The effect of physical activity on spatial perception and attention in early childhood

Sima Zach a,∗, Varda Inglis a, Orly Fox a, Itay Berger b, Ayelet Stahl a

a Zinman College of Physical Education and Sport Sciences, Wingate Institute, Netanya, Israel
b Neuro-Cognitive Center, Pediatric Division at Hadassah-Hebrew University Medical Center, Jerusalem, Israel

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ABSTRACT

This study examined whether physical activity improves spatial perception and attention in early childhood. A pre–post intervention trials design with intervention and control groups was implemented. Participants were 123 kindergarten children, divided into three groups: experimental—orienteer, experimental—dance, and control—no intervention. Instrumentations: attention measured by the MOXO-CPT, a computerized test, and The Cognitive Modifiability Battery Reproduction of Patterns measured spatial abilities. Measurements were conducted pre- and post-interventions. Results showed fast improvement from pre- to post-intervention, achieved simultaneously in both EFs for the experimental groups only. No differences were found between boys and girls. It was concluded that in order to successfully achieve the required tasks, an integration of physical and cognitive skills is needed.

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1. Introduction

Executive functions develop from childhood, peak in adulthood, and deteriorate in old age (Kamijo & Takeda, 2010; Tomporowski, Lambourne, & Okumura, 2011). In looking for ways to slow down or decrease this deterioration, researchers have examined the influence of physical activity on Executive functions (e.g., Themanson & Hillman, 2006; Themanson, Pontifex, & Hillman, 2008; Tomporowski, Davis, Miller, & Naglieri, 2008). Physical activity may support executive function because the former increases cerebral vasculature (Ding, Zhou, Rafols, Clark, & Ding, 2006), and leads to the production of neurotrophins that regulate the survival of neurons (Poehlman & Danforth, 1991; Vaynman & Gomez-Pinilla, 2006). Physical activity also affects synaptogenesis, which occurs concomitantly with myelination, and angiogenesis, which influences glucose and oxygen distribution (Ding et al., 2006; Kerr, Steuer, Pochter, & Swain, 2010). All of the above can account for improved cognitive ability following exercise over time (Guiney & Machado, 2013).

Given that executive functions have been reported to be essential for everyday life (Jackson, Loxton, Harnett, Carrochi, & Gullo, 2014; Murray, Pattie, Starr, & Deary, 2012) and associated with well-being (e.g., Brissos, Dias, & Kapczinski, 2008; Cruise et al., 2011), evidence concerning the benefits of physical activity on well-being may imply that physical activity also contributes to the performance of executive functions. Various studies have sought to explain what kind and what dose – meaning the duration, frequency, and intensity – of activity are required in order to decrease or slow down the deterioration

∗ Corresponding author at: School of Education, The Zinman College of Physical Education and Sport Sciences, Wingate Institute, 4290200, Israel. Fax: +972 9 8639 320.
E-mail addresses: simaz@wincol.ac.il (S. Zach), vardai@wincol.ac.il (V. Inglis), foxo@wincol.ac.il (O. Fox), itberg@hadassah.org.il (I. Berger).

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of executive functions in old age. Hence, the benefits of physical activity on executive functions were extensively examined, and proved to be positive among the elderly (e.g., Lin, Chan, Zheng, Yang, & Wang, 2007; Wellenius et al., 2012). Following this line of research, further studies examined the influence of physical activity on executive functions in other age groups, such as infants (e.g., Friedman, Watamura, & Robertson, 2005; Robertson, Bacher, & Huntington, 2001; Sommerville, & Woodward, 2005) and early adulthood (e.g., Sibley and Beilock, 2007; Sibley, Etnier, & Le Masurier, 2007). Other groups of interest were children with learning disabilities (e.g., Gadin & Etnier, 2010) and individuals in the process of rehabilitation (e.g., Brummel et al., 2012). Research is scarce in the early childhood age group regarding this matter.

Modern society has become increasingly sedentary, beginning in childhood (World Health Organization, 2010). The link between physical activity and cognitive performance among schoolchildren has previously been researched using two main approaches (see Barnett, 2011; Best, 2010). The first approach examined the link between chronic exercise and intelligence and academic achievements (Tomporowski et al., 2008), and the second examined the link between acute bouts of exercise and cognitive performance (Tomporowski, 2003). We suggest that in addition to these two approaches, it would be of great value to explore the benefits of physical activity on executive functions in early childhood. The kinds of activities that are appropriate for early childhood should be specifically identified, in order to achieve two main targets: increasing physical activity among children, and strengthening executive functions along the process of development.

