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Investigating the acute effect of an aerobic dance exercise program on neuro-cognitive function in the elderly

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ABSTRACT

Objective: The present study investigated the types of aerobic dance programs that positively impact cognition, such as executive function, in elderly people.
Design: Randomized controlled trial.
Method: The study compared the effects of acute aerobic dance exercise on cognitive performance using two 40-min aerobic dance programs. Thirty-four elderly participants, aged 65–75 years, were randomly assigned into either free ($N = 17$) or combination ($N = 17$) style workout groups. The free style (FR) workout consisted of several patterns of movement, while the combination style (CB) workout consisted of similar patterns of movement to FR, but the patterns were joined to form a long choreographic routine. Both dance programs were controlled to be the same in exercise intensity, approximately 40% heart rate reserve. Reaction time and correct rates were measured using a task-switching reaction time test to evaluate executive cognitive performance immediately before and after the 40-min dance exercise.
Results: A two-way (dance program × pre-post dance exercise) repeated-measures analysis of variance for switch reaction time increase (switch cost) demonstrated a significant interaction ($p = .006$), showing that the switch cost in the CB group became smaller after the dance exercise than before ($p = .009$).
Conclusion: The results suggest that the executive cognitive network was facilitated in a CB dance workout that has a dual-task nature and induces movement (task) interference with unexpected movement changes.

Introduction

Aerobic dance exercises have typically been developed as an aerobic exercise to improve physical fitness and performance and to improve cardiovascular fitness (Darby, Browder, & Reeves, 1995; Engels, Drouin, Zhu, & Kazmierski, 1998; Holmerova et al., 2010; Hopkins, Murrah, Hoeger, & Rhodes, 1990; Keogh, Kilding, Pidgeon, Ashley, & Gillis, 2009; Shigematsu et al., 2002; Williford, Blessing, Olson, & Smith, 1989; Williford, Scharff-Olson, & Blessing, 1989). Above all, low-impact aerobic dance exercise has been well adapted to keep and improve health in a wide range of the population. Low-impact aerobic dance requires participants to keep one foot on the floor during their dance workout, resulting in fewer jumping and bouncing movements. Therefore, the participants reduce the amount of impact shock thought to be associated with injuries in traditional aerobic dance. Low-impact aerobic dance exercise has been recommended as a beneficial exercise to maintain health, especially in individuals with low fitness or in the elderly population (Engels et al., 1998; Garrick & Requa, 1988; Hopkins et al., 1990; Koszuta, 1986).

There are emerging reports that dance-related aerobic exercise might positively influence psychological aspects of cognitive function as well as mood and well-being in older adults (Engels et al., 1998; Ravelin, Kylma, & Korhonen, 2006). Most participants in an aerobic dance exercise subjectively feel cognitive stimulation or effort in performing the dance, and expect to experience some type of cognitive effect (Kattenstroth, Kolankowska, Kalisch, & Dinse, 2010; Verghese, 2006). Aerobic dance exercises comprise a number of dance elements including different patterns, steps, and movements. Participants are required to pay attention and follow the instructor's lead to learn new dance elements and smoothly switch between these elements throughout the exercise. Therefore, the nature of an aerobic dance exercise might stimulate and improve cognitive function. However, no systematic or scientific

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studies have been reported on an aerobic dance program appropriate to cognitive functioning.

Aerobic dance workouts are usually composed of several short dance routines with varied cadence, high or low-impact, and step and upper body movements. These routines are sometimes sequentially repeated to compose the entire dance workout, which is called a free style (FR) program. On the other hand, the dance routines are sometimes combined as a long choreographic routine to increase the difficulty and enjoyment of performing the dance exercise. This type of program is called the combination style (CB). For the FR program, participants are required to simply follow the instructor's leads, repeating each routine independent of the others. Thus, the FR program has generally been recommended as an introduction to dance exercise for the elderly and for people unfamiliar with dance performances because it is easy to perform. In contrast, in the CB program, participants are required to remember several dance routines and rapidly and skillfully switch between them so as to construct a long, organized choreographic routine according to the instructor's leads. Thus, the CB program may require relatively higher cognitive engagement for the participants to conduct the dance workout. More specifically, the CB program might require more cognitive demands to stimulate related processes, such as executive control and working memory, in contrast to the more basic FR program.

