11 participants above age 60 with 6 females and 5 males. Like the previous study the sample size and gender distribution were similar and it was not a randomized control trial. Pre/post-test administration was conducted by certified physical therapists who maintained experimenter double-blind paradigm for test ratings. Two standardized quantitative measures were used; Fullerton Advanced Balance Scale—for measuring balance and TUG—for motor speed. While a significant improvement was found in balance ($p < 0.05$), motor speed did not yield any significant improvements post intervention. The TUG outcome was similar to the one seen in Hackney and Earhart (2009a) study where they too tested the effects of an intensive dance intervention (Argentine tango). This supports the idea that a longer intervention could help improve TUG scores significantly than short term intensive interventions. Long term less rigorous interventions (once per week etc.) could significantly improve walking speed such as observed in Hackney et al (2007), Hackney and Earhart (2009b) studies where a 13 week once and twice per week intervention was used, regardless of the specific dance form/type. The author of this study states that lack of significance in TUG scores and therefore walking speed could have also been because a small sample was tested among which few had recently fallen at home and were witnessing leg pains. Using a larger sample would have helped eliminate these outliers and yield more accurate results (Batson, 2010).

The third study was done to investigate the effects of a short duration, intensive dance intervention, which looked at contact improvisation partnered modern dance (2 weeks: 1.5 h/5 days/week) in a sample of 11 participants above age 60, with a female majority (64 %). It was not a RCT and pre/post-test administration was conducted by the researchers with experimenter double-blind paradigm not mentioned. Standardized measures were used—UPDRS, TUG, 6MWT, BBS and GAITRite walkway to measure motor performance, balance and gait. Significant improvements were seen in UPDRS, BBS scores, forward stance and swing percentages ($p < 0.05$) indicating better motor subscale, balance and gait. However, as seen in previous studies (Hackney & Earhart, 2009a; Batson, 2010; Heiberger et al., 2011), TUG scores were not significant as a result of a short duration intensive dance intervention, nor were the 6MWT scores (Marchant et al., 2010). These suggest that long term less intensive interventions are needed to significantly improve motor speed and functional motor capacity.

Unlike the previous short intensive dance interventions, a study investigated the effects of a long term 6-month (1.5 h/once/week) Irish set dancing intervention program in a sample of 24 participants above age 60, with 13 males and 11 females. It was a RCT with pre/post-test administration conducted by trained assessors who maintained experimenter double-blind paradigm for test ratings. An equal number of participants ($n = 12$) were assigned to the intervention group (Irish set dancing group) and control group (routine physiotherapy) and variables such as mobility, walking speed, balance and freezing of gait were measured using standardized

assessments—UPDRS, TUG, BBS and FOG. All showed a statistically significant outcome ($p < 0.05$) indicating an improvement in all variables as a result of a long term dance intervention program (Irish set dancing). The CG also showed such improvements but the intervention group yielded statistically significant superior results (Volpe et al., 2013). This may indicate that Irish set dancing is well suited to working with this population, or that long term interventions are more effective than short term ones. It would be interesting to examine this difference.

Dementia (D)

Only one study investigated the effects of dance on the sensorimotor performance of an elderly population with dementia. Abreau and Hartley (2013) investigated the effects of a 12 week (1 h/twice/week) salsa dance intervention on the motor performance, balance and gait in an elderly woman aged 84 years old with Alzheimer's disease. The intervention was conducted by a physical therapist who had previous experience in salsa dancing steps and instruction. A pre/post-test administration was conducted by the experimenters who used standardized assessments such as TUG, 10 m walk test, 6MWT and BBS. Improvements were seen in all variables post intervention indicating that salsa dance had a positive effect on mobility, speed, balance and gait in the individual. This study calls for a replication of results in a larger sample size in order to yield statistically significant results (Abreu & Hartley, 2013).