Orienteering and dance were chosen as the physical activities to be included in this study, for several reasons: first, both are activities that can be easily learned in early childhood, incorporated as a new activity in kindergarten, and used to diversify a physical activity program. Second, by learning these activities, executive functions may be trained, namely spatial perception and attention. Cognitive psychologists (see Coventry, Griffiths, & Hamilton, 2014; Hommel, Gehrke, & Knuf, 2000; Sanocki, 2003) have emphasized the contribution of spatial perception to a wide range of everyday human activities, such as reaching and grasping an object, learning letters while acquiring a language, typing on a keyboard, finding one’s way home, or getting along in an unfamiliar environment. Lahav (2006) claimed that mental mapping of spaces, and mapping of the possible paths for navigating these spaces, are essential for the development of efficient orientation and mobility skills. Furthermore, a recent review demonstrated that attention and spatial perception are interrelated: in fact, attention plays a particularly important part in spatial perception. Both functions have been shown to be a major factor in the way that individuals process objects, faces, and scenes, and how they interact with their environment (van der Hama, Postmaa, & Laengc, 2014). In addition, both activities – dance and orienteering – were identified as endeavors that require generating, observing, executing, and coordinating movement patterns that require the integration of physical and cognitive skills (Bläsing et al., 2012; Eccles, Walsh, & Ingleedew, 2002). Moreover, in order to improve performance, orienteers and dancers need to practice their spatial perception ability and their attention ability (Bläsing et al., 2012; Jola, Davis, & Haggard, 2011; Oña, 2005), both of which were the examined executive functions of the current study. These executive functions enable young children not only to perform well in cognitive tasks (see Eccles et al., 2002; Enghauser, 2007; Ratey, 2008), but they are also essential to their everyday life functioning (see Jola et al., 2011; Oña, 2005). Nevertheless, in these studies each activity was investigated separately, as was each executive function.

We followed Memmert’s (2006) study that aimed to examine the contribution of a diversified sport enrichment program on the development of cognitive abilities.

However, while Memmert’s study examined gifted children, we examined typically developing children.

Along these lines, we tried to determine in what way can the study of dance and orienteering contribute to the advancement of children’s cognition and behavior. Hence we hypothesized that physical activity, specifically orienteering and dance, will improve executive functions such as spatial perception and attention in early childhood.

2. Method

2.1. Participants

Kindergarten children, 60 boys and 63 girls, 4–5 (M = 5.07; S.D = 0.68) years old (n = 123), participated in the study. The participants were assigned to three groups, as follows: experimental group 1 (orienteering), n = 44; experimental group 2 (dance), n = 40, and control group (no intervention), n = 39. The three kindergartens that the children attended were selected to be part of this study because of their similar demographic background: middle-class socio-economic status, rural environment, and activity curriculum. Additionally, it should be noted that we had pre-existing groups, since every classroom as a whole was assigned to a group.

2.2. Instruments

2.2.1. Attention

The MOOX Continuous Performance Test (Neurotech Solutions Ltd.)—this is a standardized computerized test designed to measure attentional performance (see also Berger & Goldzweig, 2010). A set of target and non-target stimuli was shown in the center of a computer screen. Both the target and non-target stimuli were cartoon pictures. Thus, these stimuli do not include either letters or numbers. In each trial a stimulus (target/non-target) was presented for 500, 1000, or 3000 ms, and then followed by a “void” period of the same duration. The stimulus remained on the screen for the full duration, regardless of whether or not response was produced. This procedure allowed for the measuring of response timing (whether the
response occurred during the stimulus presentation or the void period), as well as of the accuracy of the response. The test also included visual and auditory stimuli that served as distractors. The stimuli were presented sequentially at the center of a computer screen, and the participant was instructed to respond as quickly as possible to the target stimuli by pressing the space bar once, and only once. The participant was also instructed not to respond to any other stimuli except the targets, and not to press any other key but the space bar.

