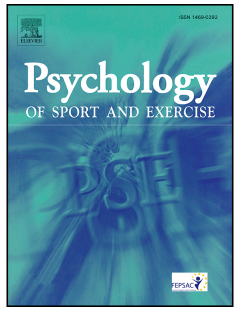
Oppici, L, Rudd, JR, Buszard, T and Spittle, S

Efficacy of a 7-week dance (RCT) PE curriculum with different teaching pedagogies and levels of cognitive challenge to improve working memory capacity and motor competence in 8–10 years old children

Journal Pre-proof



Efficacy of a 7-week dance (RCT) PE curriculum with different teaching pedagogies and levels of cognitive challenge to improve working memory capacity and motor competence in 8–10 years old children

Luca Oppici, James Rudd, Tim Buszard, Sharna Spittle

PII: S1469-0292(19)30529-1

DOI: https://doi.org/10.1016/j.psychsport.2020.101675

Reference: PSYSPO 101675

To appear in: *Psychology of Sport & Exercise*

Received Date: 17 July 2019

Revised Date: 17 February 2020

Accepted Date: 20 February 2020

Please cite this article as: Oppici, L., Rudd, J., Buszard, T., Spittle, S., Efficacy of a 7-week dance (RCT) PE curriculum with different teaching pedagogies and levels of cognitive challenge to improve working memory capacity and motor competence in 8–10 years old children, *Psychology of Sport & Exercise* (2020), doi: https://doi.org/10.1016/j.psychsport.2020.101675.

Efficacy of a 7-week dance (RCT) PE curriculum with different teaching pedagogies and levels of cognitive challenge to improve working memory capacity and motor competence in 8-10 years old children.

Luca Oppici[1, 2, 3*+], James Rudd[4+], Tim Buszard[1,5], Sharna Spittle[1]

[1] Institute for Health and Sport (IHES); Victoria University, Melbourne, Australia

[2] Psychology of Learning and Instruction, Department of Psychology, School of Science, Technische Universität Dresden, Germany.

[3] Centre for Tactile Internet with Human-in-the-Loop (CeTI), Technische Universität Dresden, Germany.

[4] Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, United Kingdom

[5] Game Insight Group, Tennis Australia. Private Bag 6060, Richmond VIC, 3121, Australia.

[*]Corresponding author: Luca Oppici

Email address: opc.luca@gmail.com

Psychology of Learning and Instruction, Department of Psychology, Technische Universität Dresden, Zellescher Weg 17, 01069, Dresden, Germany.

[+]Luca Oppici and James Rudd had an equal contribution

Abstract

Objectives: This study examined how learning a dance choreography with different teaching pedagogies and different cognitive challenge influenced the development of working memory capacity and motor competence in primary school children.

Design: Randomised-controlled trial

Methods: Eighty primary school children (8.8 ± 0.7 years old; 61% females) were recruited and randomly assigned to two experimental groups – a high-cognitive and a low-cognitive group – and a control group. The two experimental groups practiced dance for 7 weeks, twice a week, learning a choreography, while the control group participated in the school standard PE curriculum. In the high-cognitive group, the dance teachers limited visual demonstrations and encouraged children to memorise and recall movement sequences to increase the cognitive challenge.

Results: While the pre- to post-test improvements did not statistically differ between experimental groups, the analysis showed that the high-cognitive group statistically improved their working memory capacity ($p < 0.01$; $d = 0.51$), while the low-cognitive ($p = 0.04$; $d = 0.48$) and control groups did not ($p = 0.32$; $d = 0.17$). All three groups improved their motor competence from pre- to post-test, and there was a significant group*time effect ($p < 0.01$, $\eta_p^2 = 0.13$) with the high-cognitive group showing larger improvement than the control.

Conclusions: The results of this study provide initial support that dance practice coupled with a high cognitive challenge could improve working memory capacity and motor competence in children; however, the difference between groups was not statistically significant, and future research is necessary to examine the generalization of this finding.

Keywords: physical education, skill acquisition, executive function, cognition, movement skills, exercise

Introduction

It is a well-established view that a child's cognitive development determines their future health and wellbeing (Hair, Hanson, Wolfe, & Pollak, 2015; Hofer & Clouston, 2014). A particular area of focus in early childhood is the development of executive function as this has been found to be a better predictor of academic achievement than IQ and socio-economic status (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Diamond & Ling, 2016). Executive function is an umbrella term for cognitive processes underlying the organisation and control of goal-directed behaviour (Diamond, 2013). The development of these functions is critical for children to reach their full potential. Core executive function includes three types of brain function: working memory (mental work space), inhibitory control (overcoming pre-potent responses) and cognitive flexibility (shifting of attention) (Diamond, 2013). This article primarily focuses on working memory, which refers to the holding of information in mind and mentally working with it while other cognitive tasks are being performed (Diamond, 2013). Working memory is essential for making sense of things that unfold over time and has been found to be the strongest predictor of academic achievement, and low working memory capacity is associated with poorer performance at school (Alloway & Alloway, 2010). Therefore, designing suitable training interventions that improve working memory capacity in children is advantageous for children's development and, consequently, society.

Physical exercise may be an effective strategy to improve working memory capacity in children (de Greeff, Bosker, Oosterlaan, Visscher, & Hartman, 2017; Diamond & Lee, 2011; Ludyga, Gerber, Brand, Holsboer-Trachsler, & Pühse, 2016; Tomporowski, Davis, Miller, & Naglieri, 2008). In this context, researchers have recently called for a shift from the longstanding quantitative approach, which primarily focuses on exercise volume, to a qualitative approach, whereby physical exercise combines cognitive and motor challenges, to further promote the development of working memory (Diamond & Ling, 2016; Moreau & Conway, 2013; Pesce, 2012). Embodied cognition, which contends that body and mind are interrelated and body actions strengthen movement memory and planning, underpins this qualitative approach (for details see Mavilidi et al., 2018; Moreau, 2016). Specifically, Moreau and Conway (2014) suggested integrating complexity, diversity, and novelty in the design of training interventions to maximise working memory gains and transfer to everyday tasks. This integration can be best achieved by designing training tasks that focus on mastering a skill while combining cognitive and motor challenges, such as performing a sport skill or playing music (Tomporowski & Pesce, 2019). For instance, freestyle wrestling with increasing cognitive and motor demands has been shown to improve working memory capacity to a greater extent than aerobic exercise and computerised working memory training in an 8-week randomised controlled trial in adults (Moreau, Morrison, & Conway, 2015). In support of this, numerous systematic reviews and meta-analyses provide evidence for the increased benefits of the qualitative approach (for a review see Tomporowski & Pesce, 2019).

Critical elements for the success of a training intervention in improving working memory are the selection of an appropriate activity that combines cognitive and motor challenges and the modulation of cognitive challenge throughout the intervention (Pesce et al., 2013). Previous studies have adopted different activities and tasks to improve working memory capacity in children, such as taekwondo (Lakes et al., 2013), enriched Physical Education (PE) with cognitively demanding tasks (Pesce et al., 2016), and team games (Schmidt, Jager, Egger, Roebers, & Conzelmann, 2015). For example, children who participated in taekwondo lessons that focussed on technique showed larger improvement in working memory capacity than children who participated in traditional PE classes (Lakes et al., 2013). While this line of research provides preliminary evidence of the effectiveness of complex and challenging activities on improving children's working memory capacity, one issue that remains relatively unexplored and requires further investigation is how teaching pedagogy influences and can promote the development of working memory capacity. Researchers recognise the importance of teaching pedagogy in modulating a task challenge and, therefore, are urging research to address this key issue (Diamond & Ling, 2016; Tomporowski & Pesce, 2019).

Dance may be an effective strategy to engage working memory in children, and it provides a suitable context to examine how teaching pedagogy can be implemented to promote working memory capacity enhancement (Buszard & Masters, 2018). Dance not only combines movement and cognitive challenges as performers are required to memorise and perform complex whole-body movement sequences, it also provides a continuous stream of sensorimotor and rhythmic stimuli, it facilitates social skill as it is typically performed in groups, and it incorporates emotional elements (Jola et al., 2013; Merom et al., 2013). The integration of all these elements has been argued to facilitate the development of working memory capacity (for an extensive review see Diamond & Ling, in press). While research has shown promising results in adult and elderly populations (Norouzi et al., 2019; Predovan, Julien, Esmail, & Bherer, 2019), it is currently unclear how dance influences cognition in children. For example, van den Berg, Saliasi, de Groot, Chinapaw, and Singh (2019) did not show any benefit of practicing dance 10 minutes a day for 9 weeks on children´s cognition (probably, dance duration was too short). Nevertheless, dance provides the opportunity to modulate cognitive and movement challenge in an 'ecological' manner, whereby the challenge can be increased without disrupting the typical perception and action coupling of dance, thus maintaining the characteristics of dance. Learning a dance choreography (i.e., a sequence of movements) requires performers to memorise movement sequences and recall those sequences during practice, largely involving working memory (Cortese & Rossi-

Arnaud, 2010), and a teacher can modulate cognitive challenge by manipulating the amount of movement sequences that children have to memorise, recall, and perform.

In skill acquisition, a teacher's verbal instructions and visual demonstrations are critical components of the learning process as they provide information on the skill to learn, and different strategies can be adopted to promote the learning process (Davids, Button, & Bennett, 2008; Magill, 2011; Wulf & Shea, 2002). The link between a teacher's instructions and working memory is well known, as an individual's working memory is involved when a teacher provides instructions and demonstrations to use the presented information to plan and execute a movement (Buszard et al., 2017; Liao & Masters, 2001; Maxwell, Masters, & Eves, 2003). Therefore, manipulating a teacher's strategy in providing instructions and demonstrations would directly impact the challenge on children's working memory capacity during a skill learning training. Applied to learning a dance choreography whereby children need to memorise and recall movement sequences, teachers can provide continuous demonstrations and continuously guide children's movement, or they can limit demonstrations and encourage children to recall movement sequences. The latter strategy would place a higher cognitive challenge than the former as children need to store information into working memory and recall movement sequences when executing a choreography, while children that continuously follow the teacher are not encouraged to memorise and recall sequences. In summary, dance may be a suitable activity to combine cognitive and motor challenge and in turn improve working memory capacity in children, and a teacher can modulate the challenge via the manipulation of instructions and demonstrations. However, due to the limited number of studies it is currently unclear how dance can augment the development of working memory capacity (Meng et al., 2019), and it is unexplored how different teaching pedagogies – instructions and demonstrations – influence children's development of working memory capacity.