Neurological Insult: TBI, Stroke (NI)

Only one study examined the effects of DMT on the sensorimotor performance of an elderly population with Traumatic Brain injury. This study was previously described under 'Cognition' section of this paper. It was REB approved and used participant consent. The experimental group was comprised of individuals who had sustained some type of non-progressive neurotrauma. Persons with progressive dementias such as Alzheimer's disease or neurological conditions such as Parkinsons' were excluded. The study investigated the effects of DMT intervention on sensorimotor performance by using a standardized quantitative measure, Functional Assessment of Movement and Perception (FAMP), which showed statistically significant post intervention improvements in perceptual motor ability, dynamic balance, backward and sideward walk ($p < 0.05$) for the intervention group over the control group. These findings were corroborated by qualitative data obtained from the dance/movement therapists' summative reports, which chronicled increased physical ambulation of subjects for progressively longer periods. Subjects in the experimental group also had higher total mean scores on another quantitative scale, the Frailty in Injuries Cooperative Studies Intervention Techniques Battery (FICSIT). This indicated that DMT is both useful and beneficial for improving sensorimotor related activities in elderly individuals with TBI and stroke (Berrol et al., 1997).

Neurobiological Factors

A total of seven papers were found including commentaries and other relevant reviews, which talked about the effects of dance on neurobiological factors—brain growth factors, neurotrophins, neurotransmitters, proteins, and genes. These investigations were mostly with a healthy population.

Healthy Individuals

Seven papers reported the effects of dance on neurobiological factors in a healthy population. Only two of them were research studies, which used a research design and methodology (Cruz-Garza, Hernandez, Nepaul, Bradley, & Contreras-Vidal, 2014; Jola, Abedian-Amiri, Kuppuswamy, Pollick, & Grosbras, 2012). They were REB approved, used participant consent and extraneous variables were matched between individuals for consistency in evaluation and as inclusion criteria.

The remaining studies (Hafting, Fyhn, Molden, Moser, & Moser, 2005; Foster et al., 2011; McGarry & Russo, 2011; Olsson, 2012; Foster, 2013) either speculated or hypothesized the effects of dance on brain regions and brain related changes through its relation to its multimodal factors—physical rigor, visual tracking, music, improvisation, imagination, and social group. None investigated the changes in neurobiological factors as a direct result of a dance intervention for an elderly population above age 60.

The first study investigated the impact of visual experience i.e. watching two different dance forms—ballet and Indian traditional dance (Bharatanatyam)—versus non-dance acting (control condition) on motor stimulation in a sample of 29 participants with a broad age range of 20–72 years old, involving 19 females and 10 males. Motor stimulation was examined by measuring changes in corticospinal excitability using Transcranial magnetic stimulation (TMS). Experimenter double-blind paradigm was not considered. A pre/post design was used where baseline condition was established by measuring participants' corticospinal activity during a relaxed state with closed eyes. Both the ballet and Indian dance spectators with 5 years of experience watching these dance performances showed high motor expression and corticospinal excitability when watching their own dance in the lab. This study showed that corticospinal pathway is involved in motor planning and active in experienced spectators. It demonstrated that visual experience is linked to having a previous motor repertoire and associated with the mirror neuron system (Jola et al., 2012). This study helped identify a specific brain region in play and informed potential scope for research in investigating the effect of visual experience of dance versus dance performing experience on brain activity and motor stimulation.

The second study investigated the brain activity and expressive movement of five skilled dancers aged 28–62, involving 4 women and 1 man, experienced in Laban movement analysis (LMA). They were certified Laban Movement Analysts with several years of teaching experience in LMA and proficiency in expressive components with the ability to identify, differentiate, and label performance from

functional to expressive body movements. The individuals participated in three different conditions i.e. Neutral (control situation where dancers performed whole body movements without the expressive qualities of dance), Think (where dancers thought about expressive qualities but did not perform expressive movements) and Do (where dancers performed expressive movements). An electroencephalography (EEG) analysis was conducted by the experimenters post study to investigate the expressive movement and brain activity. The 'thinking condition' where dancers had to think about expressive qualities and focus on Laban effort qualities instructed by the experimenter during dance (use of frontal cortex) showed the highest sensitivity, modulating body movements (Cruz-Garza et al., 2014). This study indicated the brain structures that may be used and modified by dancing, with a focus on the computational aspects of decoding expressive human movement for neuroprosthetics rather than neurorehabilitation. Both this and the former study had a broad age range in participants, and were not exclusively limited to an elderly population above age 60; however, their findings are relevant to a broad consideration of neurobiological effects associated with exposure to dance for the few elderly individuals that did participate in these studies and were examined. The rest of the papers cited below speculated on the effects of dance on brain regions and neurobiological changes in healthy populations.