The MOXO CPT is based on an algorithm designed to test several domains of attention by using a multi-task approach. There are two kinds of tasks: elements that appear in the center of the screen – a central task, and elements that appear on the sides of the screen – a peripheral task. Each task includes two phases: (1) static—a slow change between the target and non-target element, and (2) dynamic—a fast change between the target and non-target element. Each phase lasts 160 s, and each task lasts 320 s, excluding the break between the tasks.

The system counts the number of times the spacebar is or is not pressed at each level in relation to the shown elements. It also registers the time lapse from the appearance of the element until the spacebar is pressed, and if other computer keys (not the spacebar) are pressed.

Output (performance indices)—The MOXO-CPT included four performance indices: Attention, Timing, Impulsivity, and Hyperactivity.

Attention—This index corresponded to the number of correct responses (a spacebar keystroke in response to a target stimulus) performed during the stimulus presentation, or during the “void” period that followed it. This index was considered as a pure measure of sustained attention because it measured correct responses independently of the response time.

Timing—The timing index was the number of correct responses given only during the time in which the target stimulus was present on the screen.

Impulsivity—The impulsivity index was the number of responses performed only during the time in which a non-target stimulus was present on the screen.

Hyperactivity—The hyperactivity index was the total number of responses that were coded as impulsive responses (e.g., multiple keystrokes in response to a target stimulus; responses performed in the void period after a non-target stimulus; random key pressing) (Berger & Goldzweig, 2010).

Two versions of the MOXO test were used in the study. The orienteering group was given the interactive version: Pressing the space bar produced a reaction, that is, a target stimuli (an exploding balloon), and a non-target element (a bicycle getting a flat tire). This version appeared 40 times. The other two groups, the dance group and the control group, were tested with the non-interactive version, which had a balloon as a target element and a red ball as a non-target element. Pressing the space bar did not produce any reaction. It should be noted that the paradigm and the algorithm of the MOXO CPT were similar in both versions. The only difference was the stability of the element on the screen: in the interactive version pressing the space bar produced a reaction, while in the non-interactive version pressing the space bar did not produce any reaction. We suggest that this is a relatively minor difference, which we deem unlikely to affect test performance or difficulty. Small procedural changes are common in other tasks, such as the Go/No-Go test, and they usually do not affect performance among healthy children (see Banaschewski et al., 2008; Berger & Cassuto, 2014; Van Rooij et al., 2015). Such a minor change, which did not alter the test paradigm or difficulty, should not affect performance among typically developing children such as those included in our study.

2.2.2. Spatial perception

2.2.2.1. The cognitive modifiability battery (CMB)—subtest. Reproduction of Patterns (RP). The RP sub-test is based on the simple visual-motor task of copying three-dimensional patterns. The patterns require making a distinction between the dimension of color, height, number, and position (location of a “window” in a plate and location of a block in the correct corners of each “window”). As the task proceeds, trial difficulty increases, such that trials start our presenting very simple patterns that increase in difficulty level to very complex patterns that require a fine distinction of all dimensions. The RP subtest is composed of nine items, three in each of the three phases of pre-teaching, teaching, and post-teaching (9 × 3 = 27). The child sits to the left of the examiner; the examiner presents the pattern on one plate and asks the child to reproduce it exactly on another plate. In our study we changed the learning phase to the intervention phase (orienteering or dance).

2.2.2.2. Pre-teaching/test and post-teaching/test phases. The items for both phases are parallel. No teaching is provided in these phases, with the exception of light focusing (“look here”) or self-regulation remarks (“be careful”). The child’s responses are recorded on a plate representation divided into nine “windows”, and each “window” is divided into four parts. The examiner writes only the abbreviations of the color and height in each plate. Each problem is solved by two scoring methods: (a) “none—or—all”—a score of one is given for each correctly solved “window” (a total of four for the whole problem), and a score of zero for a mistake (a mistake is scored even when only one of the dimensions is not correct), and (b) “partial credit”—a score of one is given for each correctly solved dimension in each “window”. The scores are for color, height, number, and location in the “window” (P1), and for location of the correct “window” (P2). Thus, the maximal score for each “window” is five, and the maximal score for the whole problem is 20. The maximal score according to methods one and two are 36 and 180, respectively (Tzuriel, 1995).
### Table 1
Two groups’ intervention program.

