Abstract

Objectives: This study examined the effect of two different dance curriculums on executive functions and motor competence in 6-7 years old primary-school children across an 8-week period. One dance curriculum was underscored by creativity and the other was based on a choreographed dancing curriculum with high cognitive challenge.

Design: Randomised-controlled trial.

Methods: Sixty-two primary-school children (6.6 ± 0.5 years old; 47% females) participated for a control period in the regular school PE lessons, after which they were randomly assigned to two experimental groups – choreography dance group or creative dance group. The two experimental groups practiced dance for 8 weeks, twice a week, learning either a choreographed dance sequence with high cognitive challenge or creating their own dance sequence in a creative dance curriculum. Executive functions (working memory capacity, inhibition, and flexibility) and motor competence were assessed at three time points – baseline, pre-intervention and post-intervention.

Results: There was a time effect for inhibitory control ($p < 0.01$), with a high improvement during the intervention ($d = 0.76$) than baseline ($d = 0.46$); for working memory capacity ($p < 0.01$), with a higher improvement during intervention ($d = 0.43$) than baseline ($d = 0.31$) in the high challenging task; and for motor competence ($p < 0.01$), with a higher improvement during baseline ($d = 1.7$) than intervention ($d = 0.75$); no other significant effects. Group differences revealed weak evidence that the choreography group improved inhibitory control and working memory more than the creative dance group. However, a check for pedagogy fidelity revealed that the creative-dance curriculum was not adopted as planned (i.e., high volume of teacher's instruction and small use of music).

Conclusions: An 8-week dance intervention improved inhibitory control and potentially working memory capacity in grade one and two primary-school children. Contrary to prediction, the dance intervention did not improve motor competence beyond typical development. Discrepancy between the planned and adopted creative-dance curriculum suggests caution in interpreting results. This study provides new insights into the *exercise-cognition* relationship.

Keywords: embodied cognition; education; exercise-cognition; working memory; inhibitory control

Introduction

Executive functions play a critical role in children's development (Best, Miller, & Naglieri, 2011; Blair & Razza, 2007; Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; McClelland, Acock, & Morrison, 2006). Children with weaker executive functions are susceptible to a wide range of negative health and wellbeing outcomes in adulthood (Hair, Hanson, Wolfe, & Pollak, 2015; Hofer & Clouston, 2014). Executive functions include three core cognitive constructs: (i) working memory capacity - ensures the sustained and active use of goal-relevant information whilst other cognitive tasks are being performed; (ii) inhibitory control – the ability to inhibit a behavioural response to stimuli in the environment; and (iii) cognitive flexibility – the ability to change perspective, adjust to changing demands and prioritise (Diamond, 2013). During school years, significant improvements in executive functions occur which leads to stronger links between the constructs (Best, Miller, & Jones, 2009; Miyake et al., 2000). It is essential to understand the impact of new experiences because the neural substrates that support executive functions are acutely sensitive to features of an environment (Fishbein, Michael, Guthrie, Carr, & Raymer, 2019; Romine & Reynolds, 2005). There is a growing body of empirical evidence indicating that movement can play a role in enhancing children's development of executive functions (de Greeff, Bosker, Oosterlaan, Visscher, & Hartman, 2018; Diamond & Ling, 2019; Ludyga, Gerber, Brand, Holsboer-Trachsler, & Pühse, 2016; Tomporowski, Davis, Miller, & Naglieri, 2008). A current challenge for researchers and practitioners is to investigate which aspects of a Physical Education curriculum such as dance, can reliably support the development of all three executive functions in children (Diamond, 2013, Tomporowski & Pesce, 2019).

Recent evidence demonstrates that the *exercise-cognition* relationship is heightened when motor learning is incorporated with exercise, such as playing games or learning a sport skill as opposed to running laps of the playground, or participating in activities that require rote repetition of movement (Diamond & Ling, 2016; Moreau, Morrison, & Conway, 2015; Pesce, 2012; Tomporowski & Pesce, 2019). Specifically, it was suggested that integrating complexity, diversity, and novelty into the design of skill learning programmes will challenge executive functions and increase the likelihood of transfer to everyday tasks (Moreau & Conway, 2014). Sport and art provide a suitable context; in dance, the music creates continuous sensorimotor stimuli that are synchronous with the task and offers an abundance of whole-body movement opportunities (Merom et al., 2013). A randomised-controlled trial (RCT) that included primary-school children, 8 to 10 years old, recently showed how learning a complex dance choreography improved children's working memory capacity (Oppici, Rudd, Buszard, & Spittle, 2020); results revealed that limiting visual demonstrations encouraged children to retain movement sequences and further enhanced the children's working memory capacity. Furthermore, a six-month RCT with a large sample of 5–10 year old children showed how a PE curriculum designed with a highly variable environment enhanced children's inhibitory control when compared to a traditional PE[1] curriculum (Pesce et al., 2016). However, whilst these studies provide evidence that learning complex and diverse movement skills can improve executive functions, each study only demonstrated improvement in one executive function. The design of learning environments underpinned by ecological dynamics may offer new insights into how movement can support and stimulate the development of children's executive functions. Ecological dynamics emerged from the work of Davids et al. (1994), Araújo et al. (2006), and Warren (2006). Ecological psychology emphasises the cyclical relations between a child and the environment which, integrates

[1] Traditionally physical education lessons do not take into account individual difference as they follow a linear structure one size fits all progression of learning activities (Chow et al 2016). Lessons often have the following characteristics *are* overly structured, children learn through repetitive actions, and through technical prescriptive demonstrations and feedback is often shaped with explicit instruction (Jess, McEvilly, & Carse, 2017).

executive functions in a child's search, explore and discovery behaviours (Gottiwald et al., 2016). From a dynamical systems perspective, functional movement solutions emerge from the interactions of multiple sub-systems within the individual, task and environment (Thelen, 1989; Davids et al., 2008). A sub-system that is integral to executive function which is potentially underplayed in the current cognition literature is the perceptual system (Chow et al., 2011): there are deeply entwined relations between intentions, perception and action that reflect a child's self-organization tendencies (Rudd et al., 2020). From an ecological dynamics vantage, executive functions do not direct motor behaviours or act as an 'executive' but instead are part of the self-organisation process supporting the emergence of functional movement solutions and the development of a deeper knowledge of the environment (Woods et al., 2020). In support of this, Oppici et al., (2020) found that when children were placed in an environment focussed on learning a choreographed dance and the teacher manipulated the task to make it more complex by limiting the number of demonstrations, children improved their working memory capacity. It was hypothesised that the task manipulation resulted in challenging the children's working memory via a continuous recall of movement sequences and a continual perception action coupling between the music and performer.