A previous meta-analysis study suggests that simple aerobic exercise such as walking strongly influences executive cognitive control sustained by comprehensive higher cognitive abilities, which include coordination, inhibition, scheduling, planning and working memory (Colcombe & Kramer, 2003). The task-switching reaction time test has been used as a suitable method for evaluating executive cognitive function (Cepeda, Kramer, & Gonzalez de Sather, 2001; Davidson, Amso, Anderson, & Diamond, 2006; Kramer, Hahn, & Gopher, 1999). However, effects of the aerobic exercise were unclear in perceptual-motor speed, automatic processing, and discrimination ability which have been estimated with tapping, simple and choice reaction time tasks, respectively (Blumenthal et al., 1991; Colcombe & Kramer, 2003; Hill, Storandt, & Malley, 1993). Based on these previous studies, it can be surmised that aerobic dance exercise might significantly influence executive function rather than other cognitive abilities. Thus, the present study examined executive function using a task-switching RT test to investigate the effects of dance programs on cognition. The main purpose of the study was to determine whether the acute impact of aerobic dance exercise on executive function would be greater under the CB program than under the FR program in older adults.

Method

Participants

Healthy older adults aged 65–78 years residing in residential areas participated in this study. On the basis of their annual medical examination, all participants were confirmed to be free of chronic conditions that might limit their ability to engage in physical activity. People who had engaged in habitual exercise routines within the last three years, such as strength training, jogging, swimming, or dance, were excluded from the present study. The details of this study were explained before the study began, and informed written consent was obtained from all participants. This study was approved by the ethics committees of Tokyo Denki University.

Thirty-four participants were randomly assigned, using a random number generated with computer software (Microsoft Excel 2007), into two aerobic dance exercise programs: the FR program ($N = 17$, male = 7, female = 10), or CB program ($N = 17$, male = 7, female = 10). The study was conducted in a gymnasium at Tokyo Denki University located in Inzai, Chiba Prefecture, Japan.

Dance exercise programs

The participants, who were unfamiliar with dance exercise, experienced two aerobic dance sessions supervised by a well-trained dance instructor. The instructor had 10 years of experience and was familiar with teaching low-impact aerobic dance exercise to older adults. A single instructor delivered both dance programs to eliminate potential biases or differences in teaching skills depending on instructors. The instructor had extensive experience in teaching these two dance programs and was able to adapt the routines to fit the experimental design. The aerobic dance exercise was conducted for 40 min and was formally structured to include a 10-min warm-up, a 20-min aerobic dance workout, and a 10-min cool-down period. The goal for peak intensity of the aerobic dance workout was for participants to achieve at between 40 and 50% heart rate reserve (HRR; defined by Karvonen formula (Karvonen, Kentala, & Mustala, 1957)). The music selection for the warm-up was 100 beats/min. For the main workout (the low-impact dance exercise), the music tempo was set at 120 beats/min using a CD player with a speed controller.

The FR and CB programs consisted of short dance routines that were identical between the two programs in cadence (120 beats/min), impact (low-impact), and upper body/limb movements (e.g., putting the hands on the waist, or natural motions in the arms and head simultaneously while stepping). The two dance programs required participants to perform four common dance elements (Fig. 1): A) marching with toe or heel touch on every 4th count; B) knee bend and side slide with knee bend; C) side jack and step touch; and D) lunge up and lunge leg curl. Each of these dance elements was 32 counts in length. The FR program comprised four dance elements, each of which was repeated 16 times (approximately 5 min each) in order of the dance element A, B, C, and D. On the other hand, participants in the CB program had to build up a long choreographic routine by performing four routines of combined dance elements. In the CB program, the combined routines were A, AB, ABC, and ABCD. Each of the routines was repeated eight times and comprised approximately 2-, 4-, 6-, and 8-min time sequences, respectively.