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Lessons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orienteering</td>
<td>#1</td>
</tr>
<tr>
<td></td>
<td>#2</td>
</tr>
<tr>
<td></td>
<td>#3–6</td>
</tr>
<tr>
<td></td>
<td>#7–8</td>
</tr>
<tr>
<td></td>
<td>#9</td>
</tr>
<tr>
<td>Dance</td>
<td>#1–4</td>
</tr>
<tr>
<td></td>
<td>#5–7</td>
</tr>
<tr>
<td></td>
<td>#8</td>
</tr>
<tr>
<td></td>
<td>#9</td>
</tr>
<tr>
<td></td>
<td>#10</td>
</tr>
</tbody>
</table>

2.3. Procedure

The study was approved by the Chief Scientist in the Ministry of Education. Letters of agreement were signed by the parents regarding the participation of their children in the study. Participants—children in kindergarten—were divided into three groups: (1) an experimental group with intervention—orienteering; (2) an experimental group with intervention—dance, and (3) a control group with no intervention.

A pre-post intervention trial design with the intervention groups and a control group was implemented to determine whether orienteering and dance PA influenced attention and spatial perception. The participants were examined by the two research instruments: MOXO and the RP subtest from the CMB, one week prior to the intervention, with a 10-min break between the tests. Each participant was examined individually by the examiner, and the examinations took place in a quiet corner. The intervention phase then took place, lasting nine weeks and including a weekly program of physical activity—either orienteering or a dance lesson. In the post-intervention phase, the three groups of children were re-examined.

2.4. Study design

An interventional study with pre–post examinations was employed with two experimental groups and one control group.

2.5. Intervention

Group 1, orienteering, included nine weekly orienteering activities that gradually increased in level of difficulty, starting in the classroom; see details in Table 1. Registered professional orienteers taught all the lessons. Group 2, dance, included nine weekly sessions that also gradually increased in level of difficulty, in the kindergarten classroom. A total of 10 dances were taught by a professional dance teacher; see details in Table 1. The dances that were chosen for the intervention required perception of location in space, an understanding of the difference between personal and public space, in relation to partners and other dancers, and the ability to change directions. All dances were taught in three stages: (1) oral explanation with a demonstration of each dance step, without music; (2) adding music to the demonstrations; (3) assembling all steps into a complete dance, while combining oral explanations with demonstrations. The dance group went through the process of pre-tests, intervention dance, and post-tests. The control group went through the pre-test and post-test, which were nine weeks apart, with recess instead of intervention.

2.6. Data analysis

In order to examine the differences in attention and spatial perception performance between the three groups from pre-to post-intervention, a 3 (experimental group: dance vs. orienteering vs. control) × 2 (pre vs. post) mixed ANOVA was conducted with experimental group varied between participants and pre and post within participants. In addition, two different analyses were conducted for the MOXO test: a 2(experimental group: dance vs. control) × 2 (pre vs. post) mixed ANOVA, and a t-test was performed for the orienteering experimental group.
Table 2
The differences between pre- and post-intervention in attention among the three groups.