It is likely under an ecological dynamics understanding of executive functions that a PE curriculum developed around creative dance will support all three executive functions in children aged 6-8 years. A creative dance curriculum encourages a transformational process by children using elements of dance (body, space, time, force, flow, and relationships) to search, explore, discover and adapt their movements to synchronise with the music's tempo and beat. Through the learning process of the dance they will be required to create and memorise their own creative dance sequence, challenging a child's working memory. Accordingly, the children's dancing will involve individual improvisations and spontaneous performance synchronised to music and other environmental stimuli, such as lesson themes (e.g. trip to the fun fair) (Torrents, Ric, & Hristovski, 2015). This informationally enriched environment will offer many possibilities for action that will encourage children to explore their environment and make continuous choices as they move flexibly (Rasmussen, Østergaard, & Glăveanu, 2017; Vaughan, Mallett, Davids, Potrac, & Lopez-Felip, 2019), which will challenge inhibitory control (Pesce et al., 2016) and cognitive flexibility. Additionally, a teacher can continue to challenge inhibitory control and cognitive flexibility over the whole unit of work/curriculum through a learner-centred cyclical process. For instance, the teacher could manipulate the tasks by creating scenarios or posing problems to be solved, such as: *'Today we are going to create a dance about going to the fun fair, can you move like your favourite ride at the funfair?'* The teacher's role is then to encourage children to couple the novel and diverse movement solutions with the music's beat and tempo. Once a child has mastered their movements, the teacher's role is again re-engage the child in exploratory behaviours further taxing inhibitory control and flexibility. To facilitate this process, the teacher might choose to manipulate the environment and the theme of the lesson (e.g., from the 'fun fair' to 'garden bugs'), or through tempo, volume or beat relations in the music (Torrents, Balagué, Ric, & Hristovski, 2020). In summary, we expect a creative dance curriculum to promote the development of all executive functions by encouraging children to explore features of the environment and their own body, as well as their interaction, create movement sequences, retain and assemble the "created" movement solutions to create their own choreography.

The aim of this study was to examine the effect of a creative dance curriculum, compared to a choreographed dance curriculum with high cognitive challenge (similar to the curriculum used in Oppici et al., 2020) on the development of children's executive functions. Primary school children were recruited and divided into two groups: a creative dance group and a choreography dance group. Both groups participated in an 8-week dance program.

Participants' executive functions were assessed before a control period (i.e., a baseline measure 8 weeks before the dance intervention), and pre and post the dance intervention. It was hypothesised that the creative dance group would enhance all three executive functions and the choreography dance group only working memory capacity (as previously shown in Oppici et al., 2020) beyond their typical development (i.e., control period). Furthermore, motor competence was also assessed at the same three time points - baseline, and pre and post the dance intervention. Both groups were hypothesised to improve their motor competence as a consequence of the dance intervention, but the creative dance group were expected to improve more than the choreography dance group given the emphasis on movement exploration in the creative dance group's lessons.

Methods

Study design

A randomized controlled trial (RCT) was conducted to compare the efficacy of creative dance compared to a choreographed dance. An 8-week intervention was administered to 6-7 years old children in one Victorian government-funded primary school (Australia) in 2019. Our outcomes to assess efficacy of each learning environment were the three executive functions and motor competence. The study was approved by the research team's University Ethics Committee (ref 16-288) and by the National Department of Education and Training.

The study design comprised of a baseline assessment, a control period for 8 weeks, a pre-intervention assessment (pre-test), a dance training intervention for 8 weeks, and a post-intervention assessment (post-test) (figure 1). All three assessment sessions (baseline, pre-test and post-test) included an assessment of participants' executive functions – working memory capacity, cognitive flexibility, and inhibitory control – and motor competence. Two groups took part in the study: participants in both groups participated in the school PE classes during the 8-week control period, then participants were randomly divided into two groups, which practiced dance twice a week for 8 weeks, for a total of 16 lessons lasting for approximately 50 minutes each. None of the participants were practicing dance at the time of recruitment 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 February and June 2019, during school terms 1 and 2: baseline assessment in February, pre-test in April and post-test in June. 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

Seventy-five primary school children from 3 different classes in grades 1 and 2 were invited to participate in the study, and sixty-two children (6.6 ± 0.5 years old; 47% females) accepted to participate. Given the study design (repeated-measures test, within-between interaction), this sampling allows to detect small to moderate effect sizes ($f = 0.165$), which is in line with a recent meta-analysis on the effects of physical activity on children`s executive functions (de Greeff et al., 2018).

Prior to the study, 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 (n = 2) from assessments and data analysis. Children that did not return parent consent form (n = 11) were exempt from the research, but able to participate in PE lessons.

Randomisation

All participants participated in the regular school PE lessons in their own classes during the control period. After the pre-test, the participants were randomly assigned to the two experimental groups – choreography dance group (n = 31, 6.6 ± 0.5 years old, 48% females) and creative dance group (n = 31, 6.6 ± 0.5 years old, 46% females). The randomisation process followed the minimisation procedure (Hopkins, 2010), whereby each of the 3 classes were divided into 2 experimental groups based on participants' performance on the outcome variables in the pre-test (similar to a random stratification process). Hence, there were no differences between the groups during the pre-test (Table 3).

Blinding and inter/intra rater reliability

The experimenters who administered the executive functions and motor competence tests were blinded to the group that each participant belonged to. Furthermore, the experimenters who observed the dance classes to evaluate the fidelity to pedagogical approach did not know which experimental group was which or what the specific research hypothesis was.

While the assessment of executive 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 were experienced in administering the test, as they previously performed it in Oppici et al. (2020) where their intra- and inter-rater reliability was high (i.e., ICC above 0.90).

Intervention delivery

Control period

Participants participated in the standard school PE classes, twice a week, during the control period. A typical PE class included 3 main activities: a warm-up game, an activity aiming at improving a movement skill (e.g., catching and throwing), and a final game to practice the targeted movement skill in a fun context. Throughout the control period, participants primarily practiced catch and throwing skills. The school PE teacher ran the classes and was instructed to follow the National curriculum and to avoid any type of dance activity.

Creative curriculum

We designed a creative dance curriculum to promote exploratory learning based upon dance movement language detailed in the work of Laban (1975); the lesson plan detailed how the body, awareness of space, relationships, effort, force, flow and time could be explored. Laban movement components reflect unique movements combinations prompted by continuity with familiar constraints as it branches into a new expression (Laban & Ullman, 1971). Each of the lessons had a specific theme and identified learning outcomes that incorporated some of the elements of dance, e.g., create and perform locomotor and non-locomotor movements that use circular pathways on the floor and in the air. Each lesson was 50 minutes in length and began with an introduction to set the scene, then progressed to exploration and development of movements associated with a topic or theme, and then evolved into a culminating dance. The introduction and development section involved the teacher asking a number of questions to encourage the children to create and perform movements based on their perceptions and feelings of the topic or theme. For example, *'Today we are going to create a dance about going to the playground, who likes going to the playground?', 'We are going to start today think about all the different ways we can travel to the playground, Emma how could we travel to the playground?'* Similar questions were asked in the development section with the movements that were created often being performed to a rhythm or a beat. *'Now we are at the* *park why don't we go on the slide. Let's start by climbing the ladder, use your arms and legs to pretend you are climbing a ladder for 8 counts. Ready, I will clap 8 counts and you pretend to climb; 1, 2, 3 .....'*. In these sections, children were encouraged to remember the movements they created so they could be used in the culminating dance.