The 34 participants were randomly assigned into four classes of group-exercise with 10 attendees maximum. Two classes were held in April and June, and the other two were held in May and July. The first two classes were administered so that one class was the CB program and began at 09:30, while the other class was the FR program and began at 10:20. The latter session reversed the order of the FR and CB classes. Participants' heart rates were assessed during exercise; cognitive performance was measured within 10 min immediately before and after the exercise session. In each class, no more than five participants actually received assessments because of technical limitations of the measuring devices used. Those who were not assessed at this time were assessed in the second session two months later.

Assessment of heat rate during aerobic dance exercise

To confirm the intensity of the dance exercise, heart rate was recorded during the exercise. Heart rate variability (R–R intervals) was detected by a wireless heart rate monitor (S810 HRM, Polar Electro Oy) with an elastic electrode belt (T61, Polar Electro Oy). The electrode belt was placed just below the chest muscles. The HRM signal was transferred to the Polar Precision Performance Software (release 3.00; Polar Electro Oy) and R–R intervals were exported under ASCII format. The heart rate was monitored continuously during the exercise session for 40 min.

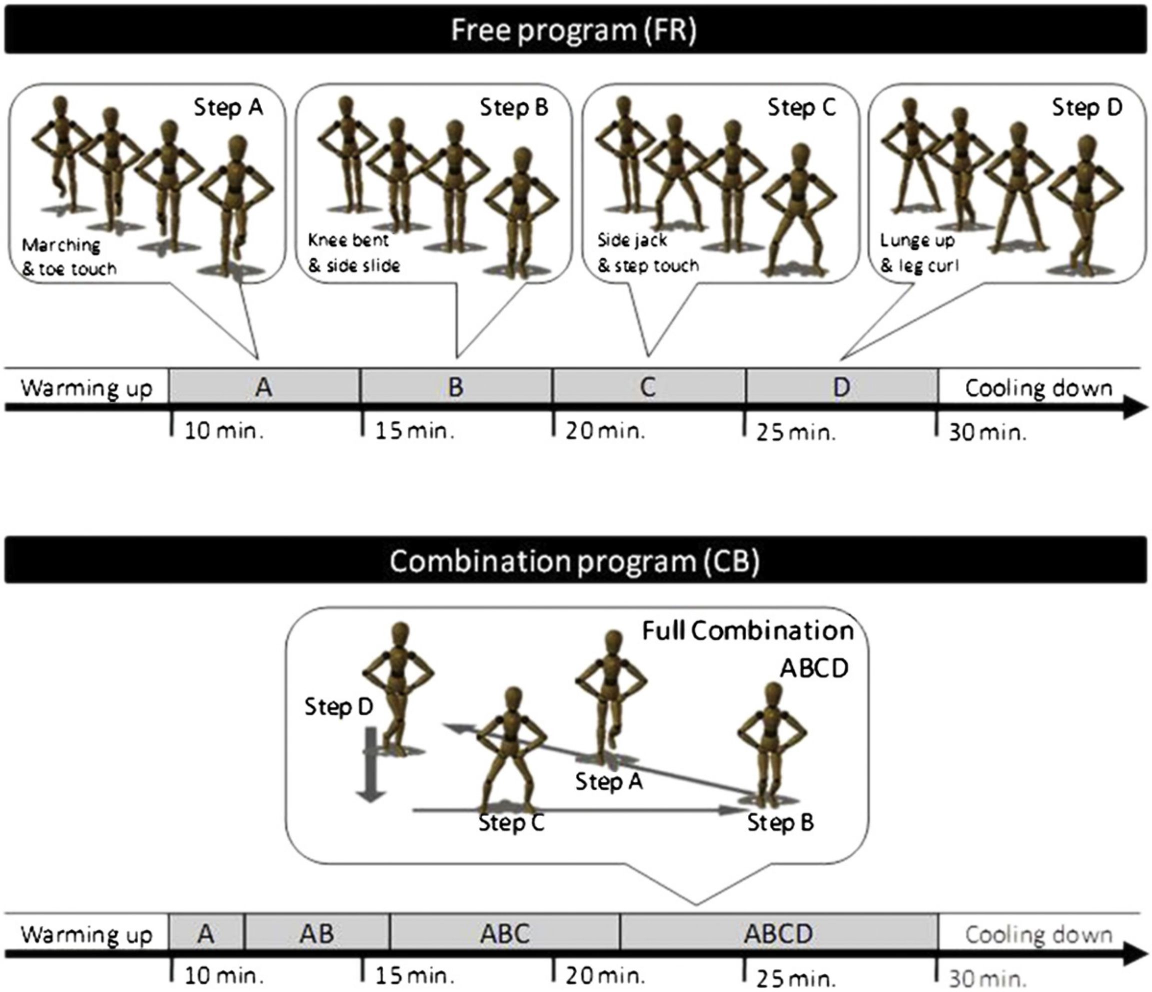

Fig. 1. Upper time line and figures show the FR dance program. The FR comprised four dance routines, each of which was repeated 16 times in order of the dance elements A, B, C, and D. Bottom time line and figures show the CB dance program. The CB built up routines by combining dance elements into sequences that grew progressively longer according to the order of A, AB, ABC, and ABCD. Each routine was repeated eight times. Times (min) under the time lines indicate the durations from the beginning of the exercise.

Estimation of executive cognitive function by task-switching test

The task-switching reaction time test has been used as an acute examination to evaluate executive cognitive function (Cepeda et al., 2001; Davidson et al., 2006; Kramer et al., 1999). The hypothesis of the present study is that low-impact aerobics dance under the CB program might strongly contribute to stimulation of executive cognitive function, more so than under the FR program. To confirm this hypothesis, the acute effects of aerobic dance exercises on the performances of switching trials were compared between the FR and CB programs.