The aim of this study was to examine how a dance curriculum with different level of cognitive challenge, induced by different teaching pedagogy, influences the development of working memory capacity in children. Primary school children were recruited and divided into three groups: two experimental groups – high cognitive and low cognitive challenge – that participated in a 7-week dance program and a control group that participated in standard PE curriculum. Based on recent findings on the exercise-cognition relation (Diamond & Ling, in press; Tomporowski & Pesce, 2019), it was hypothesised that both experimental groups would improve working memory capacity with respect to the control group, and, based on Moreau et al. (2015) work, that the high-cognitive group would enhance working memory capacity to a higher extent than the low-cognitive group. Secondly, this study aimed at examining the effect of the dance program and the different teaching pedagogy on the development of children's motor competence. The whole-body movements and sensorimotor activity of dance should promote motor competence, and the limited number of teacher's demonstrations in the high-cognitive group should facilitate children exploring different movement modalities and solutions (Tompsett, Sanders, Taylor, & Cobley, 2017). Therefore, it was hypothesised that children in both experimental groups would enhance motor competence more than control group and that the high-cognitive group would increase motor competence more than the low-cognitive group. Lastly, considering the tight relationship between working memory and other executive functions and that learning a skill has been suggested to improve all core executive functions (Tomporowski & Pesce, 2019), this study explored how the dance curriculum and the different cognitive challenges influenced the children's development of other executive functions (i.e., inhibitory control and cognitive flexibility).

Methods

Study design

A randomized controlled trial was conducted to evaluate the efficacy of a 7-week dance intervention to improve working memory capacity and motor competence in 8-10 years old children in one Victorian government-funded primary school in Australia. The study was approved by the research team's University Ethics Committee (ref 16-288) and by the Victorian Department of Education and Training.

The study design comprised of a baseline assessment (pre-test) on week 1, a dance training intervention from week 2 to week 8, and a post-test on week 9 (figure 1). Pre-test and post-test included an assessment of participants' working memory capacity, motor competence, and other cognitive functions, and the pre-test also included anthropometry measurement and a questionnaire on participants' level of physical activity (PAQ-C questionnaire Crocker, Bailey, Faulkner, Kowalski, & McGrath, 1997). Three groups took part in the study: two experimental groups practiced dance twice a week for 7 weeks, for a total of 14 lessons lasting for approximately 60 minutes each, and a control group did not practice dance (the school PE teacher was specifically instructed to avoid any type of dancing during her classes) and followed the school usual Physical Education (PE) and sport curriculum. The dance lessons took place during the participants' PE (on Tuesday or Wednesday) and sport classes (on Friday). None of the participants was practicing structured dance at the time of recruitment (confirmed in the physical activity questionnaire) and they were instructed to refrain from engaging in dance activities outside of school.

The Australian school academic calendar spans January to the middle of December. Data collection occurred between July and September 2018, during school term 3: measurements at pre-test in July and post-test in September. The design, conduct and reporting of this RCT adhere to the Consolidated Standards of Reporting Trials (CONSORT) guidelines for group trials (Begg et al., 1996).

****** Please insert figure 1 here ******

Participants and setting

Eighty primary school children (8.8 ± 0.7 years old; 61% females) were recruited from 4 different classes in grades 3 and 4. The required sample size was calculated a-priori using G*Power (version 3.1), with a repeated-measures test (within-between interaction) and the following details: $\alpha = 0.05$, power $(1 - \beta) = 0.8$, number of groups = 3, number of measurements = 2, correlation among repeated measures = 0.5, nonsphericity correction = 1, and an effect size $f = 0.18$ (derived from a recent meta-analysis on the effects of physical activity on working memory in children; de Greeff et al., 2017). The analysis resulted in a total sample size of 78. Two extra participants were recruited to account for attrition.

Prior to the study, the children and their parents were fully informed of the risks involved in participating in the experiment. Children provided written assent to participate in the study while their parents or guardians provided written consent. Children that were not able to participate in PE (e.g. due to medical conditions) or those with profound learning disabilities and formally recognised special educational needs (e.g., behavioural issues, speech and language impairment) were excluded from assessments and data analysis. Children that did not return parent consent form were exempt from the research, but able to participate in PE lessons.

Randomisation

Ideally, the participants of all involved classes should have been randomised into three groups – two experimental groups and a control group. However, for logistical reason, it was not possible to divide each class into the three groups, and it was decided to have one class as the control group and to divide the other three classes into the experimental groups. Therefore, one class (3/4D) was randomly selected as control group and the other 3 classes (3/4 A, B, and C) were divided into the two experimental groups using the minimisation procedure, which uses a technique similar to stratified randomization whereby participants are randomised into groups based on their stratification on certain variables of interest (or covariates) (Hopkins, 2010). This was performed after the pre-test, and participants were stratified based on their pre-test performance in working memory capacity. In summary, two levels of randomization were performed: first, a cluster randomization to randomize one class as control group and three classes as experimental groups; second, a (similar to) stratified randomization to assign participants of the experimental-group classes into the two experimental groups – high-cognitive group and low-cognitive group. This resulted in 3 groups: high-cognitive group (n = 30, 8.8 ± 0.5 years old, 62% females), low-cognitive group (n = 30, 8.7 ± 0.7 years old, 59% females), and a control group (n = 20, 8.9 ± 0.7 years old, 63% females). The three groups had similar age (p = 0.47), BMI (p = 0.97) and physical activity level (p = 0.90) (see table 1).

****** Please insert table 1 here ******

Blinding and inter/intra rater reliability

The experimenters who administered the working memory capacity, motor competence, and cognitive functions tests were blinded with respect to the group each participant belonged to. Furthermore, the experimenters who observed the dance classes to evaluate the fidelity to pedagogical approach knew which experimental group they were observing but they were blinded with respect to the specific research hypothesis.

While the assessment of working memory capacity and cognitive functions was iPad based and did not involve any subjective assessment, the motor competence assessment was primarily subjective and required high reliability. The two examiners that administered the motor competence test received a total of 5 hours of training on testing procedure and assessment criteria. To assess their intra- and inter-rater reliability, they independently coded the performance of 10 pilot trials from recorded videos, and then re-coded a week later. The intraclass correlation for intra- and inter-rater reliability was 0.93 and 0.91 respectively, which indicate high reliability.

Intervention delivery

Two experienced dance teachers designed the lesson content which was a jazz-dance choreography. The choreography was based on a Michael Jackson's song – Ease on Down the Road – and included a sequence of approximately 50 movements, some of which were repeated twice. The choreography combined whole-body movements on the spot and in the space. A sequence of eight movements was taught in the first lesson, and then a sequence of four to eight movements was added in each of the following lessons. Each dance lesson was comprised of approximately a 5-min warm up, 20 minutes of drills, and 30 minutes of choreography practice. Various movements were included in the drill section, such as marching, skipping, galloping, step-kicking, and chaines. These movements were preparatory for the choreography. The choreography section was structured into four main parts: rehearsal of previously learned movement sequences, learning of a new movement sequence, adding the new movement sequence to the previously learned sequence, and practice of the choreography.

The lesson content and the choreography were the same for the two experimental groups. What differentiate the groups was the teaching pedagogy. In the high-cognitive group, the teachers limited the number of demonstrations to a minimum and encouraged children to recall previously learned movement sequences, challenging their working memory capacity. Furthermore, given the limited number of demonstrations, feedback was primarily delivered verbally with an external focus of attention (i.e., directing participants' attention to the outcome of a movement). In the low-cognitive group, the dance teachers always demonstrated the movement drills and choreography sequences, and the children copied the teacher's movements. Three experienced dance teachers ran the dance lessons and they rotated across the two groups to avoid a teacher effect. The teachers were trained on delivering the lesson content differently in the two groups. While the pedagogy for the low-cognitive group was familiar to the teachers (i.e., it is the standard pedagogy in dance), for the high-cognitive group, teachers were specifically instructed to stop demonstrating a movement or a movement sequence when half of the class was able to perform at least half of a sequence.

The control group participated in PE and sport lessons following the school curriculum, which focussed on providing children with the opportunity to experience and practice different sports, team sports primarily. A different sport was practiced for 2 weeks, including athletics, Australian football, football, and volleyball. Each PE lesson comprised drills and games, while the sport lesson was primarily game-based.

Fidelity to pedagogical approach

The two experimental groups were expected to differ only on how the lesson content was delivered (i.e., teaching pedagogy). Content and volume of practice were expected to be similar across the two groups. A check of teaching pedagogy and volume of practice was performed six times in each group to assess differences and similarities between the experimental groups. Six lessons in each group were randomly selected, and during these lessons two research assistants took notes on: duration of each section (i.e., warm up, drills, and choreography); number of drills and choreography repetitions; number of demonstrations (or no demonstrations); number of visual and verbal feedback. Demonstration referred to a teacher's demonstration of the entire movement or movement sequence, while visual feedback referred to a teacher's demonstration of a movement part.

Outcomes

Primary outcome

Working memory capacity was considered the primary outcome of this study.