The teacher running the creative curriculum was instructed to use questions that support exploration a child's movement solutions and prompts that encourage the generation of information from features of the task and environment. She was told to avoid providing explicit instruction and visual demonstration on how to perform a movement. Furthermore, she was instructed to couple movement with music, and to manipulate beat and tempo to guide children's exploratory behaviour.

Choreographed curriculum

The lesson plan, lesson structure, and choreography adopted in the choreography dance group were the same adopted in and details can be found in (Oppici et al., 2020). In summary, 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, and new movements were added in each lesson. 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 chaining. In the delivery of the lesson, the teachers were instructed to limit the number of demonstrations to a minimum and encouraged children to use previously learned movement sequences. Specifically, they were 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.

Dance teacher's training and qualifications

Three professional dance teachers ran the dance classes. The teacher with more experience, in general and particularly on delivering creative dance (approximately 20 years of experience) was selected to run the creative curriculum, while the other two less-experienced teachers (approximately 10 years of experience) rotated in delivering the choreographed dance curriculum. One of the authors designed the creative dance curriculum and organised a workshop to explain to the teachers in detail how to provide instructions, pose questions, encourage children, manipulate music's tempo and rhythm, to promote children's exploratory and creative behaviour. For the choreographed dance curriculum, the two teachers were already familiar with the lesson content and pedagogy, as they delivered it in Oppici et al. (2020).

Fidelity to pedagogical approach

To ensure the groups were exposed to the dance environments we had planned for, we randomly selected and filmed six sessions from each group and assessed teaching pedagogy and practice volume. The following variables were assessed: time participants spent practicing a task (time on task), time teachers spent providing instructions (time on instructions), 'dead' time where teachers organised participants in group or participants had a break (time on other), number of activities with music, number of activities where the teacher provided counting, and number of activities where teachers provided a visual demonstration.

Furthermore, during the selected lessons three research assistants assessed students' collective engagement using the scale described in Reeve, Jang, Carrell, Jeon, and Barch (2004). The scale included an assessment of participants' attention, effort, verbal participation, persistence, and emotional tone. Each variable has a 1 to 7 scale, and the research assistants were instructed to use the middle number 4 as anchor/starting point and provide an assessment every 10 minutes, as described in Reeve et al. (2004).

Outcomes

The measures in this study related to two broad outcomes - executive functions (working memory capacity, cognitive flexibility and inhibitory control) and motor competence. Details on testing procedure and analysed variables are comprehensively described in Oppici et al. (2020).

Executive functions

Executive functions were assessed using three tasks – list sorting working memory, dimensional change card sort, and Flanker – 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 three tasks, and the overall assessment lasted for approximately 20 minutes.

Working memory capacity. Working memory capacity was assessed using the list sorting working memory test which requires participants to maintain visual and auditory information using a series of pictures of food and animals presented in a random order on the iPad screen. 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. The child has to verbally list the pictures in order of size and category once the screen has gone blank, following their presentation on screen out of order. The 2-list condition is more challenging than the 1-list condition and it is more likely to show the effect of an intervention (Oppici et al., 2020). 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 correctly recalled and ordered items.

Cognitive flexibility. Cognitive flexibility was assessed using the dimensional change card sort (DCSS) test. This 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 software provides a performance score, combining a participant's response time and accuracy.

Inhibitory control. The Flanker test was used to assess inhibitory control. This 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. The software provides a performance score, combining a participant's response time and accuracy.

Motor competence

Motor competence was assessed using the Canadian Agility and Movement Skill Assessment (CAMSA; Longmuir et al., 2017), following the procedure published in Oppici et al. (2020). CAMSA 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 in groups of 10 participants, which were provided with instructions, two demonstrations, two practice trials, and two test trials. 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. A total score was then computed combining the time and skill scores, and it ranged between 1 and 28 (Longmuir et al., 2017). The best score out of the two test trials was used for the analysis.

Statistical Analysis

Linear mixed modelling was used to examine the association between group and each dependent variable – working memory capacity (overall score and 2-list condition score), inhibitory control, cognitive flexibility and motor competence. Each model included fixed effects for the intervention group, time point, and their interaction. The model had a random intercept with subjects as the random variable. Normally distributed random effects for subject were used to account for the within-subject correlation induced by the repeated measures experimental design. Residual error was used for all dependent variables. Likelihood ratio tests were used to test for the significance of the fixed effects (i.e., group, time and the interaction between group and time). The Likelihood ratio tests were performed with a Chi-square distribution using the appropriate degrees of freedom for the comparisons being made. Assessments about the magnitude of effects between groups were based on linear contrasts of the model's fixed effects and their *p* values using the Holm method to adjust for multiple comparisons (2 comparisons for time effect, and 6 comparisons for group*time effect). Standardised effect sizes (*d*) and 95% confidence intervals were reported where appropriate to further estimate the magnitude of effects. The assumptions of linearity and homoscedasticity for the mixed models were checked by inspecting the residual plots, whilst the assumption of normality was assessed by observing histograms and qq-plots. All analyses were performed in the R (R Core Team, 2019) language using the *lme4* package (Bates, Maechler, Bolker, & Walker, 2015) for the mixed modelling. Significance was set at $\alpha < 0.05$.

Results

Six participants were excluded because they either did not complete the three testing phases (n = 5) or they left the school (n = 1) during the intervention. Consequently, the final sample size was 55 participants (choreography dance group n = 27; creative dance group n = 28).

Fidelity to pedagogical approach

The descriptive and inferential statistics for time on activities and student engagement variables across the two groups are presented in Table 1 and Table 2. The analysis showed a number of key pedagogical differences. Time on instructions was significantly higher for the creative dance group (p = 0.01). The creative dance group also experienced significantly less time participating in activities with music (p =0.01), whilst choreography dance group had significantly higher number of demonstrations (p = 0.09) and spent significantly more time on class management (p = 0.05) (Table 1). Overall student engagement was significantly higher (p=0.02) in the choreography group than the creative dance group. The choreography dance group also scored higher on all student engagement variables but they did not reach significance (Table 2).

****** Please insert Table 1 and Table 2 here ******

Working memory capacity

Overall score

The analysis showed a significant effect of time ($\chi^2[2] = 24.4$, $p < 0.01$), and no significant effect of time*group ($\chi^2[2] = 0.74$, $p = 0.69$), group ($\chi^2[3] = 1.42$, $p = 0.70$) and gender ($\chi^2[1] = 0.59$, $p = 0.44$). Post hoc showed that improvement was significant between pre and baseline ($p < 0.01$, $d = 0.59$, 95% CL[0.21, 0.98]), and between post and pre ($p = 0.04$, $d = 0.41$, 95% CL [0.02, 0.79]). Group pairwise comparison showed a significant improvement from baseline to pre in the creative dance group only ($p = 0.04$, $d = 0.45$) (Table 3 and Figure 2).