Tasks were presented on a computer screen using E-prime 1.1 (Psychological Software Tools, Inc.) to present the stimuli and record responses. Participants sat approximately 50 cm from a computer screen and held a computer mouse with both right index and second fingers to press the two response buttons. For each task, a horizontal rectangle (6 cm × 18 cm) with a central fixation cross was presented on the computer screen (25 cm × 33 cm). A dot 2 cm in diameter appeared on the monitor as the response stimulus, which randomly appeared either 4 cm right or left horizontally from the fixation point. Two types of dots (striped or solid) were used. Striped dots contained vertical black and white stripes, while solid dots were a uniform gray color. These dots were of equal size and luminance. Only one stimulus was presented per trial, and the participants were instructed to react to a stimulus as quickly as possible by either left- or right- clicking the mouse.

The task-switching reaction time test was constructed of two types of choice reaction time trials. When a solid gray dot appeared randomly on either the right or left side, participants were to click the corresponding mouse button for a correct response (congruent trial). When a striped dot stimulus appeared instead, participants were to push the opposite mouse button in response to the dot (incongruent trial). For example, participants were to click the left mouse button when the dot appeared on the right side. The stimulus type (solid and striped dot) would switch randomly every 2nd to 4th trial in the block. When the same dot was repeated, participants performed the same strategy to resolve the task (repeated condition), but when the dot unpredictably changed, participants would have to change their previous strategy (switch condition). The main dependent variables were mean reaction time (RT) and correct response rate required to perform switch and repeated conditions. The switch cost, defined as the difference between the RTs under the two conditions, was used as an indicator of computational speed in the brain circuit.