Working memory capacity. Working memory capacity was assessed using the list sorting working memory test from the National Institute for Health Toolbox (NIH Toolbox; www.NIHToolbox.org). The NIH Toolbox is a comprehensive set of neuro-behavioural measurements that quickly assess cognitive, emotional, sensory, and motor functions from the convenience of an iPad (Gershon et al., 2013), and has well established validity and reliability for use with children aged 3-15 years (Tulsky et al., 2013; Zelazo et al., 2013). Under the guidance of a trained member of the research team (1:1), in a quiet space outside the classroom (e.g. the library), individual children were asked to work through the list sorting working memory task, which lasts for approximately 7 mins (Weintraub et al., 2013).

The list sorting working memory task requires participants to memorize, elaborate and recall a series of pictures of food and animals presented on the iPad screen. At the end of each series, a blank screen appears, and participants are required to repeat the pictures in order of size, from smallest to largest. There are 2 conditions: 1-list and 2-list condition. In the 1-list condition, only one category of pictures (food or animals) is presented in each series, whereas both picture categories are presented in the 2-list condition in each series. In each condition, the number of pictures increases on successive series to overload a participant's working memory capacity. Prior to the test, participants performed 2 practice trials in each condition. The software provides an outcome variable for the 1-list and 2-list tasks, and for the overall performance. The outcome variables consist of the number of correct recalls.

Secondary outcomes

Motor competence. Motor competence was assessed using the Canadian Agility and Movement Skill Assessment (CAMSA; Longmuir et al., 2017). It is comprised of 7 tasks – two-feet jumping inside hoops, sliding sideways, catching and throwing a small soft ball, skipping, one-foot jumping inside hoops, and kicking a ball – to be completed in sequence as fast and as accurate as possible. Two examiners administered the test. One examiner measured participants' completion time using a stopwatch, provided verbal cues to the participants during their trial, threw the ball to be caught, and positioned the ball to be kicked. The other examiner assessed the quality of performance and scored penalties. Participants were assessed in groups of 10. They were provided with instructions, two demonstrations, two practice trials, and two test trials. One examiner gave the "start" and provided verbal cues to the participants during the execution of the test to avoid memory affecting their performance. CAMSA has been shown to be valid and reliable in 8-12 years-old children (Lander, Morgan, Salmon, Logan, & Barnett, 2017; Longmuir et al., 2017).

Participants' completion time and quality of movement were assessed and then combined to obtain the test score. The time to complete the test was measured from the examiner's "start" to a participant's ball kick, and it was converted to a pre-defined score (range 1–14). The faster the course completion, the higher the score. The quality of each skill was scored as either performed (score of '1') or not (score of '0') across 14 reference criteria (e.g., two feet out of the hoops and simultaneous landing, no extra jumps and no touching of hoops). A total score was then computed combining the time and skill scores, and it ranged between 1 and 28 (Longmuir et al., 2017).

Cognitive flexibility and inhibitory control. Cognitive flexibility and inhibitory control were assessed using the dimensional change card sort (DCSS) test and the flanker test, respectively, from the NIH Toolbox (Gershon et al., 2013). The DCSS test requires participants to match two target pictures with a reference picture by either colour or shape. Prior to the appearance of the reference stimulus, a cue – *shape* or *colour* – appears on the screen indicating the participant what dimension the target should be matched by. Participants are instructed to choose as quick as possible which of the two target items matches the dimension indicated by touching the screen with their index finger.

The Flanker test requires participants to focus on the central arrow appearing on the iPad screen while inhibiting attention to the arrows flanking it. On congruent trials, all the arrows point in the same direction, whereas, on incongruent trials, the middle arrow point in the opposite direction of the other arrows. Participants are instructed to choose as fast as possible one of two buttons on the screen that corresponds to the direction in which the middle arrow is pointing. Both tests were administered following the procedure of the working memory task. Participants performed 4 practice trials in each test, and 30 trials in the DCCS test and 20 trials in the Flanker test.

In both DCCS and Flanker tests, the software recorded participants' response accuracy (i.e., number of correct responses) and response time, from stimulus appearance to a button was pressed, combined them, and provided an arbitrary outcome measure, which ranges from 0 to 10. The software uses a 2-vector scoring method (vector ranges from 0 to 5 in both accuracy and response time) and considers accuracy first; if accuracy level is less than or equal to 80% (i.e., vector = 4), the outcome measure is equal to the accuracy score. When accuracy is higher than 80%, reaction time and accuracy are combined.

Statistical analysis

A repeated-measures ANOVA with group (high-cognitive, low-cognitive, and control) and time (pre and post) as fixed factors was performed on the dependent variables separately. When a group*time effect was found, a one-way ANOVA with group as fixed factor and Tukey post-hoc analysis were computed on the groups' pre-to-post changes in performance to assess which group improved the most from pre- to post-test. To test how each group responded to the intervention, pre- to post-test pairwise t-test was computed in each group on the dependent variables, using Bonferroni correction for multiple (3) comparisons. Furthermore, Pearson correlation was performed on pre- to post-test score changes (Δ) between motor competence and working memory outcomes – overall and 2-list score – for each group and the 3 groups combined. Lastly, the teaching pedagogy and volume of practice variables were analysed separately using an independent t-test.

An initial inspection of the results suggested that gender might have influenced the group´s responses to the intervention; therefore, an exploratory repeated-measures ANOVA with group (high-cognitive, low-cognitive, and control), gender (male, female), and time (pre, post) as fixed factors was performed on the dependent variables (note: gender was not considered a factor in the initial design, thus the sample size is not sufficient for a proper analysis). Furthermore, gender was included as a factor in the pairwise comparison, performing repeated-measures ANOVA in each group individually with gender as a fixed factor, and females and males were separately compared in each group using a pairwise t-test.

Prior to conducting ANOVAs, the assumption of normality was checked through the analysis of skewness and kurtosis of the data distribution and visual inspection of boxplots. Data associated with skew less than 2 and kurtosis less than 9 was evaluated as normally distributed (Schmider, Ziegler, Danay, Beyer, & Bühner, 2010). Furthermore, the assumption of homogeneity of variance was checked using Levene's test. Lastly, given that the different randomisation of the control group might have clustered the data, we computed the Intraclass

Correlation Coefficient (ICC) using linear mixed modelling on post-test motor competence and working memory variables to check whether a repeated-measures ANOVA was appropriate, or multilevel modelling was needed instead. ICC represents the proportion of variance that is explained by the grouping structure (the cluster randomization in this study) and was calculated dividing the variance between clusters by the sum of between-clusters variance and variance within groups (Chen et al., 2018). Typically, ICC below 0.05 indicates that the grouping structure does not influence the observed variance.

All statistical analyses were run using SPSS (version 25.0. Armonk, NY: IBM Corp.). Statistical significance was set at $p < 0.05$ and effect sizes were calculated to assess the magnitude of change. Considering the Bonferroni correction, statistical significance was reduced to $p < 0.017$ (0.05/3) in multiple comparisons. Partial eta-squared (η_p^2) was calculated in the ANOVAs and was evaluated as follow: < 0.01 trivial, 0.01-0.06 small, 0.06-0.14 moderate, and > 0.14 large, while Cohen's d was calculated in the t-tests and evaluated as follows: < 0.2 trivial, 0.2-0.5 small, 0.5-0.8 moderate, and > 0.8 large (Cohen, 1988). Correlations were considered of small, moderate or large size when their value was in the order of 0.1, 0.3, and 0.5 respectively (Cohen, 1988).

Results

The assumptions of homogeneity of variance and normal distribution of the data were met in all the analyses (Levene's test, $p > 0.05$; skew = 0.18 to 1.53; kurtosis = 0.21 to 8.5). ICC was 0.002 for CAMSA and could have not been computed for the working memory variables because covariance was redundant (meaning that ultimately ICC was 0; IBM, 2019). Therefore, ANOVA was considered appropriate for analysing the data.

Six participants were excluded from the initial sample due to having missed at least half of the dance lessons or having left the school, and the final sample included 74 participants (high-cognitive, n = 26; low-cognitive, n = 29; control, n = 19).

Fidelity to pedagogical approach

The descriptive and inferential statistics for teaching pedagogy and volume of practice variables across the two experimental groups are presented in table 2. The analysis showed that the volume of practice did not differ between groups, warm-up duration ($p = 0.57$), drill duration ($p = 0.64$), number of drill repetitions ($p = 0.54$), choreography practice duration ($p = 0.51$), and number of choreography repetitions ($p = 0.20$). The frequency of demonstrations and visual feedback during drills was significantly higher in the low-cognitive than the high-cognitive group ($p < 0.01$ in both), and the number of teachers' demonstrations of the choreography was significantly higher in the low-cognitive than the high-cognitive group ($p < 0.01$ in both).

****** Please insert table 2 here ******

Working memory capacity

Overall score

ANOVA showed a statistically significant effect of time ($F[1,73] = 8.32$, $p <0.01$, $\eta_p^2 = 0.11$), but there was no significant effect of group ($p = 0.73$), nor group*time ($p = 0.80$). Pairwise comparison did not show any statistically significant effect (Table 4).

The exploratory ANOVA showed a significant effect of time ($F[1,73] = 7.28$, $p <0.01$, $\eta p^2 = 0.10$) and trends towards significance effect of gender ($p = 0.054$). For the within-group pairwise comparisons, ANOVA showed a trend towards significance effect of gender ($F[1,25] = 6.80$, $p = 0.02$, $\eta p^2 = 0.24$) in the high-cognitive group; no significant effects in the low-cognitive and control groups.

2-list score

ANOVA showed a statistically significant effect of time ($F[1,73] = 11.35$, $p < 0.01$, $\eta_p^2 = 0.14$), while group ($p = 0.72$) and group*time ($p = 0.42$) effects were not statistically significant. Pairwise comparison analysis showed a statistically significant moderate improvement in the high-cognitive group ($T[25] = 3.35$, $p < 0.01$, $\Delta = 1.21 \pm 0.75$, $d = 0.51$) and a non-significant moderate improvement in the low-cognitive group ($T[28] = 2.11$, $p = 0.04$, $\Delta = 1.10 \pm 1.07$, $d = 0.48$) (Figure 2 and Table 4).