2-list condition score

There was a significant effect of time ($\chi^2[2] = 14.3$, $p < 0.01$), and no significant effect of time*group ($\chi^2[2] = 1.49$, $p = 0.48$), group ($\chi^2[3] = 4.21$, $p = 0.24$) and gender ($\chi^2[1] = 0.04$, $p = 0.84$). Post hoc showed that improvement was significant between post and pre ($p = 0.05$, $d = 0.43$, 95% CL[0.05, 0.82]), but not significant between pre and baseline ($p = 0.11$, $d = 0.31$, 95% CL[-0.07, 0.69]). Group pairwise comparison showed no statistically significant improvement, but a moderate improvement from post to pre in the choreography dance group ($p = 0.26$; $d = 0.56$) (Table 3 and Figure 2).

Inhibitory control

There was a significant effect of time ($\chi^2[2] = 34.5$, $p < 0.01$), and no significant effect of time*group ($\chi^2[2] = 0.75$, $p = 0.69$), group ($\chi^2[3] = 0.87$, $p = 0.83$) and gender ($\chi^2[1] = 0.07$, $p = 0.79$). Post hoc showed that improvement was significant between pre and baseline ($p = 0.02$, $d = 0.46$, 95% CL[0.08, 0.85]), and between post and pre ($p < 0.01$, $d = 0.76$, 95%

CL[0.37, 1.14]). Group pairwise comparison showed a moderate significant improvement from pre to post in the choreography dance group ($p = 0.02$, $d = 0.52$) and a small non-significant improvement in the creative dance group ($p = 0.058$, $d = 0.44$) (Table 3 and Figure 2).

****** Please insert Figure 2 here ******

Cognitive flexibility

The analysis showed no significant effect of time ($\chi^2[2] = 1.95$, $p = 0.37$), time*group ($\chi^2[2] = 3.78$, $p = 0.15$), group ($\chi^2[3] = 5.62$, $p = 0.13$) nor gender ($\chi^2[1] = 0.04$, $p = 0.84$). Similarly, group pairwise comparison showed no statistically significant effect (Table 3).

Motor competence

There was a significant effect of time ($\chi^2[2] = 90.7$, $p < 0.01$), and no significant effect of time*group ($\chi^2[2] = 0.39$, $p = 0.82$), group ($\chi^2[3] = 0.51$, $p = 0.92$) and gender ($\chi^2[1] = 1.80$, $p = 0.18$). Post hoc showed that improvement was significant between pre and baseline ($p < 0.01$, $d = 1.70$, 95% CL[1.30, 2.11]), and between post and pre ($p < 0.01$, $d = 0.69$, 95% CL[0.29, 1.09]). Group pairwise comparison showed a significant improvement from baseline to pre in both choreography ($p < 0.001$, $d = 0.78$) and creative ($p < 0.001$, $d = 0.75$) dance groups; a small significant improvement in the choreography dance group ($p = 0.02$, $d = 0.22$) and a small non-significant improvement in the creative dance group ($p = 0.11$, $d = 0.23$) from pre to post (Table 3 and Figure 3).

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****** Please insert Table 3 here ******

Discussion

This study examined how a creative dance curriculum, compared to a choreographed dance curriculum with high cognitive challenge, influenced children's development of the three executive functions. It was hypothesised that the creative dance group would enhance all three executive functions, whilst the choreography dance group would only display enhanced working memory capacity. The results partially supported this hypothesis. Both groups improved inhibitory control and working memory capacity (only the high-challenging 2-list condition) beyond typical development (i.e., control period), but did not improve cognitive flexibility. A closer inspection of the results suggests that only the choreography-dance group improved working memory capacity. Group difference was less apparent than hypothesised; nonetheless, there was a trend for greater improvements for the choreography group for both inhibitory control and working memory capacity. Furthermore, motor competence was hypothesised to improve in both groups, with an enhanced improvement for the creative dance group. This hypothesis was rejected, as motor competence showed lower improvement in the intervention than baseline. Taken together, these results, as opposed to our initial prediction, showed that a choreographed dance curriculum provided enhanced benefits beyond typical development for improving executive functions (inhibitory control and potentially working memory capacity) relative to a creative dance curriculum.

When interpreting these results, it is important to first consider that the actuated pedagogy did not entirely correspond to the planned pedagogy in the creative dance group: instructions were intended to set out the theme of each class and encourage children to explore and discover creative movements, and music was meant to accompany and guide the exploratory process. However, Table 2 shows that the teacher spent a large amount of time giving instructions (more than expected) and only a minimal part of the activities was performed with music. A consultation with the creative dance teacher revealed that she had to continuously recall children's attention to keep them focused on the task, and task instructions had to be repeated several times. While instructional constraints have been shown to promote releasing of movement degrees of freedom, thus creativity (Haught-Tromp, 2017; Torrents et al., 2020; Torrents et al., 2015), in this study instructions probably constrained and limited the emergence of creative movement. Furthermore, the teacher felt that music distracted children, so she had to keep it to a minimum. This took time away from actual practice, and likely reduced children's exploratory behaviour coupled with music. It is also worth highlighting that students' engagement in the creativity dance group was lower than the choreography dance group (Table 1). This might have been because the creative dance pedagogy was new to children, which may have been unsettling. These aspects likely influenced the observed results and should be considered when interpreting the findings. Despite this issue in delivering the planned pedagogy, this RCT is still valuable, as most importantly the two dance groups had a similar practice volume (i.e. time on task) which makes the two interventions comparable.

The results showed that inhibitory control improved during the intervention period beyond typical development, and the pairwise comparison showed that improvement was slightly higher in the choreography dance group than the creative dance group (Table 3 and Figure 2). The young participants' age and the structure of the dance interventions may explain these results. In fact, children in both groups were encouraged to inhibit stimuli from other children and follow the teachers' instructions. From a developmental perspective, the three executive functions have been found to develop at different rates during children's development, with inhibition being the first to be fully developed and this is the likely reason we observed inhibitory control but not the other executive functions (Best & Miller, 2010;

Pesce et al., 2016). Supporting this, in Oppici et al. (2020), older participants (8-10 years old) did not improve inhibitory control following the same dance intervention. The developmental trajectory for inhibitory control was steeper for both dance curriculums during the intervention period suggesting that the two pedagogies enhanced inhibitory control development for children aged 6 years old (Figure 2). Whilst it is difficult to pinpoint the mechanism responsible for this change, it is proposed that it was due to the emotional investment required for these young children to self-regulate their emotions in an effort to adapt to their new environment (i.e., dance lessons, and teacher's expectations and rules); acclimatising to the choreography dance group appeared to be effective because the group scored higher on all elements of the student engagement scale which, included emotional tone (Reeve et al., 2004). According to Diamond (2016), self-regulation overlaps substantially with inhibitory control, but does not overlap with working memory or cognitive flexibility. The adoption of self-regulation into inhibitory control emphasises that cognition is best conceptualised as embedded in the body-mind-environment dynamics, and skills emerge through the development of a learner's deeper, more integrated relationship with their environment (Araújo, Davids, & Hristovski, 2006; Button, Seifert, Chow, Araújo, & Davids, 2020; Warren, 2006). Within this behavioural ecosystem, emotional engagement is defined as a "hot" element of executive function that mobilises children's self-organisation tendencies to solve motivationally significant problems (Adolph, 2020; Harms, Zayas, Meltzoff, & Carlson, 2014; Rudd, Pesce, Strafford, & Davids, 2020; Zelazo & Carlson, 2012).

