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A post COVID lockdown pilot study on the effect of physical activity intensity on cognitive functions of children aged 6-8 years old

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ABSTRACT

Physical activity practice is very important for individual's wealth status. Moreover, it is possible to consider physical activity one of the teachers' tool to improve the academic achievement and the cognitive functions in children. However, according to some evidences it seems that the physical activity at high intensity increase the cognitive functions compared to the low intensity physical activity. In this project, we investigate how the intensity of physical activity affects a series of cognitive functions such as Attention and Working Memory. Eleven participants of a summer camp participated at the study. Three experimental weeks with different physical intensities were involved (Standard Intensity, High intensity and Low Intensity). Participants performed the cognitive tasks at the beginning and at the end of each experimental week. Our results indicated an effect of the physical activity intensity in some kind of attention. Working Memory instead, was not affected. Thus, our results suggested that intensity could be an important factor to increase some cognitive functions, but not all of them.

Keywords: Physical activity; High intensity; Low intensity; Attention; Working-Memory.

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INTRODUCTION

Physical activity practice is very important for individual's wealth status. When it is little or null, or when it is not allowed, as in the COVID-19 lockdown happened (Zhou, Yu, Du, Fan, Liu et al., 2020; Who, 2020), it can produce a negative relation with physiological and psychological functions and psychosocial aspects (Harridge & Lazarus, 2017; Paluska & Schwenk, 2000; WHO, 2018; Elward & Larson, 1992, Russo, Nigro, Raiola & Ceciliani, 2019). Moreover, it is possible to consider physical activity one of the teachers' tool to improve the academic achievement and the cognitive functions in children (Donnelly, Hillman, Castelli, Etnier, Lee, Tomporoski et al., 2016). Much research has been shown a positive relation between cognitive functions and physical activity. Several investigations have been summarized in reviews, systematic reviews and meta-analysis (Biddle, Stuart, Asare, Mavis, 2011; Biddle, Stuart, Ciaccioni, Thomas & Vergeer, 2019; Tomporowski, Lambourne & Okumura2011). These overviews highlighted physical activity has a role on several cognitive functions such as attention and working memory. However, authors agree with the fact that some studies have low quality design and especially the interventional and longitudinal ones. These issues may lead to a distorted data. Furthermore, in last years, researchers have focused their attention on the type and the quality of the physical activity proposed. Specifically, some investigations analysed the effect of different type of physical/sport activities on the cognitive functions (Gu, Qioan, Zou, Liye, Loprinzi, Paul, Quan, Minghui, Huang & Tao, 2019; Russo & Ottoboni, 2019) while others analysed how the different intensities of the physical activities affect the cognitive functions (Pesce, Crova, Cereatti, Casella & Bellucci, 2010). For instance, the majority of the studies found the activities that involves situational sport environments (open skills sport) like football and basketball (e.g. football and basketball) increase more the cognitive functions than not variable sport environments (closed skills sports) like running and biking. Moreover, according to other evidences it seems that physical activity at high intensity increases the cognitive functions compared to low intensity physical activity (Angervaren, Vanheesm, Wendel-Vos, Verhaar, Aufdemkampe, Aleman et al., 2007; Brown, Peiffer, Sohrabi, Mondal, Gupta, Rainey-Smith et al., 2012). However, the results are not so reliable and intervention studies are few, thus these topics are still matter of debate.

In the present research, we investigate how physical activity intensity affects a series of cognitive functions. In particular, during a post-lock down summer camp, children participate to several physical activities characterized by different levels of intensity. Specifically, in a week (Standard Week, SW), no suggestions were given to trainer about the intensity of the activities, in the other two experimental weeks, instead, trainers promote activities with high intensity (High Intensity Week – HIW) and low intensity activities (Low Intensity Week – LIW). At the beginning (pre-test) and at the end (post-test) of each experimental week, children performed four cognitive tasks. In particular, we tested the Working Memory Capacity (Auditory Digit Span Forward and Backwards, DS-F/B) and Attention (Posner Cueing task and Visual Search task). These abilities are particularly important in physical activity session because children should be able to remember a series of instructions (Working-Memory capacity) and they are trained to extrapolate the important piece of information when they play team games (Attention) (Furley & Memmert, 2010; 2015, Pesce & Bosel, 1998, 2001). In all the three weeks we expected differences between the test sessions (Pre and Post) where an increment cognitive functions tested should be recorded. However, a greater increment was hypothesised for the high intensity week compared to the post test of the other two experimental weeks. No differences were hypothesised in all Pre-test sessions of the three experimental weeks. Intensity of Physical activities were monitored through the subjective scale "The Children's Effort Rating Scale – CERT" (Lamb, 1996). At the end of the main sessions of each day physical activity, participants reported their effort. We expected an increment of the cognitive function on all the three experimental weeks, but a greater increment was hypothesised for the high intensity week compared to the post test of the other two experimental weeks.