The exploratory ANOVA showed a significant effect of time ($F[1,73] = 9.51$, $p <0.01$, $\eta p^2 = 0.13$). For the within-group pairwise comparisons, ANOVA showed an effect of time ($F[1,25] = 7.23$, $p = 0.01$, $\eta p^2 = 0.25$) and gender ($F[1,25] = 10.92$, $p = 0.01$, $\eta p^2 = 0.25$) in the high-cognitive group; no significant effects in the low-cognitive and control groups. T-test showed that females significantly improved their score ($T[1,15] = 2.13$, $p < 0.01$, $\Delta = 1.69 \pm 1.02$, $d = 0.97$) while the males did not statistically improve in the high-cognitive group (Table 4).

****** Please insert figure 2 here ******

Motor competence

ANOVA showed a significant time effect ($F[1,73] = 152.05$, $p < 0.01$, $\eta_p^2 = 0.70$) and a group*time effect ($F[2,73] = 5.02$, $p < 0.01$, $\eta_p^2 = 0.13$) in the CAMSA score; group effect was not significant ($p = 0.18$). Furthermore, the analysis showed a significant group effect in the pre-test ($F[1,73] = 4.75$, $p = 0.012$, $\eta_p^2 = 0.12$) and the post hoc analysis showed that the control group had a significantly higher score than the high-cognitive ($p = 0.02$) and low-cognitive ($p = 0.03$) groups (figure 4). Pre-to-post pairwise comparisons showed significant improvement in all three groups (high-cognitive, $T[25] = 7.73$, $p < 0.01$, $\Delta = 4.58 \pm 1.29$, d =

1.50; low-cognitive, T[28] = 11.53, $p < 0.01$, Δ = 4.03 ± 0.71, d = 1.15; control, T[18] = 3.94, $p < 0.01$, Δ = 2.74 ± 1.28, d = 0.95) (Table 4).

One-way ANOVA on the groups' pre- to post-test changes showed a group effect (same as group*time effect in the repeated-measures ANOVA) and the post-hoc analysis showed that the high-cognitive group had a larger improvement than the control group (p = 0.01), while there were no other significant effects (high-cognitive vs low-cognitive, p = 0.29; low-cognitive vs control, p = 0.27) (Figure 3).

The exploratory ANOVA showed a significant effect of time (F[1,73] = 137.82, $p < 0.01$, $\eta p^2 = 0.69$), group (F[1,73] = 4.08, p = 0.02, $\eta p^2 = 0.12$) and gender (F[1,73] = 4.33, p = 0.04, ηp2 = 0.07) and towards significance effect of time*group (p = 0.051). For the within-group pairwise comparisons, ANOVA showed a time effect in all three groups (high cognitive, F[1,25] = 49.81, $p < 0.01$, $\eta p^2 = 0.98$; low cognitive, F[1,28] = 118.50, $p < 0.01$, $\eta p^2 = 0.83$; control, F[1,18] = 16.92, $p < 0.01$, $\eta p^2 = 0.51$). T-test showed that all subgroups (i.e., gender) improved their score except the females in the control group (p = 0.03) (Table 4).

****** Please insert figure 3 here ******

Correlations

While not being statistically significant, the analysis showed a moderate positive correlation in the high-cognitive group between Δ CAMSA and Δ working memory capacity - overall score (r = 0.27, p = 0.27) and 2-list score (r = 0.34, p = 0.13), a moderate negative correlation in the low-cognitive group for working memory capacity overall score (r = -0.31, p = 0.12) and 2-list score (r = 0.34, p = 0.08), trivial correlations in the control group and in the three groups combined (Table 3).

****** Please insert table 3 here ******

Cognitive flexibility

ANOVA showed a statistically significant time effect (F[1,73] = 9.84, p < 0.01, $\eta_p^2 = 0.13$), and no significant effect of group (p = 0.30) nor group*time (p = 0.53) in the DCSS score. Pairwise comparisons did not show any statistically significant improvement in the three groups (Table 4).

The exploratory ANOVA showed a significant effect of time (F[1,73] = 9.70, p < 0.01, $\eta p^2 = 0.13$). For the within-group pairwise comparisons, ANOVA showed no significant effects in all three groups. T-test showed that the males significantly improved their score (T[1,11] = 2.20, p = 0.015, Δ = 0.81 ± 0.62, d = 1.04) in the low-cognitive group.

Inhibitory control

ANOVA showed a statistically significant time effect (F[1,73] = 10.44, p < 0.01, $\eta_p^2 = 0.13$), and no significant effect of group (p = 0.69) nor group*time (p = 0.33) in the Flanker task score. Pairwise comparisons showed a significant pre-to-post improvement in the control group only (T[18] = 3.3, p < 0.01, Δ = 0.33 ± 0.21, d = 0.41) (Table 4).

The exploratory ANOVA showed a significant effect of time (F[1,73] = 7.83, p < 0.01, $\eta p^2 = 0.11$) and gender (F[1,73] = 8.21, p < 0.01, $\eta p^2 = 0.11$). For the within-group pairwise comparisons, ANOVA showed no significant effects in the high-cognitive and low-cognitive groups, and a significant effect of time (F[1,18] = 8.65, p < 0.01, $\eta p^2 = 0.34$) in the control group. T-test showed that the females significantly improved their score ($T[1,11] = 2.20$, $p < 0.01$, $\Delta = 0.50 \pm 0.23$, $d = 0.73$) in the control group.

****** Please insert table 4 here ******

Discussion

This study examined whether the implementation of a dance intervention during PE classes in a primary school improved children's working memory capacity and motor competence, and how different teaching pedagogies, which impacted on the cognitive challenge of dance practice, would influence any change in working memory capacity and motor competence. It was hypothesised that the two experimental groups, who each learned a dance choreography for 7 weeks (total of 14 lessons), would improve their working memory capacity relative to the control group, and that a high cognitive challenge during dancing would result in a larger improvement relative to a low challenge. While statistically there were not significant differences between groups, the results provided preliminary support for our hypotheses. The high-cognitive group significantly improved their working memory capacity (in the 2-list task) from pre to post test, while the low-cognitive group showed large but no significant improvement and the control group did not show any statistically significant improvement. Furthermore, improvement in working memory capacity were positively and moderately correlated with improvement in motor competence in the high-cognitive group, while correlation was trivial in the control group. This suggests a parallel improvement in working memory capacity and motor competence as a result of the activities and pedagogy adopted in the high-cognitive group. Interestingly, working memory capacity did not significantly improve in the low-cognitive group (contrary to prediction) and there was a moderate-negative correlation between improvement in working memory capacity and motor competence. This may suggest that the designed pedagogy (i.e., continuous demonstrations of movement sequences and movement form) caused a trade-off between cognition and movement: children who strictly followed the teacher's movement improved their motor competence but were not cognitively engaged, while children who made an effort to memorize and recall movement sequences improved their working memory capacity at the cost of movement execution (however, this is merely a speculation and should be considered cautiously). Interestingly, gender was found to be a significant factor in the high cognitive group where females significantly improved their working memory capacity score (2-list score) whilst males did not. Although this was an exploratory analysis, it does align with the premise that females prefer dance more than males and, consequently, may be more engaged when participating in a dance curriculum (Gao, Zhang, & Podlog, 2014). In our study, however, this was only the case in the high cognitive group. Together, the results of this study suggest that a dance curriculum can promote the development of children's working memory capacity if the adopted teaching pedagogy encourages an enhanced cognitive challenge (i.e. limited visual demonstrations and encouraging children to recall movement sequences).

It has been suggested that dance can improve working memory capacity (Diamond & Ling, 2016; Eggenberger, Schumacher, Angst, Theill, & de Bruin, 2015; Tomporowski & Pesce, 2019) and the results of this study provide initial support for this argument. Dance provides continuous sensorimotor stimuli, including a variety of whole-body movements, requires individuals to memorise and recall long sequences of movements, and performers time their movement with the rhythm of the music (Cortese & Rossi-Arnaud, 2010; Jola et al., 2013; Merom et al., 2013). While this sounds appealing, previous research focussed on the effect of dance on slowing the decline of working memory capacity in the elderly and did not show clear benefits of practicing dance on working memory capacity (Merom et al., 2013; Müller et al., 2017). Furthermore, teaching pedagogies have been argued to influence the development of working memory capacity in physical exercise interventions (Moreau & Conway, 2014; Tomporowski & Pesce, 2019). The current study is the first showing how learning a dance choreography for 14 lessons coupled with a teaching pedagogy that challenges cognition could promote the development of working memory capacity in primary school children. In its novelty, this study suggests that limiting visual demonstrations and encouraging children to memorise and recall movement sequences, as opposed to the teacher providing continuous demonstrations, could promote the development of children's working memory capacity.

This study also examined how dance and the two different teaching pedagogies – low and high cognitive challenge – influenced the development of motor competence in primary school children. It was hypothesised that the two experimental groups would improve motor competence more than the control group, and that the high-cognitive group would show larger improvement than the low-cognitive group. All 3 groups improved from pre to post, with the high-cognitive group having the largest effect size and showing statistically significant larger improvement than control group, partially confirming the initial hypothesis. While we did not measure the potential processes that may underpin the motor competence improvement, we can speculate that the limited demonstrations in the high-cognitive group encouraged participants to continuously adapt their movements and perfect their technique repetition after repetition, while the low-cognitive participants copied the teacher and kept repeating the same movements. However, we need to be cautious in the interpretation of these results. The control group had a high score in the pre-test (significantly higher than the experimental groups), and a ceiling effect could possibly be responsible for the lower group's improvement relative to the experimental groups. Furthermore, the fact that all 3 groups, including the control group, statistically improved from pre to post may suggest a test learning effect (i.e., participants learned how to perform the test rather than improving motor competence), which, in turn, may have masked between-groups differences. However, the control group performed team sports throughout the intervention period and they may also have improved motor competence; therefore, it could be difficult to discern motor competence improvement from a test learning effect.