As opposed to our initial hypothesis, working memory capacity did not statistically improve in any of the groups. However, a closer inspection of the results suggests that some improvement was starting to appear within the choreography dance group. There was a time effect between pre and post but not a significant effect between baseline and pre, and while not statistically significant the choreography dance group showed a moderate improvement in the 2-list condition score, which was the most demanding task for working memory capacity (this trend can be appreciated in Figure 2). This offers weak support for previous research which adopted the same dance intervention (Oppici et al., 2020), suggesting that the process of learning a dance sequence by retaining and actively using goal relevant information during movements seems to place large demands on working memory, and therefore may enhance working memory capacity. However, both in this study and Oppici et al. (2020), improvement in working memory capacity did not statistically differ between experimental groups. In both studies, the intervention lasted for 8 weeks, and statistically significant difference to other dance or PE interventions may start to appear later down the track. Future research should examine this issue in longer interventions that last for at least a half school year (i.e., 4 to 6 months).

The creative intervention was hypothesised to increase working memory capacity by encouraging the children to explore new movement solutions, rather than repeating previously learnt movements. However, the results did not support this hypothesis. This may be partly explained by the limited adopted pedagogy, as previously mentioned. The teacher continuously providing instructions might have limited the children’s ability to sustain and actively use goal relevant information, and the limited use of music might have de-coupled perception and action, thus restricting exploratory behaviour. Furthermore, recent research has shown that the manipulation of working memory load did not affect the search or execution of either creative convergent and/or divergent movements (Moraru, Memmert, & van der Kamp, 2016; Orth, McDonic, Ashbrook, & van der Kamp, 2019). This opens up interesting avenue for future research to examine whether a creative curriculum with the addition of remembering movement sequences may load working memory and, in turn, improve working memory capacity.

The aforementioned results provide new insights into the efficacy of coupling exercise with learning a movement skill to promote the development of working memory capacity (Moreau et al., 2015; Pesce, 2012). Dance has been suggested to provide a suitable context to apply key training aspects (i.e., complexity, diversity and novelty) into learning environments for children and enhance working memory capacity (Tomporowski & Pesce, 2019). While future research is needed to confirm and strengthen the observed results, this study combined with Oppici et al. (2020) suggest that improvement in working memory capacity is driven by retaining movement sequences as opposed to simply dancing. In both studies, the task of simultaneously performing a dance choreography whilst maintaining movement sequences was most effective. An important question is whether the load placed on working memory when learning new movements needs to be task relevant (as in this study) or can be task irrelevant (e.g., counting numbers or answering irrelevant questions whilst learning a movement). In accordance with the embodied perspective of cognition (Chemero, 2009; Thompson & Varela, 2001), we expect that working memory capacity improvements are heightened when the working memory load is task relevant. Indeed, we hypothesise that working memory capacity might best improve when cognition (and strategies to load working memory) are embedded in the dynamic interaction between performer-environment-task. While we are speculating and results of this study and Oppici et al. (2020) are not clear cut, this certainly opens an interesting avenue for future research.

Neither group showed changes in cognitive flexibility as was the case in Oppici et al. (2020) dance study. On a review of factorial structures of executive functions, it seems that children's executive functions load consistently onto two constructs (working memory and inhibitory control; Hughes, Ensor, Wilson, & Graham, 2009; St Clair-Thompson & Gathercole, 2006; Wiebe et al., 2011), whilst in adults onto three constructs (working memory, inhibitory control, and cognitive flexibility; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Miyake et al., 2000). This aligns with our findings that improvement in cognitive flexibility is not present either in this cohort of young children or the older cohort found in Oppici et al. (2020). This does not mean cognitive flexibility should be ignored in children, as the ability to adapt behaviour to changes in the environment is important (Diamond, 2016). Instead, future research should aim to design interventions that directly challenge this executive function by requiring learners to continuously switch between tasks. For example, principles of nonlinear pedagogy can guide the design of a suitable learning environment and promote high movement variability, active problem-solving, decision-making and exploration of innovative movement solutions (Chow et al., 2007).

Contrary to prediction, the two dance interventions did not promote development of motor competence beyond the control period. It was actually the other way around (Figure 3). Furthermore, the two groups showed a similar small improvement during the intervention. While previous research suggested that learning a dance choreography may improve motor competence (results were not statistically significant, Oppici et al., 2020) and we hypothesised that the creative curriculum would have further enhance motor competence (Richard, Lebeau, Becker, Boiangin, & Tenenbaum, 2018), the results showed the opposite. The aforementioned issues in adopting the planned pedagogy and a potential practice-testing effect (as observed in Oppici et al., 2020) makes the interpretation of these results quite difficult. Different explanations are possible: the limited amount of practice volume in both groups (25 to 30% of time on task) did not provide enough movement opportunities, the creative curriculum might have enhanced motor competence if adopted as planned, a practice-testing effect biased and boosted results in the control period, or a combination of them. Future research is required to clarify whether dance is a suitable activity for improving motor competence. One option is a careful task analysis to identify age appropriate challenge of the intervention curriculum design. Secondly, the development of pedagogy based on motor learning theory would enable investigations of emergent behaviours and the challenge point from an embedded cognition perspective (Rudd et al., 2020). Future research also needs to take into account the validity of tests used to assess motor competence. CAMSA is validated for 8 years-old and above children and, while the test seems to be valid for this study (i.e., there was not any floor or ceiling effect), future research is recommended to examine its sensitivity, specificity and feasibility in 6-7 year old children.

This study presents some limitations worth mentioning. As previously discussed, the adopted pedagogy in the creative dance group did not reflect the planned pedagogy, likely influencing the results. Assessment of the groups' pedagogy fidelity was carried out in the second half of the intervention period, which did not leave room for adjustment of unplanned events (e.g., too many teacher's instruction). Future research should perform fidelity check in the early phase of an intervention and promptly intervene if the pedagogy does not match with the planned one. Furthermore, we did not control the physical activity children performed outside of school. They were instructed and regularly reminded to refrain from engaging in dance activities, but we did not record whether children participated in other sports outside of school, which might have confounded the results. Lastly, while only visuo-spatial working memory was assessed, it would be important to measure both visuo-spatial and verbal working memory in future assessments of executive function.

Another important consideration for future research is the development of ecologically valid assessment tools. While we used validated tools, we acknowledge that the NIH Toolbox is somewhat detached (i.e., I-Pad- based in the classroom) to the practice environment where the executive functions are predicted to develop. This may create an issue of transfer from practice to the test environment, and the development of executive functions may not be fully captured. Currently, tools for assessing executive functions lack ecological validity from an embodied cognition perspective. Future research should develop ecologically valid assessment tools for a proper embodied-embedded assessment of executive functions.