The participants were asked to complete three practice blocks conducted in the following order: congruent, incongruent, and congruent–incongruent mixed (task-switching) blocks with 20 trials in each block. If the participant completely understood the task-switching block, they moved on to the test session. Otherwise, they repeated the practice session. The test session consisted of 80 trials (4 mixed blocks of 20 trials) including 32 switch and 48 repeated trials. The time line of each trial consisted of 750-msec stimulus presentations maximum and of 500-msec inter-stimulus intervals. The rests taken in between blocks were self-paced. Each person was able to finish the practice and test session within 10 min before and after the exercise session. The mean correct rate of test blocks (task-switching trials) in the pre-exercise session was above 65%, meaning the participants understood the task requirements of the test blocks, but that participants also still had difficulty with the task.

Statistical analysis

After randomization, we evaluated differences in each measurement between groups using unpaired t tests. Sex distributions between groups were confirmed by a χ^2 test. The RTs and correct response rates of task-switching trials were analyzed using three-way analysis of variance (ANOVA) with a repeated-measures design. The three-way ANOVA was conducted to reveal whether switch RTs immediately after an aerobic workout differed between groups by testing interactions between group, time, and task. For the switch cost, the effect of acute aerobic dance exercise was compared using two-way ANOVA with a repeated-measures design. When the ANOVA revealed interactions between groups and time courses, within-group analyses were performed using one-way ANOVA with a repeated-measures design. Statistical significance was set at the $p < .05$ level. Partial effect sizes were calculated and expressed by η^2. Data were analyzed using SPSS 14.0J for Windows software (SPSS, Chicago, IL).

Results

Demographic information of participants

Table 1 shows the demographic information, parameters of physical function and daily physical activity, and the results of the Mini-Mental State Examinations (MMSE) for the participants. Physical functions were found to be at a normal level in the general population of older Japanese people (Nishijima et al., 2006), and the levels of daily physical activity were appropriate for keeping healthy, showing step counts > 7500 steps (Tudor-Locke & Bassett, 2004), and duration of moderate activity > 30 min (ACSM, 2009). The body mass indexes (BMI) of the participants were at normal levels (=22) suggesting no increased risk of chronic diseases, such as obesity and diabetes. The MMSE showed that none of the participants were currently at risk of dementia. The demographic information confirmed that relatively fit and healthy older adults participated in the present study. Table 1 also shows the results of statistical analyses of comparisons between characteristics of the CB and FR groups. No significant differences were seen for any variables, indicating that the two groups displayed similar characteristics.

Heart rate variability during the aerobic dance programs

The peak exercise intensities in both the FR and CB programs were aimed at between 40 and 50% HRR. Both dance workouts were successful at keeping approximately 40% HRR during the dance exercise period (Fig. 2). The two-way ANOVA (dance program and time) revealed that there was no significant main effect on the factor of the dance program ($F(1, 30) = .184$, $p = .671$). However there was a significant interaction between the dance program and time ($F(1, 30) = 5.579$, $p = .025$). There were no significant differences between the FR and CB programs in each recorded point during both the warm-up and dance workout periods; however, there were significant differences between the two conditions during the cool-down period (Fig. 2). The difference in FR and CB during the cool-down period became smaller and finally became insignificant immediately after completion of the entire workout.

Reaction times and correct response rates in the task-switching test

A summary of the effects of aerobic dance exercise on executive cognitive performance, estimated by the task-switching test, is shown in Table 2. The three-way ANOVA (conjunct with factors of Group, Time, and Task) for reaction times (RTs) revealed significant main effects of Time (pre- vs. post-exercise; $F(1, 32) = 13.52$, $p = .001$, $\eta^2 = .297$), and Task (switch vs. repeated trial; $F(1, 32) = 154.81$, $p = .000$, $\eta^2 = .829$), but did not show effects of Group (FR vs. CB program; $F(1, 32) = .229$, $p = .636$, $\eta^2 = .007$). There was a significant interaction between all three factors, $F(1, 32) = 8.555$, $p = .006$, $\eta^2 = .211$. However, a follow-up two-way ANOVA did not reveal significant interactions between Time and Group for each switch and repeat RT (switch RT; $F(1, 32) = 3.765$, $p = .061$, $\eta^2 = .105$, repeat RT; $F(1, 32) = .055$, $p = .816$, $\eta^2 = .002$). RTs under post-exercise became significantly shorter than RTs under pre-exercise. In addition, RTs in switch trials were significantly prolonged compared with RTs in repeated trials. The effect of switch trials on RTs was not influenced by the factors Time and Group.