<table>
<thead>
<tr>
<th></th>
<th>Orienteeing^t</th>
<th>Dance^t</th>
<th>Control^t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre M (S.D)</td>
<td>Post M (S.D)</td>
<td>Pre M (S.D)</td>
</tr>
<tr>
<td>Timing b</td>
<td>32.34</td>
<td>33.44</td>
<td>31.75</td>
</tr>
<tr>
<td></td>
<td>(5.24)</td>
<td>(6.59)</td>
<td>(6.37)</td>
</tr>
<tr>
<td>Attention b</td>
<td>36.73</td>
<td>37.05</td>
<td>42.02</td>
</tr>
<tr>
<td></td>
<td>(3.45)</td>
<td>(3.31)</td>
<td>(4.89)</td>
</tr>
<tr>
<td>Hyperactivity b</td>
<td>1</td>
<td>1.24</td>
<td>8.66</td>
</tr>
<tr>
<td></td>
<td>(1.46)</td>
<td>(2.38)</td>
<td>(15.19)</td>
</tr>
<tr>
<td>Impulsivity b</td>
<td>0.9</td>
<td>1.24</td>
<td>3.25</td>
</tr>
<tr>
<td></td>
<td>(1.37)</td>
<td>(1.64)</td>
<td>(3.43)</td>
</tr>
<tr>
<td>Timing D a</td>
<td>33.62</td>
<td>33.62</td>
<td>35.02</td>
</tr>
<tr>
<td></td>
<td>(4.37)</td>
<td>(5.12)</td>
<td>(7.29)</td>
</tr>
<tr>
<td>Attention D c</td>
<td>38.36</td>
<td>38.1</td>
<td>47.86</td>
</tr>
<tr>
<td></td>
<td>(2.1)</td>
<td>(2.41)</td>
<td>(6.24)</td>
</tr>
<tr>
<td>Hyperactivity D</td>
<td>0.79</td>
<td>0.71</td>
<td>9.61</td>
</tr>
<tr>
<td></td>
<td>(1.26)</td>
<td>(0.74)</td>
<td>(15.15)</td>
</tr>
<tr>
<td>Impulsivity D c</td>
<td>0.79</td>
<td>0.74</td>
<td>4.33</td>
</tr>
<tr>
<td></td>
<td>(1.31)</td>
<td>(0.93)</td>
<td>(4.16)</td>
</tr>
</tbody>
</table>

D = disturbance; a = main effect group; b = main effect time; c = main effect interaction.
^t MOXO interactive.
" Two-way ANOVA only for control and dance groups that went through the revised MOXO.

3. Results

The hypothesis of the study was that PA, specifically orienteeering and dance, would improve executive functions such as spatial perception and attention in early childhood.

3.1. Attention—dance and control groups

The MOXO CPT examined target stimuli that appeared randomly—those facing the participant and those that sometimes appeared from different directions on the screen and were accompanied by disturbances. Results for the three groups’ Attention performance, at two measurements times are presented in Table 2.

ANOVA with repeated measures revealed differences between the two times of measurements in the two groups that were tested by the non-interactive version of the MOXO (dance and control), when the stimuli came from the center of the screen forward, in all test parameters: Timing: F(1, 67) = 9.67; p < .01; η² = .126; Attention: F(1, 67) = 6.71; p < .05; η² = .155; Hyperactivity: F(1, 67) = 3.99; p < .05; η² = .056 and Impulsivity: F(1, 67) = 4.59; p < .05; η² = .064 with no interaction. Additionally, a significant interaction was found in Attention (F(1, 68) = 4.53; p < .05; η² = .062) and in Impulsivity (F(1, 67) = 9.77; p < .01; η² = .126) when the stimuli were accompanied by disturbances.

Improvement in performance of the dance experimental group from pre- to post-intervention was also demonstrated when the stimulus appeared from different directions in parameters Attention and Hyperactivity. No improvement was demonstrated for Impulsivity. Timing improved only when the stimuli came from the bottom of the screen. No differences were found between boys and girls. Therefore, the hypothesis regarding attention was confirmed.

3.2. Attention—orienteeering group

The orienteeering experimental group, tested by the interactive version of the MOXO, improved its performance from pre-to post-intervention in Timing (t(37) = -2.068; p = .046).

3.3. Spatial perception

Results of the spatial perception performance of the three groups at two times of measurements are presented in Fig. 1.

In the general score of success in the CMB task, significant differences were demonstrated between the two times of measurements (pre–post) (F(2, 120) = 44.26; p < .001; η² = .269), and between the experimental groups and the control group (F(2, 120) = 6.502; p = .002; η² = .096), and interaction was also demonstrated (F(2, 120) = 5.66; p = .004; η² = .086). No differences were found between the two times of measurements and among the groups in the color and number of the cubes. As illustrated in Fig. 1, significant differences were also found in choosing the appropriate cube height between the two times of measurement (F(1, 120) = 47.10; p < .001; η² = .282) between the experimental groups and the control group (F(2, 120) = 4.42; p = .014; η² = .069), with no interaction. In arranging the cubes within each window (P1), differences were found between the two times of measurements (F(1, 120) = 7.41; p < .01; η² = .058), as well as between the experimental groups and the control group (F(2, 120) = 4.01; p < .05; η² = .063), and interaction also took place (F(2, 120) = 5.136; p = .007; η² = .079). A similar pattern of results was demonstrated for placing the right window (P2). Differences were found between the two
times of measurements ($F(1, 120) = 8.06; p < .01; \eta^2 = .063$), and between the experimental groups and the control group ($F(2, 120) = 6.47; p < .01; \eta^2 = .097$), and interaction also took place ($F(2, 120) = 6.18; p < .001; \eta^2 = .093$). To summarize, the study hypothesis as examined by the CMB tests was confirmed, as illustrated, the two experimental groups significantly improved from pre- to post-intervention measurement in four measures, while no such improvement was demonstrated for control group.