Foster et al. (2011) stated that the amount of physical activity obtained through dance program routines enhances cognitive plasticity due to the increased expression of brain-derived neurotrophic and growth factor proteins BDNF, IGF-1, IGF-2 etc. It was also suggested that dancing enhances spatial memory by activating hippocampal and entorhinal cortical cells of the brain that are associated with spatial memory. Spatial memory deteriorates in AD participants but is improved through dance as it involves visual tracking in 3D space (Hafting et al., 2005). In Olsson (2012), moderate physical activity obtained from dance increases brain activity and preserves important brain regions such as the hippocampus and frontal cortex, enhancing memory, cognition and sensorimotor performance. Brain structures such as the hippocampus, entorhinal cortex, frontal cortex, basal ganglia, corticospinal cortex and mirror neuron system, are all surmised to be implicated in dance. McGarry and Russo (2011) suggest the practice of mirroring in DMT enhances emotional understanding, recognition and empathy in individuals due to increased mirror neuron activity. These neural factors are essential to improvements in neurological conditions (Salgado & de Paula Vasconcelos, 2010). Other beneficial features of dance interventions such as background music or song also enhance the grey matter in the auditory cortex of the brain. Moreover, using improvisation and imagination during dance also trains the prefrontal regions of the brain which are responsible for executive functions (Foster, 2013).

Parkinson's Disease, Dementia, Neurological Insult and Multiple Sclerosis

No studies looked at the effects of dance interventions on neurobiological factors in these populations of elderly individuals above age 60.

Discussion

The field of dance research in the elderly is relatively young and continues to evolve. Existing literature examines the effects of different dance forms, and research has begun on variables associated with cognition and sensorimotor performance. However, underlying neurobiological factors require further investigation, and studies are required to explain the neural underpinnings behind observed neurological improvements. Our critical analysis highlights dance forms that have been investigated in this context, and indicates the many benefits dance offers elderly individuals, both with and without neurological impairments. The studies discussed in this paper provide robust evidence that beyond providing physical activity for neurorehabilitation, dance incorporates interesting and enjoyable ways of improving mental, social, and emotional well-being, while stimulating and improving both cognitive and sensorimotor performance related variables and several underlying neurobiological factors. Post dance intervention impacts demonstrate the potential for dance to enrich every area of life, contributing to health and better function.

Under the 'cognition' domain, ballroom dances were the most explored in the studies. Traditional ballroom dances such as waltz, slow fox, quick step, cha-cha-cha, paso doble, samba, rumba and jive as well as other partner dances such as Argentine and adapted tango were used in these studies. Although less utilized, circle dances, ballet, and Danzon (an adapted Latin dance) were also incorporated for cognitive assessment. Experience with these dances showed positive benefits in almost all aspects of cognition—attention, concentration, episodic memory, general intelligence, procedural learning, planning, executive function, mood, spatial and visuospatial ability. However, none of the studies explored effects on language and perception aspects of cognition. Fluid Intelligence was another cognitive aspect that was explored but only showed an improvement in individuals who had several years of experience with ballroom dancing in contrast to a few months of participation in a dance intervention program. As well, dances such as Argentine and adapted tango when investigated in a partnered versus non-partnered form and a community based form showed greater enhancement in mood and emotion than performing alone. This highlighted an important feature of dancing, which is the opportunity for social interaction and proximity that is usually an absent feature with physical exercises such as walking, running, swimming etc. Such features are what distinguish the benefits of dance interventions from physical exercise related interventions. Ballroom dance interventions were investigated in healthy elderly populations as well as populations with Parkinson's disease and dementia. Overall, ballroom dancing was found to be a cognitively useful activity for the elderly.

Other forms of interventions that examined the 'cognition' domain involved aerobic dancing, social dancing, Turkish folkloric cultural dancing, DMT, and dance mixed with reality orientation therapy (RO). All showed positive benefits in either one cognitive aspect or the other (see "Results" section for details). Post intervention results showed an improvement in cognitive performance scales and an enhancement in mood and emotional states. Among these, only social dancing

showed mixed results when tested on a healthy elderly population versus a dementia population. However, we cannot infer these results to be due to the difference in population, but rather to the study design with the lack of control over extraneous variables creating unforeseen confounds. In the dementia population, social dancing was investigated in a RCT and saw qualitative improvement in mood and emotions. However, in the healthy elderly population social dancing was studied using a cross sectional survey, which did not control for extraneous variables such as participation in other leisure activities or a similar level of social dancing participation among the social dancers, which hindered in showing statistically significant differences in cognitive functions with the non-social dancers group. This highlights the importance of controlling for extraneous variables and maintaining consistent baseline levels, which is extremely difficult to do within this type of study but needs to be worked on in the future.