Conclusions

This study compared the efficacy of learning a dance choreography and practicing creative dance on improving executive functions and motor competence in 6-8 years old children, providing new insights into the *exercise-cognition* relationship. Regardless of the shifts in intervention design, both dance curriculums improved inhibitory control, while only the choreographed curriculum showed small signs of improvement for working memory capacity. This study supports previous research (Oppici et al., 2020), showing that dance is indeed a suitable activity to promote the development of executive functions in primary school children. Importantly, these studies seem to suggest that retaining movement sequences during dance may be the main driver of working memory capacity improvement. Contrary to prediction, the dance interventions did not boost improvement in motor competence. This and the results on executive functions have been likely influenced by the discrepancy between the planned and the adopted pedagogy in the creative curriculum, which resulted in a higher-than-planned amount of instruction to children and a lower-than-predicted volume of practice with music. Therefore, the results of this study should be interpret with a degree of caution. This study also showed that the fidelity to the teaching pedagogy required of a creative curriculum design presents a challenge for teachers, regardless of their experience. Future research should explore the influence different aspects of a dance curriculum have on executive functions by examining implementation factors through an extensive process evaluation, which plans for quality checks and subsequent adjustments to be made during the training to ensure fidelity of a contemporary pedagogical approach.

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References

Adolph, K. E. (2020). An ecological approach to learning in (not and) development. *Human Development, 63*(3-4), 180-201. doi:10.1159/000503823

Araújo, D., Davids, K., & Hristovski, R. (2006). The ecological dynamics of decision making in sport. *Psychology of Sport and Exercise, 7*(6), 653-676. doi:10.1016/j.psychsport.2006.07.002

Araújo, D., Hristovski, R., Seifert, L., Carvalho, J., & Davids, K. (2019). Ecological cognition: Expert decision-making behaviour in sport. *International Review of Sport and Exercise Psychology, 12*(1), 1-25. doi:10.1080/1750984X.2017.1349826

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*, 1-48. doi:10.18637/jss.v067.i01

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.

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development, 81*(6), 1641-1660. doi:10.1111/j.1467-8624.2010.01499.x

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. *Developmental review 29*(3), 180-200. doi:10.1016/j.dr.2009.05.002

Best, J. R., Miller, P. H., & Naglieri, J. A. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative national sample. *Learning and Individual Differences, 21*(4), 327-336. doi:10.1016/j.lindif.2011.01.007

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78*(2), 647-663. doi:10.1111/j.1467-8624.2007.01019.x

Brock, L. L., Rimm-Kaufman, S. E., Nathanson, L., & Grimm, K. J. (2009). The contributions of ‘hot’ and ‘cool’ executive function to children's academic achievement, learning-related behaviors, and engagement in kindergarten. *Early Childhood Research Quarterly, 24*(3), 337-349. doi:https://doi.org/10.1016/j.ecresq.2009.06.001

Button, C., Seifert, L., Chow, J. Y., Araújo, D., & Davids, K. (2020). *Dynamics of skill acquisition: An ecological dynamics rationale*. Champaign, Il: Human Kinetics.

Chemero, A. (Ed.) (2009). *Radical embodied cognitive science*. Cambridge, MA: MIT Press.

Chow, J. Y., Davids, K., Hristovski, R., Araújo, D., & Passos, P. (2011). Nonlinear pedagogy: Learning design for self-organizing neurobiological systems. *New Ideas in Psychology, 29*(2), 189-200. doi:10.1016/j.newideapsych.2010.10.001

Chow, J. Y., Davids, K., Renshaw, I., Button, C., Shuttleworth, R., & Araújo, D. (2007). The role of nonlinear pedagogy in physical education. *Review of Educational Research, 77*(3), 251-278. doi:10.3102/003465430305615

de Greeff, J. W., Bosker, R. J., Oosterlaan, J., Visscher, C., & Hartman, E. (2018). 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. *Annual Review of Psychology, 64*, 135-168. doi:10.1146/annurev-psych-113011-143750

Diamond, A. (2016). Why improving and assessing executive functions early in life is critical. In J. A. Griffin, P. McCardle, & L. S. Freund (Eds.), *Executive function in preschool-age children: Integrating measurement, neurodevelopment, and translational research* (pp. 11-43). Washington, DC: American Psychological Association.

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). 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.

Fishbein, D. H., Michael, L., Guthrie, C., Carr, C., & Raymer, J. (2019). Associations between environmental conditions and executive cognitive functioning and behavior during late childhood: A pilot study. *Frontiers in Psychology, 10*, 1263-1263. doi:10.3389/fpsyg.2019.01263

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

Harms, M. B., Zayas, V., Meltzoff, A. N., & Carlson, S. M. (2014). Stability of executive function and predictions to adaptive behavior from middle childhood to pre-adolescence. *Frontiers in Psychology, 5*, 331-331. doi:10.3389/fpsyg.2014.00331

Haught-Tromp, C. (2017). The Green Eggs and Ham hypothesis: How constraints facilitate creativity. *Psychology of Aesthetics, Creativity, and the Arts, 11*(1), 10-17. doi:10.1037/aca0000061

Hofer, S. M., & Clouston, S. (2014). Commentary: On the importance of early life cognitive abilities in shaping later life outcomes. *Research in Human Development, 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.

Hughes, C., Ensor, R., Wilson, A., & Graham, A. (2009). Tracking executive function across the transition to school: A latent variable approach. *Developmental Neuropsychology, 35*(1), 20-36. doi:10.1080/87565640903325691

Jess, M., McEvilly, N., & Carse, N. (2017). Moving primary physical education forward: start at the beginning. *Education 3-13, 45*(5), 645-657. doi:10.1080/03004279.2016.1155072

Laban, R. (1975). *Laban's principles of dance and movement notation*. London: MacDonald & Evans.

Laban, R., & Ullman, L. (1971). *The mastery of movement*. Boston: Plays.

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. *Journal of Science & Medicine in Sport, 20*(6), 590-594. doi:10.1016/j.jsams.2016.11.007

Lehto, J. E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology, 21*(1), 59-80. doi:10.1348/026151003321164627

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

McClelland, M. M., Acock, A. C., & Morrison, F. J. (2006). The impact of kindergarten learning-related skills on academic trajectories at the end of elementary school. *Early Childhood Research Quarterly, 21*(4), 471-490. doi:https://doi.org/10.1016/j.ecresq.2006.09.003

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

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*(1), 49-100. doi:10.1006/cogp.1999.0734

Moraru, A., Memmert, D., & van der Kamp, J. (2016). Motor creativity: the roles of attention breadth and working memory in a divergent doing task. *Journal of Cognitive Psychology, 28*(7), 856-867.