To summarize, the hypothesis of the study, as examined by the CMB tests was confirmed. As illustrated in Fig. 1, the two experimental groups significantly improved from the pre- to post-intervention measurement in three measures, while no such improvement was demonstrated for the control group.

4. Discussion

The findings of the present study show a clear and significant improvement from pre- to post-intervention in both measured executive functions – spatial perception and attention – in the two experimental groups, whereas no improvement was demonstrated in the control group in either of the executive functions. Such unequivocal results strengthen the research findings from the point of view of a variety of disciplines, including developmental psychology, kinesiology, cognitive neuroscience, and biopsychology, as reviewed by Best (2010).

The uniqueness of this study can be seen in the examination of two specific activities, each demanding spatial perception and attention in order to successfully achieve the tasks at hand (Jola et al., 2011; Oña, 2005). As in other studies (e.g., Enghauser, 2007; Jola et al., 2011; Ratey, 2008), the executive functions examined in our study enabled the young children to perform well in cognitive tasks.

Our results demonstrate that the orienteering group significantly improved in spatial perception compared with the dance group. Such a finding was expected, given that orienteering demands cognitive processes that are characterized by complexity, dynamism, uncertainty, and time constraints. Orienteering tasks require interpreting a situation and making decisions, while at the same time considering information provided by the natural environment and by the map representing that environment. Orienteers must continuously divide their attention between these two sources of information in order to make decisions, and make sure that they are consistent (Mottet & Saury, 2013).

In order to orienteer effectively, children have to acquire and enhance the ability to transform two-dimensional map representations into three-dimensional environmental objects, and they must repeat this activity many times while they orienteer. In addition, the children have to be attentive to a variety of objects scattered through the environment, such as stones, rocks, and plants, which require their attention and need an appropriate motor response.

While research using virtual reality is aimed at training participants in a variety of skills and abilities by simulating obstacles in the laboratory (e.g., Finkelstein et al., 2011; Man, Chung, & Lee, 2012), our study used orienteering in a natural context.
environment to enhance cognitive abilities. The dance group also improved executive functions as compared to their peers in the control group. Dance requires activities that combine motor and cognitive abilities, such as memorizing the order of steps, hand-feet coordination, congruency of movement to the rhythm of the music, matching movements with pairs and others, and understanding directions and positions in the space around them. Hence, an intervention that included practicing these abilities would naturally have the expected results.

We do not have an explanation for the phenomenon that Timing improved only when the stimuli came from the bottom of the screen. This might be incidental and certainly requires further study. Nevertheless, this result did have an effect on the overall study results.

Some limitations of this study should be mentioned. First, the interventions were administered by two professional experts who came to the kindergarten and provided activities that were additional to the kindergarten’s typical activity routine. We cannot be sure that at the participants’ young age, receiving nine weeks of additional activity of any kind could improve their executive functions, regardless of the specific chosen activities. Furthermore, it is possible that a professional kindergarten expert would be able to improve the children’s executive functions without any physical activity intervention. In the current study we did not monitor the influence of the regular kindergarten teacher, who might have had a considerable impact on the children’s improvement in addition to the influence of the kind of the activity. Additionally, it should be noted that we had pre-existing groups, since every classroom, as a whole, was assigned to one of the three groups. Nevertheless, the strength of our results relies on the fast and sharp executive functions improvement among the experimental groups compared to the control group.

In addition, a different version of the MOXO test was used for the orienteering group than for the dance and control groups. Even so, the fact that in both variations there was a clear and significant improvement in EF from pre- to post-intervention for the experimental groups (which used different variations), whereas no improvement was demonstrated in the control group (which used a similar variation to the dance group), highlights this study’s conclusions. Moreover, attentional and spatial perception training may enhance performance in young children, while minor variations in the different tests probably did not affect executive functions performance.