Moreover, in all Pre-test sessions we hypothesised no-differences among the three experimental weeks were expected.

METHODS

Participants

Eleven (1 female) children participated at the experiment. Their age was between 6 and 8 years old (M = 6.83, SD = 0.82 yr..). The study was performed according to the Declaration of Helsinki. Permission for children's personal data processing and the informed consent were asked to parents.

The study was approved by the Association Board of the Summer Camp. Unfortunately, due to some absences, not all participants performed all the tests in the three experimental weeks (See Table 1).

Instruments

The children's Effort Rating Scale – CERT

In order to control the physical effort of the three type of intensities, the CERT scale (Lamb, 1996) was employed. In each day of the week, participants reported their physical effort in the main activities practiced.

Cognitive tasks

In order to analyse the Working Memory capacity and Attention, four cognitive tasks were involved in the study. Specifically, they were: Digit Span Forward and Backwards, Posner Cueing task (Chun, 2000) and the Visual Search task (Treisman, 1977; Treisman & Gelade, 1980). DS-F and DS-B were performed individually with one of the summer camp trainers.

Both Visual Search task (Treisman, 1977; Treisman & Gelade, 1980) Posner Cueing task (Chun, 2000) were programmed in Psychtoolkit (Stoet, 2010; 2017) and run on a Lenovo 80EW laptop, Intel Core i5, 2.20 GHZ, RAM 4 GB, OS: Windows 8.1 64 bit. Screen 15.6".

Experimental design

Games employed in the SW were a mixture of static and dynamic games and trainers did not follow any specific suggestions on how much the intensity should be.

In the HIW, trainers were asked to organize high intensity games. Moreover, free play time, trainers involved children in playing high intensity physical games such as football and basket matches as well as speed races.

On the contrary, in the LIW, trainers organized games that had a low level of physical activity. Moreover, in the free play time, trainer suggested to play card games or drawing.

Procedure

Each participant performed the *Auditory Digit Span Backwards* task individually with one of the summer camp's trainers. BS-F and BS-B required participants to memorize a sequence of digits presented verbally. Each digit was spelt within one second, while the inter-interval pause between two consecutive digits was of one second. The number of digits was incremental starting from a sequence of two. After each sequence, participants were required to tell the digits in the same (BS-F) or reserve (BS-B) order to the one they were presented to the participant. For both BS-F and BS-B, when participant was unable to remember one-digit sequence, another digit sequence of the same length was provided. If a participant was unable to remember

even this sequence, the test was interrupted and the last remembered digit sequence was scored among the data records.

Visual search and Posner Cueing task were performed in a silent place. The tasks were run on a laptop using the online software Psytoolkit (Stoet, 2010; 2017). Before to start the experiments, participants read the instruction If something was not clear, adult better explained the task. In the case of Visual Search task, they had to press the spacebar as quickly as possible if they looked a straight orange “T” among upside down “T”’s orange or blue coloured and straight blue “T”s. If there was not straight orange T, participants had top press nothing and wait for the next trial. In the Posner Cueing task, participants had to respond as quickly as possible when a green circle appeared. Two yellows boxes were presents at the right and at the left of median line of the screen. When green circle appeared in the left yellow box, participants had to press with key "a" on the keyboard. When the stimulus appeared in the right yellow box, the key “l” should be pressed on the keyboard. Moreover, participants were informed that in some trials, the green circle will be preceded by an "x" (Cue). They should not pay attention and they should not respond to it. One-hundred trials were presented and the 75% of them had a Valid Cue in which the Cue appeared in the same location of the green circle. The remaining 25% had Invalid Cue (appeared in the opposite site of the green circle) or the Cue was not shown.

Data analysis

In order to analyse physical effort, we created a linear mixed regression model with Dependent Variable the CERT value and the Independent Variable was the Type of Intensity (3 levels).