Table 1
Demographic information of participants.

	CB ($N = 17$, Men = 7)		FR ($N = 17$, Men = 7)		t	p
	Mean	SD	Mean	SD		
Age	70.7	4.3	71.1	4.9	−.260	.797
Height (cm)	159.0	6.5	158.4	9.3	.205	.839
Weight (kg)	56.3	8.5	52.9	10.9	1.003	.323
BMI	22.2	2.4	20.9	2.7	1.442	.159
Physical functions						
Handgrip strength (kg)	27.7	6.6	27.3	8.2	.147	.884
Sit and reach (cm)	28.2	12.2	28.0	15.5	.024	.981
One-leg standing with eyes open (secs)	46.9	17.0	47.2	19.9	−.045	.964
One-leg standing with eyes closed (secs)	6.6	5.4	11.5	17.0	−1.134	.266
Daily physical activity						
Total energy expenditure (kcal/day)	1699.7	168.7	1628.4	211.1	1.087	.285
Energy expenditure with daily physical activity (kcal/day)	208.8	58.8	189.9	62.8	.906	.372
Step counts (steps/day)	8853.4	2367.6	8637.3	2909.9	.237	.814
Duration of moderate physical activity (min/day)	37.0	23.2	40.1	28.0	− .356	.724
Risk of dementia						
MMSE	28.2	1.7	28.3	1.5	−.237	.814

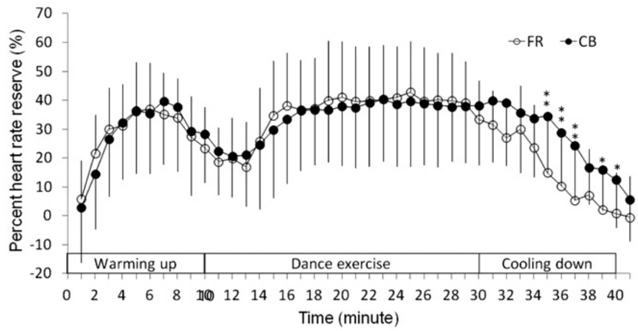

Fig. 2. Variability of percent heart rate reserve (%HRR) during exercise. There are no significant differences for %HRR between the CB and FR dance programs in any recorded point during the dance exercise, although differences were seen in the cool-down period. Bars indicate standard deviations. Asterisks indicate the recorded points at which significant differences between the FR and CB were detected with either p-value $< .05^{*}$ or $.01^{**}$.

The analysis for correct response rates found significant main effects of Time and Task (Time; $F(1, 32) = 39.645$, $p = .000$, $\eta^2 = .553$, Task; $F(1, 32) = 10.727$, $p = .003$, $\eta^2 = .251$). There was no main effect of Group for correct response rates, $F(1, 32) = 2.247$, $p = .144$, $\eta^2 = .066$, nor were there significant interactions between the three factors, $F(1, 32) = .917$, $p = .345$, $\eta^2 = .028$. The correct response rates post-exercise were significantly higher than those pre-exercise. Correct response rates for switch trials significantly decreased compared to the correct response rates for repeated trials. This decrease in accuracy for switch trials was identified regardless of the factors in Time and Group.

For the switch costs, defined as the differentiations between the switch and repeated RTs, two-way ANOVA (Group and Time) did not identify any significant main effects (Group; $F(1, 32) = .441$, $p = .511$, $\eta^2 = .014$, Time; $F(1, 32) = .074$, $p = .787$, $\eta^2 = .002$). Instead, it revealed a significant interaction between Group and Time, $F(1, 32) = 8.555$, $p = .006$, $\eta^2 = .211$. That is, the switch cost in the CB group was significantly smaller post-exercise compared to pre-exercise, $F(1, 16) = 8.936$, $p = .009$, $\eta^2 = .358$, while in the FR group there were no significant differences between pre- and post-exercise measurements, $F(1, 16) = 3.183$, $p = .093$, $\eta^2 = .166$.