Overall, the quality of studies under the 'cognition' domain was consistent and effective, showing that the research claims and findings were robust. Good research methodologies were used to yield valuable evidence. The purpose was clearly highlighted, duration of interventions mostly lasted from 2 to 6 months, 1.5–2 h, once or twice per week. Sample sizes were below 50 participants (all aged 60 and older) and most studies used an RCT design with pre/post-test administration done by credible assessors. Although experimenter double-blind paradigms were inconsistent among studies, it did not seem to contribute to experimenter bias because even when incorporating or not incorporating experimenter double-blind paradigm, studies showed significant outcomes. Moreover, studies used both quantitative and qualitative measurements. Quantitative assessments were mostly used to evaluate cognitive based variables such as RSPM, AKT tests etc. While qualitative assessments such as videotaping, self-reports, and interviews were used to capture participants' moods, emotional states and perceptions to the intervention programs. Both type of methods aided in the evaluation of the dance interventions. The only bias found was in terms of gender where most studies used a female majority and the tango studies conducted by Hackney et al. (2007) consisted of a high male majority. Using an equal distribution of both genders would be ideal for generalizability. Also, there were a series of studies under the cognition domain, Parkinson's disease subsection which mostly explored the mood variable using qualitative analysis methods. Future research could incorporate investigating more cognition based variables and other quantitative measures of analysis to complement qualitative findings for this population.

Under the 'sensorimotor performance' domain, many more studies and dance interventions were conducted. There were a large variety of dance forms investigated, from a broad scope of ballroom and partnered dances such as Agilando, Latin/Danzon, Argentine tango and salsa- to aerobic dancing; cultural dances such as Greek, Caribbean, Turkish folkloric, Irish set; social dancing; modern; jazz dancing and DMT interventions. Each of the studies tested a large range of variables under the sensorimotor performance domain—static and dynamic balance, posture and gait, tactile performance, motor performance—mobility, speed, steadiness, aiming, pin plugging, tapping, freezing and reaction times.

Ballroom dancing interventions showed an effective improvement in all domains especially balance and motor performances. However, they did not seem to show a significant positive impact on tactile performance or motor control and coordination with hands. Aerobic dance interventions which used an American population and Japanese population also showed similar outcomes. The authors suggested the lack of significance in tactile improvements could have been due to the specific dance interventions used, which do not precisely train for tactile acuity. This shows that for interventions such as ballroom or aerobic, tactile based training should be incorporated more in their routines for improving motor control, coordination with hands and tactile based performance in the elderly. These findings cannot be generalized to other dancing interventions such as Argentine tango, because studies conducted by Hackney et al. did not test the tactile performance variable specifically. Future studies should study tactile variables as they pertain to dance.

On the other hand, a series of studies that conducted short duration intensive ballroom dancing interventions, including Argentine Tango and modern dance, which were performed 3–5 days per week for 2 weeks or so did not show an improvement in TUG and 6MWT scores. This finding is interesting as it showed that although other aspects of sensorimotor performance are improved such as balance and gait, motor related functions such as speed (TUG) and functional exercise based capacity (6MWT) are only significantly improved through long term interventions. Therefore, in order to improve in all aspects of sensorimotor performance, elderly individuals may find it more useful to undergo a long term dance intervention program.

Another important finding was that almost all studies tested balance—either static, dynamic, functional etc. and found significant post study improvements. All the cultural dances, social, modern, jazz, mixed, DMT as well as ballroom showed this finding, which suggests that any of these approaches would be extremely useful for improving balance in the elderly.

Conversely, a vital observation across studies was that many different standardized quantitative and qualitative measures were used to test very similar variables. For example, balance can be tested using BBS or FSST or TUG, and TUG can also be used to test motor speed. Although these measures are standardized and have been tested for their validity and reliability, variation in choice of measures leads to difficulties in comparing or generalizing outcomes between studies, which cause ambiguity. In other words, each assessment can be used to measure many different variables, making results confusing and ambiguous. For instance, motor performance or activity can be measured by both UPDRS and 6MWT but one shows significant outcome while the other doesn't. There needs to be more specificity between the measure and variable being tested and this standard must be maintained across studies. Studies need to state a clear relationship between assessment and variable in order to compare or generalize outcomes from one dance intervention study to another.