A final aim of this study was to explore if the dance curriculums supported children's development of inhibitory control and cognitive flexibility. For both inhibitory control and cognitive flexibility there was no statistically significant differences between groups. However, a closer inspection of the results for inhibitory control showed that the two experimental groups did not improve their inhibitory control from pre to post test, whilst the control group did show a statistically significant improvement, thus suggesting that some improvement may have occured in the control group. Pesce et al. (2016) found similar improvements in inhibitory control that were mediated by improvements in ball skills and suggested that a game-based pedagogy that promoted problem solving and encouraged children to explore a wider range of movement solutions may have challenged and then honed the interceptive and planning processes of the children. The control group in our study had a similar nonlinear experience where every two weeks they would play different drills and games in PE, and sports ranging from athletics to Australian football, volleyball and soccer. On reflection the lack of improvement in inhibitory control in the experimental groups is possibly due to the nature of the highly linear structure of the dance curriculums devised for both low and high cognitive challenge, where both groups had to learn a sequence of eight movements in the first lesson, and then add new moves to this sequence each week.

This study showed how learning a dance choreography with a linear lesson structure (i.e., each lesson added 8 new movements to the choreography) improved working memory in children. The fact that the females showed greatest improvement in working memory capacity may suggest the importance of the activity tapping into a child's 'hot executive functions' that call into play the emotional dimensions of self-control and self-regulation (Lakes, 2012), and future studies should explore children's motivations and engagement into their dance physical activity experiences. Although this study found no change in cognitive flexibility and inhibitory control after the dance curriculum, future research should also examine how different dance curriculums may influence all three executive functions. For example, creative dance whereby individuals explore, discover, and create different movements to the rhythm of music could challenge and improve all three executive functions (Torrents, Castaner, & Anguera, 2011). Another option could be adopting a nonlinear pedagogy, which has been recently argued to support the key characteristics to improve executive functions (Rudd, Crotti, et al., 2019; Rudd, O'Callaghan, & Williams, 2019) – challenge executive function, elicit commitment and emotional investment, supportive environment, promote individual's feeling of competence and self-confidence (Diamond & Ling, 2019). A nonlinear pedagogy could as well address some of the shortfalls within our current study due to the linear lesson structure.

It must be acknowledged that the current study presents some limitations. For logistical reason, we have not been able to control for and measure the PE curriculum of the control group. Also, we did not measure children's physical activity outside of PE classes throughout the intervention, which might have been a confounder. We instructed children to refrain from engaging in dance activities outside of school; however, we did not record whether children participated in other sports outside of school. Knowing these details would have improved the interpretation of the results, and we encourage future research to address these issues.

Conclusions

This study showed that a 7-week (RCT) dance curriculum could improve working memory capacity in primary school children and that limiting visual demonstrations and encouraging children to recall movement sequences – high-cognitive group – could further enhance working memory capacity. Furthermore, the results suggest that the high-cognitive group improved motor competence to a larger extent than the low-cognitive group, which received continuous visual demonstrations during dance practice. Together, these results suggest that dance practice can improve working memory capacity and motor competence in children; however, the difference between experimental groups and control group were not statistically significant, and future research is necessary to better examine this issue. Lastly, this study suggested that the dance curriculum adopted, which was linearly structured, does not improve other executive functions (i.e., inhibitory control and cognitive flexibility), and future research should examine different teaching pedagogies (for example, nonlinear pedagogy) that may improve all 3 executive functions.

Acknowledgements

We would like to thank all participants, research assistants, Mrs Leanne Dumaresq, and the dance teachers – Rebecca, Stevi and Mary – for their important contribution to this study.

References

Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology, 106*(1), 20-29. doi:10.1016/j.jecp.2009.11.003

Anderson, V. A., Anderson, P., Northam, E., Jacobs, R., & Catroppa, C. (2001). Development of executive functions through late childhood and adolescence in an Australian sample. *Developmental Neuropsychology, 20*(1), 385-406. doi:10.1207/s15326942dn2001_5

Begg, C., Cho, M., Eastwood, S., Horton, R., Moher, D., Olkin, I., . . . Stroup, D. F. (1996). Improving the quality of reporting of randomized controlled trials. The CONSORT statement. *Jama, 276*(8), 637-639.

Buszard, T., Farrow, D., Verswijveren, S. J. J. M., Reid, M., Williams, J., Polman, R., . . . Masters, R. S. W. (2017). Working memory capacity limits motor learning when implementing multiple instructions. *Frontiers in Psychology, 8*(1350). doi:10.3389/fpsyg.2017.01350

Buszard, T., & Masters, R. S. W. (2018). Adapting, correcting and sequencing movements: Does working-memory capacity play a role? *International Review of Sport and Exercise Psychology, 11*(1), 258-278. doi:10.1080/1750984X.2017.1323940

Chen, G., Taylor, P. A., Haller, S. P., Kircanski, K., Stoddard, J., Pine, D. S., . . . Cox, R. W. (2018). Intraclass correlation: Improved modeling approaches and applications for neuroimaging. *Human Brain Mapping, 39*(3), 1187-1206. doi:10.1002/hbm.23909

Cohen, J. (Ed.) (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, N.J.: L. Erlbaum Associates, 1988.

Cortese, A., & Rossi-Arnaud, C. (2010). Working memory for ballet moves and spatial locations in professional ballet dancers. *Applied Cognitive Psychology, 24*(2), 266-286. doi:10.1002/acp.1593

Crocker, P. R., Bailey, D. A., Faulkner, R. A., Kowalski, K. C., & McGrath, R. (1997). Measuring general levels of physical activity: preliminary evidence for the Physical Activity Questionnaire for Older Children. *Med Sci Sports Exerc, 29*(10), 1344-1349. doi:10.1097/00005768-199710000-00011

Davids, K., Button, C., & Bennett, S. (Eds.). (2008). *Dynamics of skill acquisition: A constraints-led approach*. Champaign, IL: Human Kinetics.

de Greeff, J. W., Bosker, R. J., Oosterlaan, J., Visscher, C., & Hartman, E. (2017). Effects of physical activity on executive functions, attention and academic performance in preadolescent children: A meta-analysis. *Journal of Science and Medicine in Sport, 21*(5), 501-507. doi:https://doi.org/10.1016/j.jsams.2017.09.595

Diamond, A. (2013). Executive functions. *Annu Rev Psychol, 64*, 135-168. doi:10.1146/annurev-psych-113011-143750

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science, 333*(6045), 959-964. doi:10.1126/science.1204529

Diamond, A., & Ling, D. S. (2016). Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. *Developmental Cognitive Neuroscience, 18*, 34-48. doi:10.1016/j.dcn.2015.11.005

Diamond, A., & Ling, D. S. (2019). Aerobic-Exercise and resistance-training interventions have been among the least effective ways to improve executive functions of any method tried thus far. *Developmental Cognitive Neuroscience, 37*, 100572. doi:10.1016/j.dcn.2018.05.001

Diamond, A., & Ling, D. S. (in press). Review of the evidence on, and fundamental questions about, efforts to improve executive functions, including working memory. In J. M. Novick, M. F. Bunting, M. R. Dougherty, & W. E. Randall (Eds.), *Cognitive and working memory training: Perspectives from psychology, neuroscience, and human development*. NYC, NY: Oxford University Press.

Eggenberger, P., Schumacher, V., Angst, M., Theill, N., & de Bruin, E. D. (2015). Does multicomponent physical exercise with simultaneous cognitive training boost cognitive performance in older adults? A 6-month randomized controlled trial with a 1-year follow-up. *Clinical Interventions in Aging, 10*, 1335-1349. doi:10.2147/CIA.S87732

Gao, Z., Zhang, P., & Podlog, L. W. (2014). Examining elementary school children's level of enjoyment of traditional tag games vs. interactive dance games. *Psychology, Health & Medicine, 19*(5), 605-613. doi:10.1080/13548506.2013.845304

Gershon, R. C., Wagster, M. V., Hendrie, H. C., Fox, N. A., Cook, K. F., & Nowinski, C. J. (2013). NIH toolbox for assessment of neurological and behavioral function. *Neurology, 80*(11 Suppl 3), S2-6. doi:10.1212/WNL.0b013e3182872e5f

Hair, N. L., Hanson, J. L., Wolfe, B. L., & Pollak, S. D. (2015). Association of child poverty, brain development, and academic achievement. *JAMA Pediatrics, 169*(9), 822-829. doi:10.1001/jamapediatrics.2015.1475

Hofer, S. M., & Clouston, S. (2014). Commentary: On the importance of early life cognitive abilities in shaping later life outcomes. *Res Hum Dev, 11*(3), 241-246. doi:10.1080/15427609.2014.936173

Hopkins, W. G. (2010). Assigning subjects to groups in a controlled trial. *Sportscience, 14*, 7-12.

IBM. (2019). Final Hessian matrix not positive definite or failure to converge warning. In *https://www.ibm.com/support/pages/final-hessian-matrix-not-positive-definite-or-failure-converge-warning*. Retrieved on 17/12/2019.