Discussion

The present study investigated the acute effects of two types of aerobic dance exercises on executive cognitive function and compared the effects between the two aerobic dance programs (FR vs. CB dance programs). The FR dance program comprised four kinds of dance routines. The participants simply repeated the dance steps/movements in each routine by following the instructor's lead. On the other hand, although the CB dance program comprised four kinds of dance routines much like the FR condition, the participants in the CB group were required to combine these dance routines so that they could finally perform a long choreographic routine by combining the four types of dance steps/movements.

The effects of dance programs on executive cognitive function were evaluated using the task-switching reaction time test. The study found that the switch cost (differential reaction time (RT) between the switch and repeat conditions) in the CB group decreased at post-exercise relative to pre-exercise. However, there was no significant difference in the switch cost between pre- and post-exercise in the FR group despite the fact that the participants in the FR program performed the same dance elements at the same exercise intensity as those who participated in the CB program. Because the switch cost is the extra time for the switch RT compared to the repeat RT, the switch cost may express the higher cognitive processing time required for changing one stimulus-response configuration to another, and may not account for residual time such as the time taken in sensory and motor processes and muscle contractions. Therefore, the present findings indicate that the dance program under the CB condition could significantly influence higher cognitive processes, particularly executive cognitive function. However, the FR condition did not show such a clear impact on cognitive function.

Of course, we cannot ignore the results of task performance in the RTs and correct response rates in both switch and repeat conditions. These results commonly improved after the CB and FR dance workouts in the same manner. The improvements indicate the typical acute effects underlying the facilitation of perceptual processes in accord with an increase in general arousal level (Brisswalter, Collardeau, & Rene, 2002; Kashihara, Maruyama, Murota, & Nakahara, 2009) as well as the neuromuscular system (Davranche, Burle, Audiffren, & Hasbroucq, 2006; Spirduso, Macrae, Macrae, Prewitt, & Osborne, 1988). Thus, the present study also confirmed the basic effect that has been well established through previous studies investigating the effect of simple aerobic exercise (i.e., jogging or cycling exercise) on perceptual-motor speed. The present discussion focuses on the significance of the different acute effect in switch cost (executive function) between the CB and FR dance programs. We describe below potential reasons why such a difference was observed between the two conditions.

Generally, executive function has been conceptualized as four components: the abilities to form goals, plan, carry out goal-oriented plans, and perform effectively. These components are mediated through cognitive processes such as working memory, attention, inhibition, and the ability to smoothly shift between behaviors (Alvarez & Emory, 2006; Davidson et al., 2006; Jurado & Rosselli, 2007). Computer-based cognitive training approaches

Table 2
Comparison between the effects of the FR and CB aerobic dance exercise programs on executive function.

	FR ($N = 17$)		CB ($N = 17$)		ANOVA			
	Pre-exercise	Post-exercise	Pre-exercise	Post-exercise	Time (Pre vs. Post)		Interaction (Group vs. Time)	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	F	p	F	p
Correct response rate (%)								
Repeat	68.5 (19.1)	79.8 (15.8)	76.3 (15.2)	86.4 (13.6)	51.40	.000	.21	.648
Switch	60.0 (27.0)	72.4 (24.0)	73.2 (17.6)	81.3 (18.2)	23.65	.000	1.02	.320
Reaction time (msec)								
Repeat	588.78 (42.14)	565.06 (50.12)	581.22 (39.71)	554.43 (50.84)	14.95	.001	.06	.816
Switch	628.40 (42.43)	619.05 (51.29)	639.27 (37.71)	600.56 (50.68)	10.09	.003	3.77	.061
Switch cost (msec)								
(Switch RT − Repeat RT)	39.62 (24.93)	53.99 (26.12)	58.05 (29.47)	46.13 (25.73)	.074	.787	8.555	.006*