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 Psychologica (Amst), 157*, 44-55. doi:10.1016/j.actpsy.2015.02.007

Oppici, L., Rudd, J., Buszard, T., & Spittle, S. (2020). 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 and Exercise, 50,* 101675. doi:https://doi.org/10.1016/j.psychsport.2020.101675

Orth, D., McDonic, L., Ashbrook, C., & van der Kamp, J. (2019). Efficient search under constraints and not working memory resources supports creative action emergence in a convergent motor task. *Human Movement Science, 67*, 102505. doi:https://doi.org/10.1016/j.humov.2019.102505

Pesce, C. (2012). Shifting the focus from quantitative to qualitative exercise characteristics in exercise and cognition research. *Journal of Sport and Exercise Psychology, 34*(6), 766-786. doi:10.1123/jsep.34.6.766

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

R Core Team. (2019). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

Rasmussen, L. J. T., Østergaard, L. D., & Glăveanu, V. P. (2017). Creativity as a developmental resource in sport training activities. *Sport, Education and Society, 24*(5), 491-506. doi:10.1080/13573322.2017.1403895

Reeve, J., Jang, H., Carrell, D., Jeon, S., & Barch, J. (2004). Enhancing students' engagement by increasing teachers' autonomy support. *Motivation and Emotion, 28*(2), 147-169. doi:10.1023/B:MOEM.0000032312.95499.6f

Richard, V., Lebeau, J., Becker, F., Boiangin, N., & Tenenbaum, G. (2018). Developing cognitive and motor creativity in children through an exercise program using nonlinear pedagogy principles. *Creativity Research Journal, 30*(4), 391-401. doi:10.1080/10400419.2018.1530913

Romine, C. B., & Reynolds, C. R. (2005). A model of the development of frontal lobe functioning: Findings from a meta-analysis. *Applied Neuropsychology, 12*(4), 190-201. doi:10.1207/s15324826an1204_2

Rudd, J. R., Pesce, C., Strafford, B. W., & Davids, K. (2020). Physical Literacy, a journey of individual enrichment: an Ecological Dynamics rationale for enhancing performance and physical activity in all *Frontiers in Psychology, 11*(1904), 1-13. doi:10.3389/fpsyg.2020.01904

St Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *Quarterly Journal of Experimental Psychology (Hove), 59*(4), 745-759. doi:10.1080/17470210500162854

Thompson, E., & Varela, F. J. (2001). Radical embodiment: Neural dynamics and consciousness. *Trends in Cognitive Sciences, 5*(10), 418-425. doi:10.1016/s1364-6613(00)01750-2

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, 145*(9), 929-951. doi:10.1037/bul0000200

Torrents, C., Balagué, N., Ric, Á., & Hristovski, R. (2020). The motor creativity paradox: Constraining to release degrees of freedom. *Psychology of Aesthetics, Creativity, and the Arts*. doi:10.1037/aca0000291

Torrents, C., Ric, Á., & Hristovski, R. (2015). Creativity and emergence of specific dance movements using instructional constraints. *Psychology of Aesthetics, Creativity, and the Arts, 9*(1), 65-74. doi:10.1037/a0038706

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

Vaughan, J., Mallett, C. J., Davids, K., Potrac, P., & Lopez-Felip, M. A. (2019). Developing creativity to enhance human potential in sport: A wicked transdisciplinary challenge. *Frontiers in Psychology, 10,* 2090. doi:10.3389/fpsyg.2019.02090

Warren, W. H. (2006). The dynamics of perception and action. *Psychological Review, 113*(2), 358-389. doi:10.1037/0033-295X.113.2.358

Wiebe, S. A., Sheffield, T., Nelson, J. M., Clark, C. A., Chevalier, N., & Espy, K. A. (2011). The structure of executive function in 3-year-olds. *Journal Of Experimental Child Psychology, 108*(3), 436-452. doi:10.1016/j.jecp.2010.08.008

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. *Monographs of the Society for Research in Child Development*, *78*(4), 16-33. doi:10.1111/mono.12032

Zelazo, P. D., & Carlson, S. M. (2012). Hot and cool executive function in childhood and adolescence: Development and plasticity. *Child Development Perspectives, 6*(4), 354-360.

Table 1 Groups’ engagement during the dance classes.

	Creative dance group	**Choreography dance group**	**Difference (p value)**
Attention	4.4 ± 0.8	4.5 ± 1.3	3% (0.83)
Effort	4.9 ± 0.6	5.3 ± 0.6	8% (0.17)
Verbal participation	5.0 ± 0.6	5.7 ± 0.7	13% (0.06)
Persistence	4.8 ± 0.7	4.8 ± 0.9	1% (0.87)
Emotional tone	4.9 ± 0.8	5.4 ± 1.0	12% (0.18)
Overal Student engagment	4.8 ± 0.2	5.1 ± 0.4	6% (0.02)

Table 2 Time on different activities, number of activities with music, counts and demonstrations expressed as percentage.

	Creative dance group	**Choreography dance group**	**Difference (p value)**
Time on task (%)	24 ± 8	28 ± 3	15% (0.42)
Time on instructions (%)	42 ± 6	17 ± 8	85% (0.01)
Other (organising groups, observing other students, drinking, "dead" time) (%)	34 ± 13	55 ± 8	47% (0.04)
Activities with music (%)	7 ± 8	89 ± 11	170% (<0.01)
Activities with counts (%)	46 ± 46	2 ± 4	183% (0.15)
Activities with demonstrations (%)	18 ± 10	32 ± 7	56% (0.09)

Table 3 Outcomes of working memory capacity, inhibitory control, cognitive flexibility and motor competence among the 2 dance groups are presented along with baseline, pre and post improvements.

		Baseline	**Pre**	**Post**	**Baseline vs Pre**	**Pre vs Post**
Working Memory Total Score (a.u.)	Choreography	11.0 ± 4.7	12.1 ± 3.5	13.3 ± 2.9	p = 0.40; d = 0.26	p = 0.24; d = 0.41
	Creative	10.2 ± 3.7	11.8 ± 3.4	12.4 ± 2.7	p = 0.04; d = 0.45	p = 1.00; d = 0.12
Working Memory 2-List Condition Score (a.u.)	Choreography	4.2 ± 1.9	4.3 ± 1.9	5.2 ± 1.6	p = 1.00; d = 0.05	p = 0.26; d = 0.56
	Creative	3.1 ± 2.1	4.0 ± 2.1	4.4 ± 1.9	p = 0.26; d = 0.42	p = 0.76; d = 0.20
Flanker Task (a.u.)	Choreography	78.6 ± 11.0	81.7 ± 9.6	86.6 ± 8.7	p = 0.21; d = 0.34	p = 0.02; d = 0.52
	Creative	80.3 ± 9.7	82.5 ± 8.7	86.4 ± 8.8	p = 0.45; d = 0.24	p = 0.058; d = 0.44
DCSS (a.u.)	Choreography	88.4 ± 6.6	87.6 ± 7.1	87.9 ± 9.3	p = 1.00; d = 0.16	p = 1.00; d = 0.04
	Creative	82.1 ± 15.0	85.6 ±9.7	85.7 ± 4.0	p = 0.27; d = 0.27	p = 1.00; d = 0.04
CAMSA (a.u.)	Choreography	12.8 ± 3.9	16.0 ±4.4	17.5 ± 4.7	p < 0.01; d = 0.78	p = 0.02; d = 0.22

Creative	12.5 ± 4.5	15.8 ± 3.9	16.9 ± 4.5	$p < 0.01$; $d = 0.75$	$p = 0.11$; $d = 0.23$

p values are corrected for multiple comparisons using Helm methods and significance is set at $\alpha = 0$

Figure 1 Schematic of study design.