A major contribution of this study to the knowledge about children’s executive functions relies on the results regarding the fast improvement in both executive functions examined. While Betts, McKay, Maruff, and Anderson (2006) have previously observed and reported rapid development in sustained attention in children aged 5–6 years to 8–9 years, our findings showed that the examined activities not only enhanced cognitive function in a relatively short time, but also did it simultaneously (attention and spatial perception at the same time). These findings are consistent with van der Hama, Postmaa, and Laengc’s (2014) recent review, that indicated the important role attention plays as a part of spatial cognition. Still, the relationship between these functions should be researched further to assess the practical implications. For example, it would be interesting to explore the contribution of physical activity not only to the improvement of executive functions but also to the improvement of human’s everyday activities in a local space (such as acquiring language or controlling a keyboard), or in a global space (such as going home, or to other, unfamiliar places).

We do suggest that attentional and spatial perception training may enhance performance. In saying this, we refer specifically to children’s activities that are characterized by multiple and dynamically varying components, such as the activities chosen for this study. A question that remains unsolved in our study is whether the rapid improvement observed will be maintained or decrease, or if will it be easier to be further developed among groups that went through an intervention as opposed to the control group.

5. Conclusions

Our results mirror the effects found in other studies that examined the effect of physical activity on executive functioning among children (see Guiney & Machado’s review, 2013). However, previous research dealt with the question of whether aerobic or anaerobic, or acute or chronic, activity contributes to children’s executive functions (e.g., Best, 2010), whereas we examined physical activities that require specific abilities, and were in essence the examined executive functions. Moreover, unlike others (e.g., Memmert, 2006), we examined typical, normative children. Consequently, the applied recommendations of our study would be targeted to educators of the majority of young children. These should include specific activities designated for developing abilities that are required for their comprehensive development. In addition, we recommend that adults also adopt the kinds of activities that demand a combination of abilities, such as executive functions, since being active may slow down the deterioration of these functions over the years. Finally, it is recommended that future research be performed to determine the long-term effects of these interventions.

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**Sima Zach, Ph.D** Zach is the head of the School of Education in the Zinman College of Physical Education and Sport Sciences at the Wingate Institute, Israel. She is also the Director of Teacher Education Program. She is a graduate of the College and has been with the faculty since 1984. She earned her Ph.D from Temple University, Philadelphia, specializing in sport psychology. Her research interests are in sport psychology, physical education psychology, and psychology of leisure-time physical activity.

**Varda Inglis, Ph.D** Inglis is the academic assistant of School of Education in the College of Physical Education and Sport Sciences at the Wingate Institute. She has graduated from the college and has been with the faculty since 1987 while teaching in the educational system in Jerusalem. She earned her Ph.D from Bar Ilan University, Ramat Gan, Israel, specializing in humor research. Her research interests are in physical education, teacher education, psychology, and humor research.

**Orly Fox, Ph.D** Fox is a lecturer in the School of Education and in the School of Physical Education in the Zinman College of Physical Education and Sport Sciences at the Wingate Institute, Israel. She has graduated from the college and has been teaching there since 1985 while teaching in the educational system. She earned her Ph.D from Haifa University, Israel, specializing in learning disability. Her research interests are in long-term memory consolidation and motor learning especially regarding individuals with learning disability (particularly ADHD).

**Dr. Itai Berger, MD** Specialist in pediatrics and pediatric neurology. Serves as the Director of the Neuro-Cognitive Center, Pediatric Division at Hadassah-Hebrew University Medical Center, Lecturer in the Hebrew University School of Medicine. Primary clinical and research interests involve early brain development, the factors affecting it (both genetic and environmental), and the impact on long-term neuro-developmental outcome with special focus on cognitive (higher) functions. Address: The Neuro-Cognitive Center, Hadassah-Hebrew University Medical Center, Mount Scopus Campus, P.O.Box 24035, Jerusalem 91240, Israel. Tel: +972 2 584 4903; fax: +972 2 532 8963.

**Ayelet Shtahl** graduated from Zinman College. She is a professional dance teacher and teaches mainly in kindergartens. Address: Kibutz Kfar-Masarick, Israel.