Jola, C., McAleer, P., Grosbras, M. H., Love, S. A., Morison, G., & Pollick, F. E. (2013). Uni- and multisensory brain areas are synchronised across spectators when watching unedited dance recordings. *Iperception, 4*(4), 265-284. doi:10.1068/i0536

Lakes, K. D. (2012). The response to challenge scale (RCS): The development and construct validity of an observer-rated measure of children's self-regulation. *The International journal of educational and psychological assessment, 10*(1), 83-96. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/25750758

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4349369/

Lakes, K. D., Bryars, T., Sirisinahal, S., Salim, N., Arastoo, S., Emmerson, N., . . . Kang, C. J. (2013). The healthy for life taekwondo pilot study: A preliminary evaluation of effects on executive function and BMI, feasibility, and acceptability. *Mental Health and Physical Activity, 6*(3), 181-188. doi:10.1016/j.mhpa.2013.07.002

Lander, N., Morgan, P. J., Salmon, J., Logan, S. W., & Barnett, L. M. (2017). The reliability and validity of an authentic motor skill assessment tool for early adolescent girls in an Australian school setting. *J Sci Med Sport, 20*(6), 590-594. doi:10.1016/j.jsams.2016.11.007

Liao, C. M., & Masters, R. S. (2001). Analogy learning: a means to implicit motor learning. *J Sports Sci, 19*(5), 307-319. doi:10.1080/02640410152006081

Longmuir, P. E., Boyer, C., Lloyd, M., Borghese, M. M., Knight, E., Saunders, T. J., . . . Tremblay, M. S. (2017). Canadian Agility and Movement Skill Assessment

(CAMSA): Validity, objectivity, and reliability evidence for children 8–12 years of age. *Journal of Sport and Health Science, 6*(2), 231-240. doi:10.1016/j.jshs.2015.11.004

Ludyga, S., Gerber, M., Brand, S., Holsboer-Trachsler, E., & Pühse, U. (2016). Acute effects of moderate aerobic exercise on specific aspects of executive function in different age and fitness groups: A meta-analysis. *Psychophysiology, 53*(11), 1611-1626. doi:10.1111/psyp.12736

Magill, R. A. (Ed.) (2011). *Motor learning and control: Concepts and applications* (9th ed.). New York: McGraw-Hill.

Mavilidi, M. F., Ruiter, M., Schmidt, M., Okely, A. D., Loyens, S., Chandler, P., & Paas, F. (2018). A narrative review of school-based physical activity for enhancing cognition and learning: The importance of relevancy and integration. *Frontiers in Psychology, 9*(2079). doi:10.3389/fpsyg.2018.02079

Maxwell, J. P., Masters, R. S. W., & Eves, F. F. (2003). The role of working memory in motor learning and performance. *Consciousness and Cognition, 12*(3), 376-402. doi:10.1016/S1053-8100(03)00005-9

Meng, X., Li, G., Jia, Y., Liu, Y., Shang, B., Liu, P., . . . Chen, L. (2019). Effects of dance intervention on global cognition, executive function and memory of older adults: A meta-analysis and systematic review. *Aging Clinical and Experimental Research*. doi:10.1007/s40520-019-01159-w

Merom, D., Cumming, R., Mathieu, E., Anstey, K. J., Rissel, C., Simpson, J. M., . . . Lord, S. R. (2013). Can social dancing prevent falls in older adults? A protocol of the Dance, Aging, Cognition, Economics (DAnCE) fall prevention randomised controlled trial. *BMC Public Health, 13*, 477. doi:10.1186/1471-2458-13-477

Moreau, D. (2016). Brains and brawn: Complex motor activities to maximise cognitive enhancement *Educational Psychology Review, 27*(3), 475-482.

Moreau, D., & Conway, A. R. (2013). Cognitive enhancement: A comparative review of computerized and athletic training programs. *International Review of Sport and Exercise Psychology, 6*(1), 155-183. doi:10.1080/1750984x.2012.758763

Moreau, D., & Conway, A. R. (2014). The case for an ecological approach to cognitive training. *Trends in Cognitive Science, 18*(7), 334-336. doi:10.1016/j.tics.2014.03.009

Moreau, D., Morrison, A. B., & Conway, A. R. (2015). An ecological approach to cognitive enhancement: Complex motor training. *Acta Psychol (Amst), 157*, 44-55. doi:10.1016/j.actpsy.2015.02.007

Müller, P., Rehfeld, K., Schmicker, M., Hökelmann, A., Dordevic, M., Lessmann, V., . . . Müller, N. G. (2017). Evolution of neuroplasticity in response to physical activity in old age: The case for dancing. *Frontiers in Aging Neuroscience, 9*, 56-56. doi:10.3389/fnagi.2017.00056

Norouzi, E., Hosseini, F., Vaezmosavi, M., Gerber, M., Pühse, U., & Brand, S. (2019). Zumba dancing and aerobic exercise can improve working memory, motor function, and depressive symptoms in female patients with Fibromyalgia. *European Journal Of Sport Science*, 1-11. doi:10.1080/17461391.2019.1683610

Pesce, C. (2012). Shifting the focus from quantitative to qualitative exercise characteristics in exercise and cognition research. *Journal of Sport & Exercise Psychology, 34*, 766-786.

Pesce, C., Crova, C., Marchetti, R., Struzzolino, I., Masci, I., Vannozzi, G., & Forte, R. (2013). Searching for cognitively optimal challenge point in physical activity for children with typical and atypical motor development. *Mental Health and Physical Activity, 6*(3), 172-180. doi:10.1016/j.mhpa.2013.07.001

Pesce, C., Masci, I., Marchetti, R., Vazou, S., Saakslahti, A., & Tomporowski, P. D. (2016). Deliberate play and preparation jointly benefit motor and cognitive development: Mediated and moderated effects. *Frontiers in Psychology, 7,* 349. doi:10.3389/fpsyg.2016.00349

Predovan, D., Julien, A., Esmail, A., & Bherer, L. (2019). Effects of dancing on cognition in healthy older adults: A systematic review. *Journal of Cognitive Enhancement, 3*(2), 161-167. doi:10.1007/s41465-018-0103-2

Rudd, J. R., Crotti, M., Fitton'Davies, K., O'Callaghan, L., Bardid, T., Utesch, T., . . . Foweather, L. (2019). Skill Acquisition Methods fostering Physical Literacy in early-physical Education (SAMPLE-PE) in 5-6 year old children: Rationale and study protocol for a cluster randomised controlled trial. *BMC Health Services Research*(In Press).

Rudd, J. R., O'Callaghan, L., & Williams, J. (2019). Physical education pedagogies built upon theories of movement learning: How can environmental constraints be manipulated to improve children's executive function and self-regulation skills? *International Journal of Environmental Research and Public Health, 16*(9). doi:10.3390/ijerph16091630

Schmider, E., Ziegler, M., Danay, E., Beyer, L., & Bühner, M. (2010). Is it really robust? Reinvestigating the robustness of ANOVA against violations of the normal distribution assumption. *Methodology: European Journal of Research Methods for the Behavioral and Social Sciences, 6*(4), 147-151. doi:10.1027/1614-2241/a000016

Schmidt, M., Jager, K., Egger, F., Roebers, C. M., & Conzelmann, A. (2015). Cognitively engaging chronic physical activity, but not aerobic exercise, affects executive functions in primary school children: A group-randomized controlled trial. *Journal of Sport & Exercise Psychology, 37*(6), 575-591. doi:10.1123/jsep.2015-0069

Tomporowski, P. D., Davis, C. L., Miller, P. H., & Naglieri, J. A. (2008). Exercise and Children's Intelligence, Cognition, and Academic Achievement. *Educational Psychology Review, 20*(2), 111-131. doi:10.1007/s10648-007-9057-0

Tomporowski, P. D., & Pesce, C. (2019). Exercise, sports, and performance arts benefit cognition via a common process. *Psychological Bulletin*. doi:10.1037/bul0000200

Tompsett, C., Sanders, R., Taylor, C., & Cobley, S. (2017). Pedagogical approaches to and effects of fundamental movement skill interventions on health outcomes: A systematic review. *Sports Med, 47*(9), 1795-1819. doi:10.1007/s40279-017-0697-z

Torrents, C., Castaner, M., & Anguera, M. T. (2011). Dancing with complexity: Observation of emergent patterns in dance improvisation. *Education, Physical Training, Sport, 80*(1), 76-81.

Tulsky, D. S., Carlozzi, N. E., Chevalier, N., Espy, K. A., Beaumont, J. L., & Mungas, D. (2013). V. NIH Toolbox Cognition Battery (CB): Measuring working memory. *Monographs of the Society for Research in Child Development, 78*(4), 70-87. doi:10.1111/mono.12035

van den Berg, V., Saliasi, E., de Groot, R. H. M., Chinapaw, M. J. M., & Singh, A. S. (2019). Improving cognitive performance of 9–12 years old children: Just dance? A randomized controlled trial. *Frontiers in Psychology, 10*(174). doi:10.3389/fpsyg.2019.00174

Weintraub, S., Bauer, P. J., Zelazo, P. D., Wallner-Allen, K., Dikmen, S. S., Heaton, R. K., . . . Gershon, R. C. (2013). I. NIH Toolbox Cognition Battery (CB): Introduction and pedriatic data. *Monographs of the Society for Research in Child Development, 78*(4), 1-15. doi:10.1111/mono.12031

Wulf, G., & Shea, C. H. (2002). Principles derived from the study of simple skills do not generalize to complex skill learning. *Psychonomic Bulletin & Review, 9*(2), 185-211.

Zelazo, P. D., Anderson, J. E., Richler, J., Wallner-Allen, K., Beaumont, J. L., & Weintraub, S. (2013). II. NIH Toolbox Cognition Battery (CB): measuring executive function and attention. *Monogr Soc Res Child Dev, 78*(4), 16-33. doi:10.1111/mono.12032

Table 1 Age, Body Mass Index (BMI), physical activity level, and gender distribution among the 3 groups are presented.

	High-cognitive	**Low-cognitive**	**Control**	**Differences**
Age	8.8 ± 0.5	8.7 ± 0.7	8.9 ± 0.7	p = 0.47
BMI	19.3 ± 3.3	19.2 ± 3.8	18.9 ± 4.5	p = 0.97
Physical Activity level	3.0 ± 0.6	3.1 ± 0.7	3.1 ± 0.7	p = 0.90
Female (%)	62	59	63	p = 0.90

Physical activity level and BMI were measured at pre-test. Physical activity level was assessed using the Physical Activity Questionnaire for Children, which provides a score ranging from 0 to 5 (Crocker et al., 1997).