Overall, the quality of studies under the 'sensorimotor performance' domain was consistent and effective, similar to the cognition domain, which shows that the research aims and findings were robust. The purpose was clearly highlighted, duration of interventions mostly lasted from 2 to 6 months, 1–2 h, twice/thrice per

week and intensive dance interventions lasted 2 weeks, 1.5 h, 3–5 times per week. Sample sizes ranged from 10 to 80 participants (all aged 60 and older) with a few exceptions and most studies used an RCT design with pre/post-test administration. Many studies did not account for experimenter double-blind paradigm but still showed significant outcomes. More studies used both quantitative and qualitative measures to observe, record and evaluate sensorimotor based variables. The most commonly used quantitative measures were BBS, TUG, UPDRS and GAITRite while the qualitative ones involved videotaping or interviewing. Gender bias was also apparent involving a high female majority in many studies and a high male majority in some.

Under the 'neurobiological factors' domain only two studies were found that examined the direct relation of dance with brain activity and neurological functions. Only ballet, traditional Indian dance and contemporary dance were examined. These studies were not strictly limited to an elderly population with all participants over age 60. However, they were included as there were elderly individuals who participated. The quality of these studies and strength of the findings could have been improved with the use of a larger sample size, a similar age range and comparisons of an intervention group with a control group.

More studies using direct and objective, valid and reliable brain neuroimaging methods such as fMRI, EEG, DTI or biological, genetic methods such as genotyping, microarray analysis are required to investigate the effects of dance in the elderly. Studies that did use fMRI or EEG targeted a younger or middle aged population and conducted a virtual reality experiment where the participants were asked to imagine dance versus perform dance (Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2005; Brown, Martinez, & Parsons, 2006; Cross, Hamilton, & Grafton, 2006; Brown & Parsons, 2008; Cross, Kraemer, Hamilton, Kelley, & Grafton, 2009; Bläsing et al., 2012; Cameron et al., 2013; Houston & McGill, 2013; DeSouza, Di Noto, Levkov, & Bar, 2014; Olshansky, Bar, Fogarty, & DeSouza, 2014). A study conducted in a youth population found two important genes, serotonin and vasopressin receptor gene polymorphisms, which were implicated in creative dance performance (Bachner-Melman et al., 2005). It would be interesting to analyze such changes for an elderly population.

There is a large scope for potential research in this field. Advancements in neuroimaging are making possible the collection of data related to mental states and neural connectivity, providing insight on both short- and long-term effects of complex interventions such as dance. It would be extremely beneficial if more studies were to assess effects from baseline to post intervention at the neurological, neurochemical, and genetic expression level that can be directly attributed to dance intervention programs for the elderly. This would clarify what neural regions, genes, and neurochemicals are stimulated or affected by dance interventions, facilitating developments in our understanding of targeted brain-behavior relationships which may support current speculations or hypotheses on the effects of dance.

Studies pointing to observable changes in neurobiological factors provide measurable results for reported improvements; this data may influence medical and other professionals to adopt or suggest rehabilitative dance programs. Protocols suitable to examining neurobiological effects of dance are currently under

development; neuroimaging methods such as resting state functional connectivity magnetic resonance imaging (rs-fcMRI) can identify and quantify functionally related resting state networks which are common in healthy individuals, and detect changes in these networks related to a variety of neurological disorders (Earhart, Duncan, Huang, Perlmutter, & Pickett, 2015). This method holds great promise for dance related research, as it avoids the difficulties traditionally associated with collecting neuroimaging data during a movement task, or the broad engagement of visualization networks in imagined tasks. Moving forward, these protocols may provide further support for the use of dance in neurorehabilitation, and may help to specify mechanisms for improvements in symptoms associated with various disorders, while clarifying best practices for addressing these needs.

Conclusion

Dance represents an area of extreme interest for further study (Dhami et al., 2015). This review showed some of the major findings from studies that incorporated dance interventions and tested their effects in both healthy and neurological elderly populations. Many positive benefits were found in terms of cognitive and sensorimotor-based improvements in the elderly. Although underlying neurobiological factors were positively shown to be affected through dance interventions, few studies relating data and significance to aspects of brain related biological factors and structural changes were found. Future research must aim to address some of the limitations and gaps in the field of dance and aging research, which have been carefully highlighted in this review.

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