Note. Reaction times and correct responses are shown for the switch and repeat conditions, respectively, and switch costs. Asterisk indicates a significant interaction (Group vs. Time) with p-value $< .01$.

have demonstrated that a cognitive training program to improve memory and attentional control positively influences executive function as well as the ability of elderly people to complete tasks necessary for daily life (Ball et al., 2002; Bherer et al., 2005; Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Willis et al., 2006). These previous studies imply that an activity that engages attention and memory processes would improve executive cognitive function. The CB dance program seems to involve actions that facilitate attentional control and even memory processes. For example, the participants were asked to retain each of the dance movements that they had done in order to perform a long choreographic routine consisting of all four movements. Moreover, they had to pay attention to various movement patterns, one after another, and flexibly switch their attention to those movements. It is probable that the combination of memory usage and attentional processes within the CB condition could facilitate the improvement of cognitive performance related to executive function.

In addition, there is evidence that activities requiring complex motor functions with a dual-task nature can improve untrained executive cognitive performance. Cortis and colleagues reported that more complex sports activities such as basketball and soccer significantly improved and maintained a player's executive and attentional abilities (Cortis et al., 2011, 2009). Furthermore, Budde, Voelcker-Rehage, Pietrabyk-Kendziorra, Ribeiro, and Tidow (2008) investigated the effect of short bouts of exercise with motor complexity (coordinative exercise) on cognition (Budde et al., 2008). They demonstrated the acute effect of a 10-min coordinative exercise on attention and concentration compared with the simple aerobic exercise of jogging in healthy adolescents. The participants for the coordinative exercise were asked to bounce a ball using either their right or left hand alternately while at the same time standing on a turning sport bench. They found coordinative exercise positively influenced attentional ability, concluding that such a complex task effectively facilitates neuronal networks responsible for cognitive behavior mediated by attentional and executive functions. Likewise, the CB dance program also has a coordinative or dual-task nature in which the participants have to make an effort to follow the instructor's lead even during frequent performance interruptions, namely, during moments of switching dance elements. Thus, it can be inferred that the control of performance interference in the CB condition could yield more beneficial effects on neuro-cognitive activation related to executive cognitive performance immediately after the dance workout.

However, there are limits to our ability to reach a concrete conclusion from the study outcomes due to the following methodological limitations. First, the sample size in the present study yielded statistical power at approximately 40% in regard to the effect size ($\eta^2 = .211$) in the two-way ANOVA for the interaction in the switch cost. The confidence of the difference between the effects in the CB and FR conditions was not sufficient to reach an exact conclusion. Second, the study could not observe and assess participants' daily physical/exercise activity during the two-month period in which data were not collected. The two groups might not have been well matched in daily physical and exercise activity throughout the experimental period. Third, there remains a possibility that differences in heart rate between the two groups during the cool-down periods might result in different acute effects on cognition between the two groups. Finally, we could not observe the accuracy of participants' dance movements. Differences in the performance achievement or difficulty between individuals might influence the present results.

The present study only revealed an acute effect of a complex aerobic dance program on executive cognitive function immediately after the dance workout. In the future, an intervention study will be needed to thoroughly investigate the training effects over a long period of participation in aerobic dance exercise. Ideally, such a study should address the following remaining issues, for example, whether the CB program would be more beneficial for cognitive function than other aerobic exercise, such as walking and running, and whether the dance workout improves general cognitive abilities needed for daily life, and if so, how long the benefits are retained after termination of exercise. In addition, we need systematic investigation of the effect of cadence, types of steps/movements/patterns and the effects of various combinations on cognitive function. These investigations of aerobic dance exercise are expected to establish new principles for the kinds of exercise needed to improve and maintain cognitive function in healthy elderly people.

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