Table 2 Fidelity to pedagogical approach variables are presented as mean ± SD.

	High-cognitive	Low-cognitive	(T value) p value
Warm up duration (s)	358 ± 31	380 ± 88	(0.59) p = 0.57
Drill duration (s)	967 ± 62	985 ± 71	(0.48) p = 0.64
# drill repetitions	7.2 ± 1.0	7.5 ± 0.8	(0.63) p = 0.54
Demonstration before (%)	73 ± 17	78 ± 23	(0.75) p = 0.47
Demonstration during (%)	27 ± 21	94 ± 14	(6.59) p < 0.01
Visual feedback (%)	27 ± 21	100 ± 0	(9.66) p < 0.01
Verbal feedback (%)	100 ± 0	64 ± 43	(1.63) p = 0.14
Choreography duration (s)	1683 ± 68	1708 ± 58	(0.68) p = 0.51
# choreography repetitions	14.0 ± 2.1	12.5 ± 1.6	(1.38) p = 0.20
Teacher demonstrated (%)	38 ± 6	100 ± 0	(8.14) p < 0.01
Teacher counted (%)	37 ± 14	38 ± 16	(0.14) p = 0.87
Teacher provided verbal cues (%)	41 ± 13	41 ± 24	(0.29) p = 0.77

Table 3 Correlations between pre- to post-test score changes (Δ) in CAMSA and working memory outcomes – overall and 2-list score – for each group and the 3 groups combined. Pearson correlation and (p value) are presented.

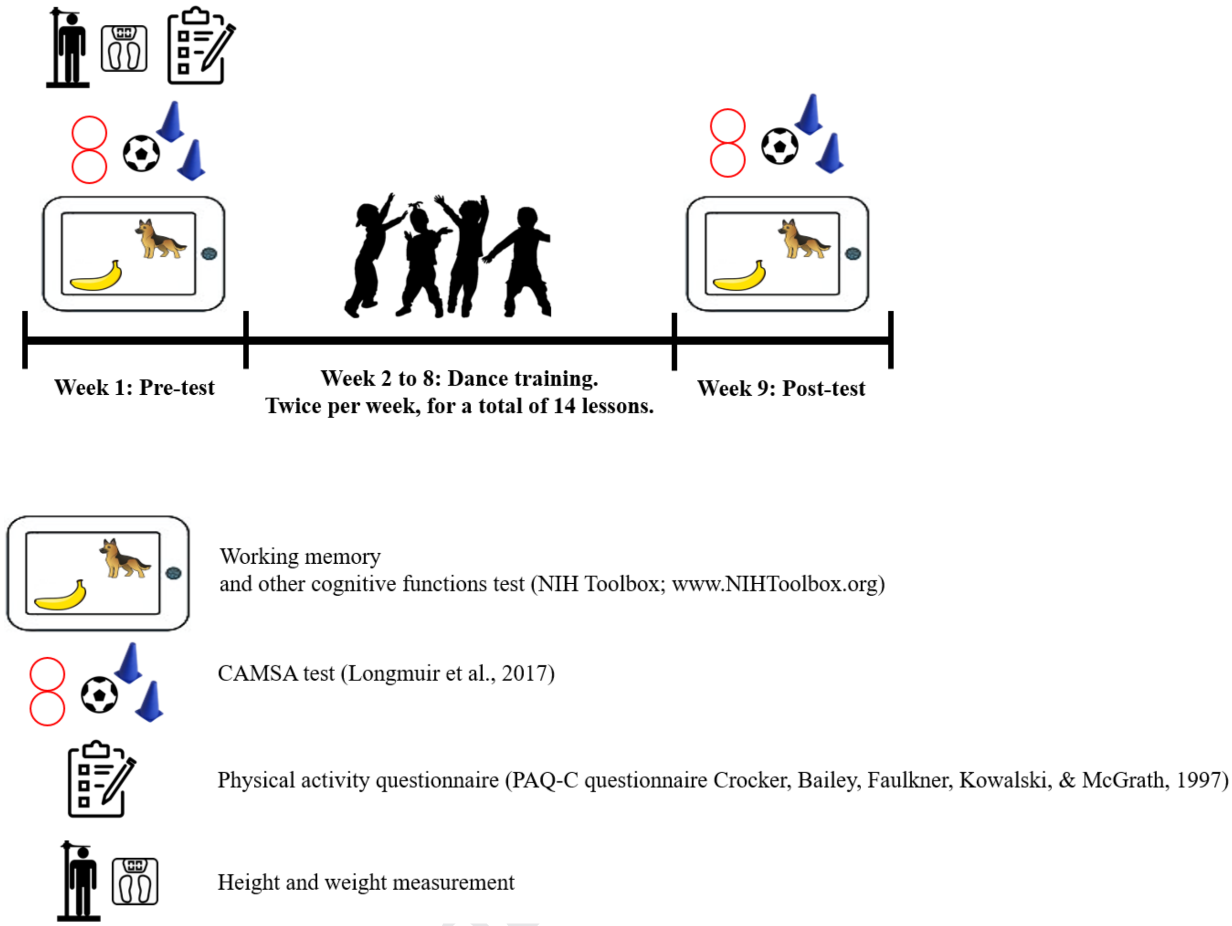
		Δ working memory capacity overall score	**Δ working memory capacity 2-list score**
Δ CAMSA	**Groups combined**	0.058 (0.64)	0.041 (0.74)
	High-cognitive	0.274 (0.27)	0.337 (0.13)
	Low-cognitive	-0.305 (0.12)	-0.339 (0.08)
	Control	0.021 (0.93)	-0.005 (0.98)

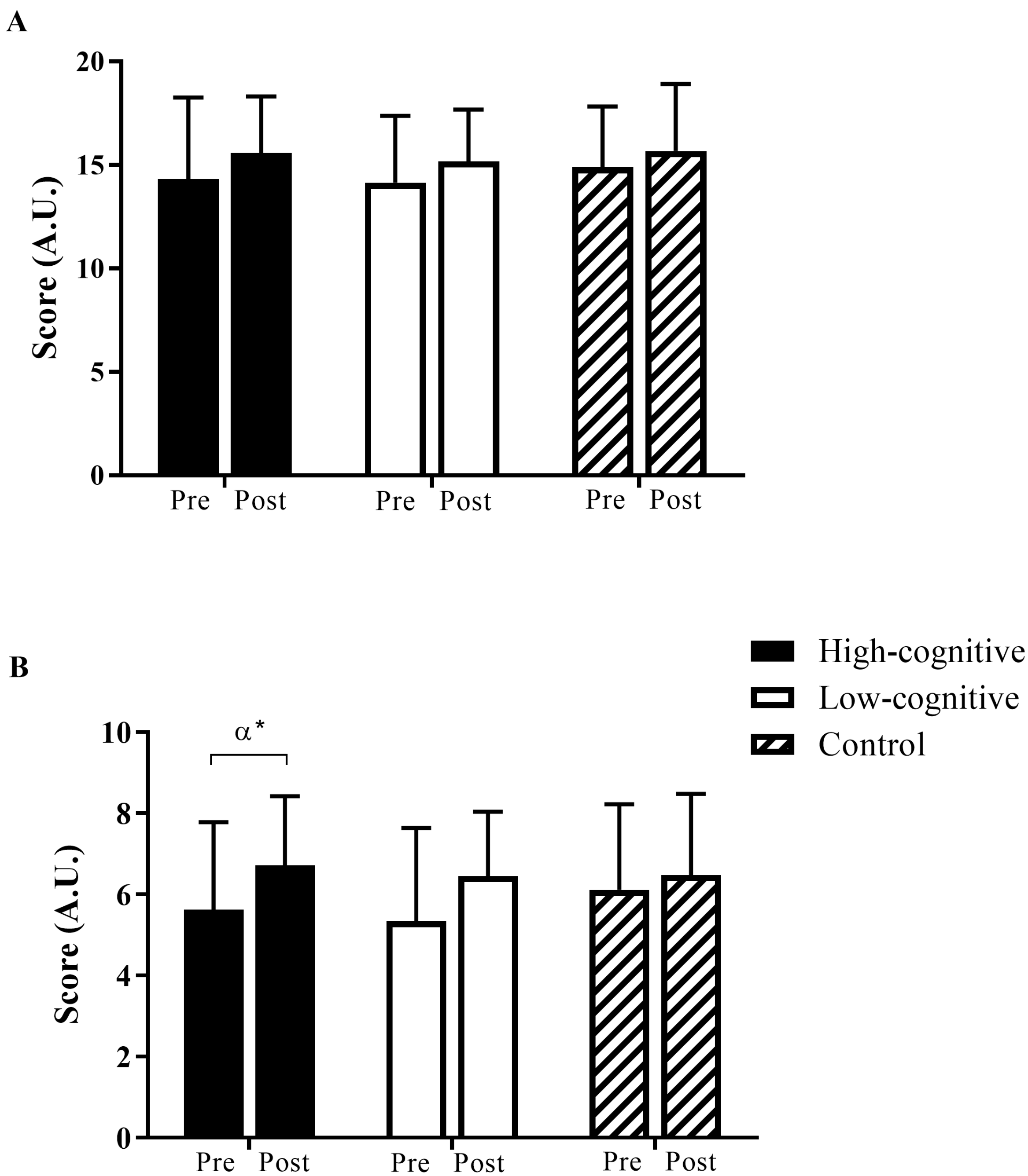
Table 4 Outcomes of working memory capacity, motor competence, cognitive flexibility and inhibitory control among the 3 groups are presented along with pre to post improvements. After Bonferroni correction, significance was set at p < 0.017. Significant effects are indicated with *