Linear regression analysis was performed for both Digit Span Forward and Backwards and for Physical fatigue. Specifically, for both DS-F and DS-B, the dependent variables were the last sequence of Digit remembered. Whereas the independent variables were Session (Pre and Post factor - 2 levels), and Type of Intensity (3 levels). The analysis was conducted examining the single factor Session and the interaction between the two independent variables. Linear mixed model regressions were performed to analyse Visual Search and Posner Cueing.

In the Visual Search task, the Dependent Variable was Reaction Time, while the Independent Variables were Session (Pre and Post - 2 levels), Type of Intensity (3 levels) and the Condition of the Trial (5 levels). We analysed the single factor Condition of the Trial and the interaction Type of Intensity X Session. Regarding the Posner cueing task, the Dependent Variable was Reaction Time while the Independent Variables were Session (Pre and Post-test – 2 levels), Type of Intensity (2 levels) and Cue Validity (Valid and Invalid, 2 levels). We analysed the interaction Session X Type of Intensity, and the triple interaction Session X Type of Intensity X Cue-Validity. For both Posner Cueing task and Visual Search task only correct responses were analysed.

RESULTS

Children Cognitive Effort Rating Scale - CERT

Data analysis revealed the single effect Type of Intensity was significant ($F(2, 8.65) = 304.04$, $p < .001$). Post-hoc analysis revealed participants reported a greater effort in HIW compared to SW and LIW ($t(10.3) = 7.15$, $p = .0001$, $M = 8.41$, $SE = 0.15$ VS $M = 6.78$, $SE = 0.18$; $t(10.1) = 24.17$, $p < .0001$, $M = 8.41$, $SE = 0.15$ VS $M = 3.07$, $SE = 0.19$, respectively). Moreover, the physical effort reported in SW was higher than LIW ($t(10.6) = 13.41$, $p < .0001$; $M = 6.78$, $SE = 0.18$ VS $M = 3.07$, $SE = 0.19$).

Digit Span – Forward – DS-F

Results on DS-F highlighted the single factor Session and the interaction Type of Intensity X Session were not significant (1, 32.1) = 0.61, p = .44; F (4, 32.1) = 1.76, p = .16, Figure 1).

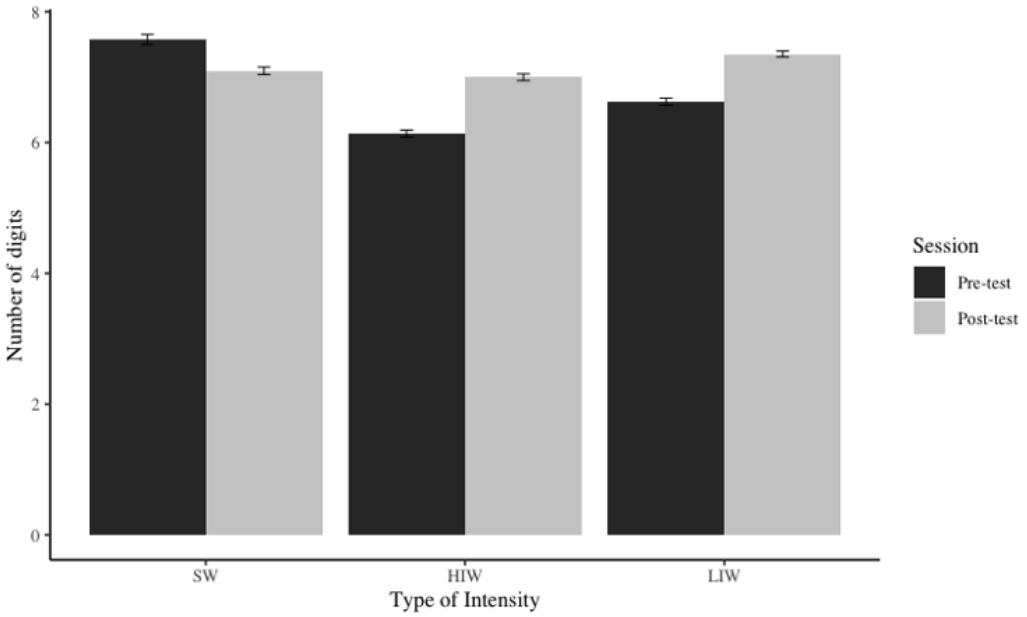

Figure 1. Means and error bars of the Pre and Post-tests results for DS-F task.