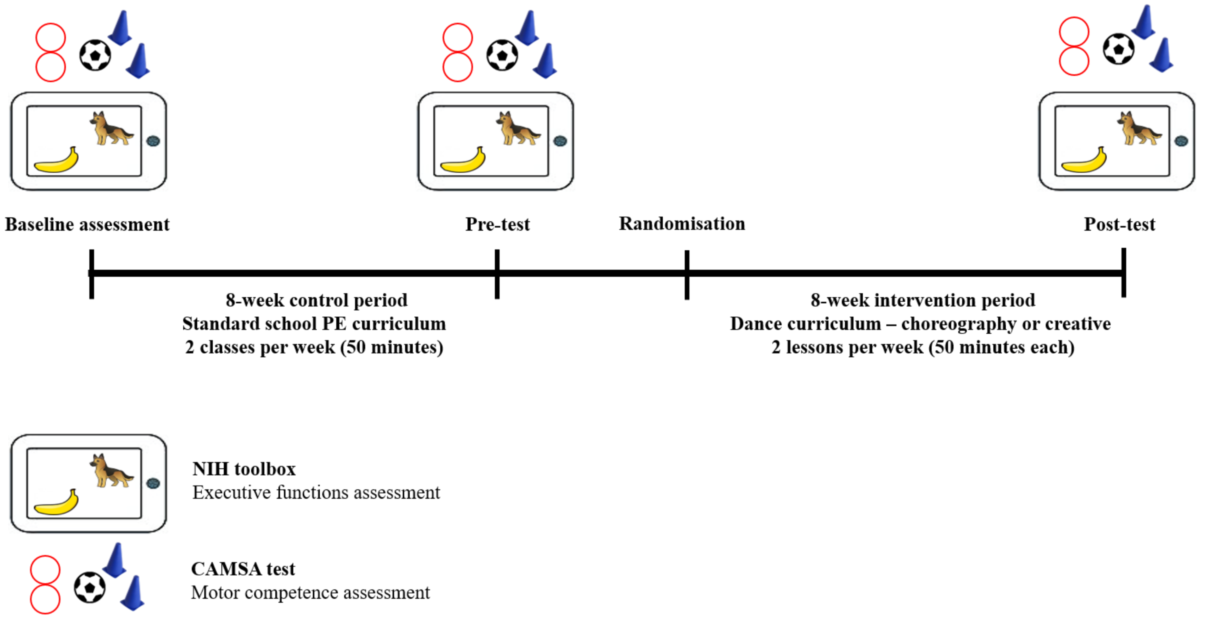

Figure 2 Groups' improvements in working memory total score (A) and 2-list score (B), and inhibitory control (C) are shown across the three time points. α represents a significant change ($p < 0.025$); * and ** represent small and moderate effect sizes respectively.

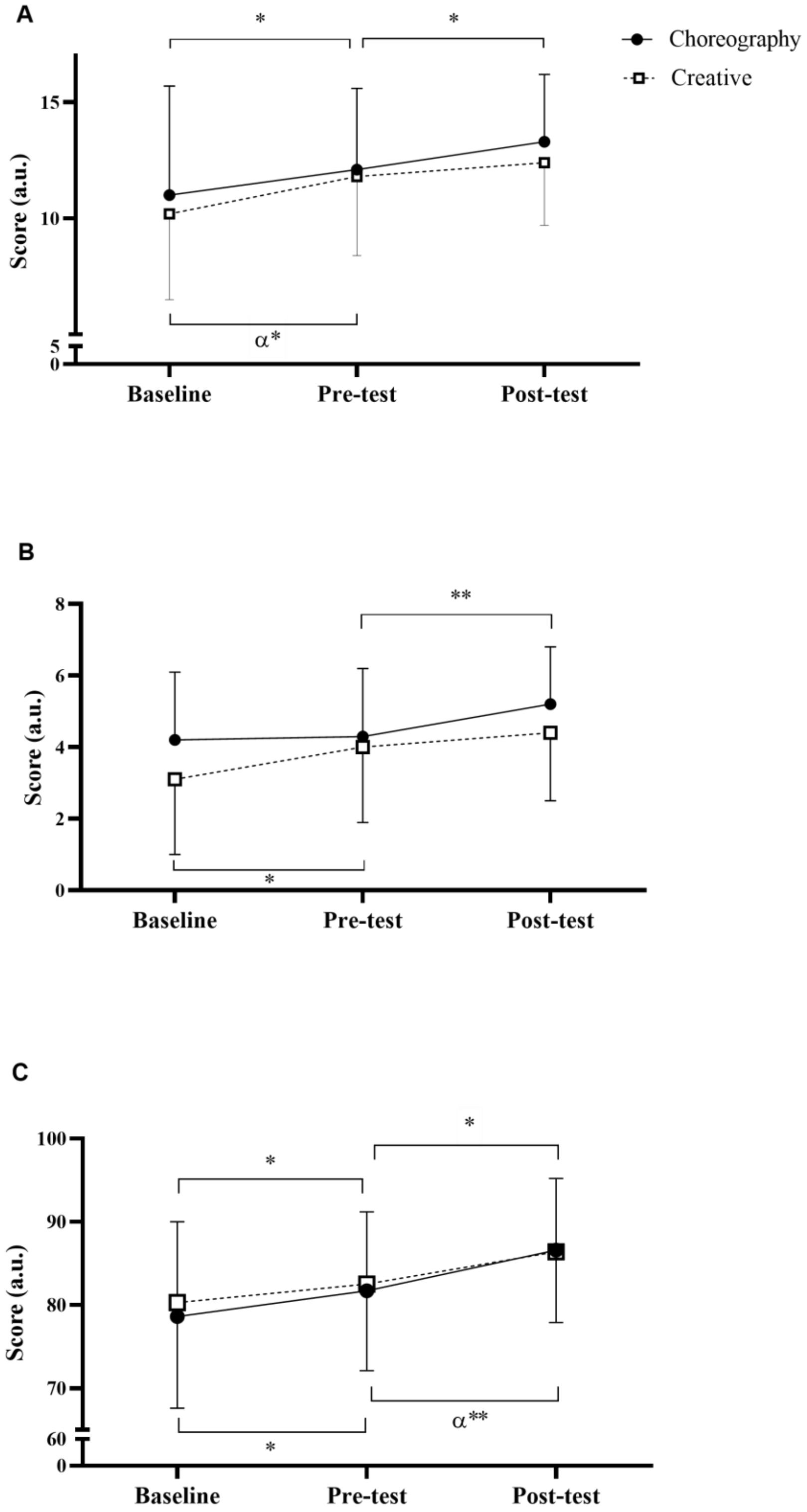

Figure 3 Groups' improvement in motor competence in the CAMSA test is shown across the three time points. α represents a significant change ($p < 0.025$); * and ** represent small and moderate effect sizes respectively.