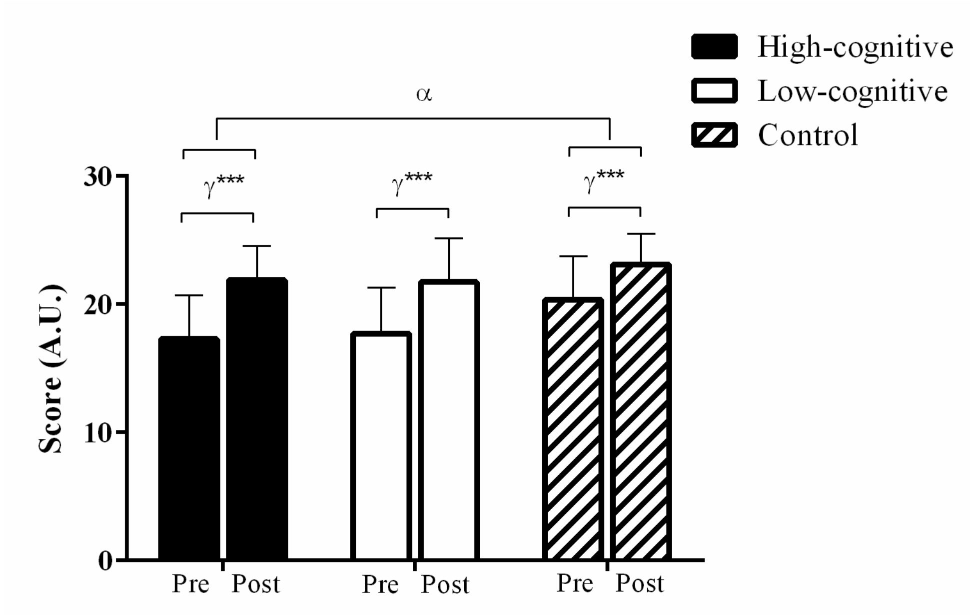
	Females and males combined			**Females**			**Males**		
	Pre	**Post**	**Post vs Pre** Delta ± confidence interval; p value; Cohen's d	**Pre**	**Post**	**Post vs Pre**	**Pre**	**Post**	**Post vs Pre**
			Working memory capacity – overall score						
High-cognitive	14.3 ± 4.0	15.6 ± 2.7	Δ = 1.42 ± 1.37; p = 0.04; d = 0.32	13.7 ± 2.4	14.9 ± 2.7	Δ = 1.13 ± 0.98; p = 0.03; d = 0.45	16.8 ± 2.5	17.1 ± 2.4	Δ = 0.38 ± 1.73; p = 0.62; d = 0.15
Low-cognitive	14.1 ± 3.2	15.2 ± 2.5	Δ = 1.03 ± 1.26; p = 0.10; d = 0.32	13.8 ± 2.9	15.4 ± 1.8	Δ = 1.59 ± 1.67; p = 0.06; d = 0.66	14.6 ± 3.7	14.8 ± 3.3	Δ = 0.25 ± 2.15; p = 0.80; d = 0.07
Control	14.9 ± 2.9	15.7 ± 3.2	Δ = 0.79 ± 1.28; p = 0.21; d = 0.27	15.0 ± 3.2	15.1 ± 3.9	Δ = 0.08 ± 1.81; p = 0.92; d = 0.02	14.7 ± 2.6	16.7 ± 1.1	Δ = 2.00 ± 1.77; p = 0.03; d = 1.09
			Working memory capacity – 2-list score						
High-cognitive	5.6 ± 2.2	6.7 ± 1.7	Δ = 1.21 ± 0.75; p < 0.01*; d = 0.51	4.6 ± 1.8	6.3 ± 1.7	Δ = 1.69 ± 1.02; p < 0.01*; d = 0.97	7.4 ± 1.6	7.6 ± 1.5	Δ = 0.25 ± 0.74; p = 0.45; d = 0.16
Low-cognitive	5.3 ± 2.3	6.5 ± 1.6	Δ = 1.10 ± 1.07;	5.0 ± 2.5	6.6 ± 1.5	Δ = 1.64 ± 1.62;	5.8 ± 2.0	6.2 ± 1.7	Δ = 0.33 ± 1.36;

			p = 0.04; d = 0.48			p = 0.05; d = 0.83			p = 0.60; d = 0.18
Control	6.1 ± 2.1	6.5 ± 2.0	Δ = 0.37 ± 0.76; p = 0.32; d = 0.17	6.3 ± 2.3	6.3 ± 2.5	Δ = -0.08 ± 1.10; p = 0.87; d = -0.03	5.7 ± 1.7	6.9 ± 0.9	Δ = 1.14 ± 0.83; p = 0.02; d = 0.88
Motor competence – CAMSA score									
High-cognitive	17.3 ± 3.4	21.9 ± 2.7	Δ = 4.58 ± 1.29; p < 0.01*; d = 1.50	16.2 ± 2.9	21.4 ± 3.2	Δ = 5.20 ± 1.69; p < 0.01*; d = 1.71	18.5 ± 3.3	22.6 ± 1.5	Δ = 4.13 ± 1.02; p < 0.01*; d = 0.97
Low-cognitive	17.7 ± 3.6	21.7 ± 3.4	Δ = 4.03 ± 0.71; p < 0.01*; d = 1.15	17.3 ± 3.8	21.3 ± 3.7	Δ = 4.00 ± 0.89; p < 0.01*; d = 1.06	18.6 ± 3.4	22.5 ± 2.8	Δ = 3.90 ± 1.41; p < 0.01*; d = 1.25
Control	20.4 ± 3.4	23.1 ± 2.4	Δ = 2.74 ± 1.28; p < 0.01*; d = 0.95	20.4 ± 3.0	22.3 ± 2.3	Δ = 1.92 ± 1.72; p = 0.03; d = 0.72	21.3 ± 3.5	24.7 ± 1.6	Δ = 3.33 ± 2.27; p = 0.01*; d = 1.30
Cognitive flexibility – DCSS score									
High-cognitive	6.7 ± 0.9	6.9 ± 0.5	Δ = 0.19 ± 0.36; p = 0.31; d = 0.22	6.6 ± 1.0	6.9 ± 0.4	Δ = 0.38 ± 0.53; p = 0.15; d = 0.52	7.1 ± 0.5	6.9 ± 0.6	Δ = -0.17 ± 0.49; p = 0.43; d = -0.31
Low-cognitive	6.9 ± 1.1	7.4 ± 0.7	Δ = 0.43 ± 0.39; p = 0.03; d = 0.39	7.1 ± 1.3	7.2 ± 0.7	Δ = 0.15 ± 0.51; p = 0.53; d = 0.16	6.8 ± 0.8	7.6 ± 0.8	Δ = 0.81 ± 0.62; p = 0.01*; d = 1.04
Control	6.8 ± 1.0	7.3 ± 0.7	Δ = 0.47 ± 0.39;	6.8 ± 0.6	7.2 ± 0.8	Δ = 0.34 ± 0.32;	6.8 ± 1.5	7.5 ± 0.6	Δ = 0.70 ± 1.09;

			p = 0.02; d = 0.48			p = 0.04; d = 0.50			p = 0.16; d = 0.67
Inhibitory control – Flanker test score									
High-cognitive	7.4 ± 0.6	7.6 ± 0.5	Δ = 0.12 ± 0.22; p = 0.29; d = 0.19	7.3 ± 0.6	7.5 ± 0.5	Δ = 0.13 ± 0.29; p = 0.34; d = 0.23	7.7 ± 0.5	7.7 ± 0.6	Δ = 0.08 ± 0.43; p = 0.66; d = 0.15
Low-cognitive	7.6 ± 0.8	7.7 ± 0.7	Δ = 0.15 ± 0.21; p = 0.16; d = 0.18	7.5 ± 0.8	7.6 ± 0.6	Δ = 0.10 ± 0.29; p = 0.47; d = 0.14	7.7 ± 0.8	7.9 ± 0.6	Δ = 0.21 ± 0.35; p = 0.21; d = 0.30
Control	7.4 ± 0.8	7.7 ± 0.7	Δ = 0.33 ± 0.21; p < 0.01*; d = 0.41	7.1 ± 0.7	7.6 ± 0.7	Δ = 0.50 ± 0.23; p < 0.01*; d = 0.73	8.0 ± 0.8	8.1 ± 0.7	Δ = 0.05 ± 0.39; p = 0.76; d = 0.07


Week 1: Pre-test
Week 2 to 8: Dance training.
Twice per week, for a total of 14 lessons.
Week 9: Post-test
Working memory
and other cognitive functions test (NIH Toolbox; www.NIHToolbox.org)
CAMSA test (Longmuir et al., 2017)
Physical activity questionnaire (PAQ-C questionnaire Crocker, Bailey, Faulkner, Kowalski, & McGrath, 1997)
Height and weight measurement


A
Score (A.U.)
0
5
10
15
20
Pre
Post
Pre
Post
Pre
Post
B
High-cognitive
Low-cognitive
Control
Score (A.U.)
0
2
4
6
8
10
α*
Pre
Post
Pre
Post
Pre
Post


High-cognitive
Low-cognitive
Control
α
γ***
γ***
γ***
Score (A.U.)
30
20
10
0
Pre
Post
Pre
Post
Pre
Post

Highlights

- Learning a dance choreography with a high-cognitive challenge promoted the development of working memory capacity and motor competence in primary school children
- Teacher limiting visual demonstrations facilitated an enhanced improvement of working memory capacity and motor competence relative to continuous teacher's demonstrations
- This study provides new insights into the exercise-cognition link, highlighting the role of cognitive challenge during exercise in promoting cognitive development

Conflicts of Interest and Source of Funding

This work was supported by a Macedon Ranges and North Western Melbourne Medicare local grant. Luca Oppici is funded by the Excellence Strategy of the DFG (EXC 2050/1– Project ID 390696704 – Cluster of Excellence "Centre for Tactile Internet with Human-in-the-Loop"). The authors declare that they have no conflict of interest relevant to the content of this study.