Digit Span – Backwards – DS-B

Analysis on DS-B revealed that both single factor Session and interaction Type of Intensity X Session were not significant (F (1, 32.22) = 0.13, p = .73; F (4, 32.32) = 2.24, p = .087, respectively, Figure 2).

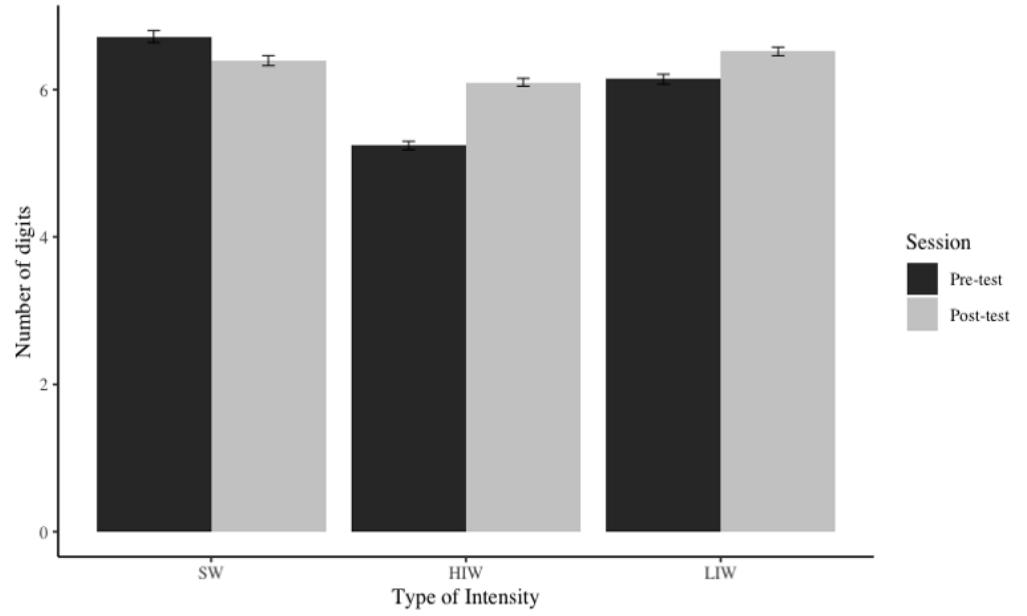

Figure 2. Means and error bars of the Pre and Post-tests results for DS-Backwards task.

Visual search task

The analysis on the single factor Condition of the Trial revealed significant differences among the five conditions (F (3, 186.83) = 45.43, p < .0001). Post-hoc analysis highlighted faster RTs for Condition with low number of T compared to the other four conditions as well as the RTs increased when T on the trial increased (See Table 2).

Interaction Type of Intensity X Session was significant (F (5, 191.75) = 34.42, p < .0001, Fig. 3). The post-hoc analysis on the differences between pre and post tests showed faster RTs for the post-test compared to pre-test in SW (t (192) = 7.071, p < .0001; M = 1880.72, SE = 46.49 ms VS M = 1444.56, SE = 40.21 ms). No RT differences in HIW and LIW (t (192) = 7.07, p = .32, M = 1343.46, SE = 35.41 ms VS M = 1213.82, SE = 30.70 ms; t (189) = 1.34, p = 1, M = 1343.88, SE = 51.29 ms VS M = 1288.91, SE = 42.87 ms, respectively) emerged (See Figure 3).

RTs were longer in pre-test SW compared to pre-test HIW RTs and LIW RTs (t (195) = 9.59, p < .0001, M = 1880.72, SE = 46.49 ms VS M = 1343.46, SE 35.42 ms; t (196) = 8.85, p < .0001, M = 1880.72, SE = 46.49 ms VS 1343.88, SE = 51.29 ms, respectively).

Analysis on post-test sessions revealed differences between SW and HIW (t (194) = 3.94, p = .001; M = 1444.56, SE = 40.21 ms VS M = 1213.83, SE = 30.70 ms) and between SW and LIW (t (196) = 8.85, p < .0001, M = 1444.56, SE = 40.21 ms VS M = 1288.91, SE = 42.87 ms). No difference between HIW and LIW were found (t (190) = .008, p = 1; M = 1213. 83, SE = 30.70 ms VS M = 1288.92, SE = 42.87 ms).

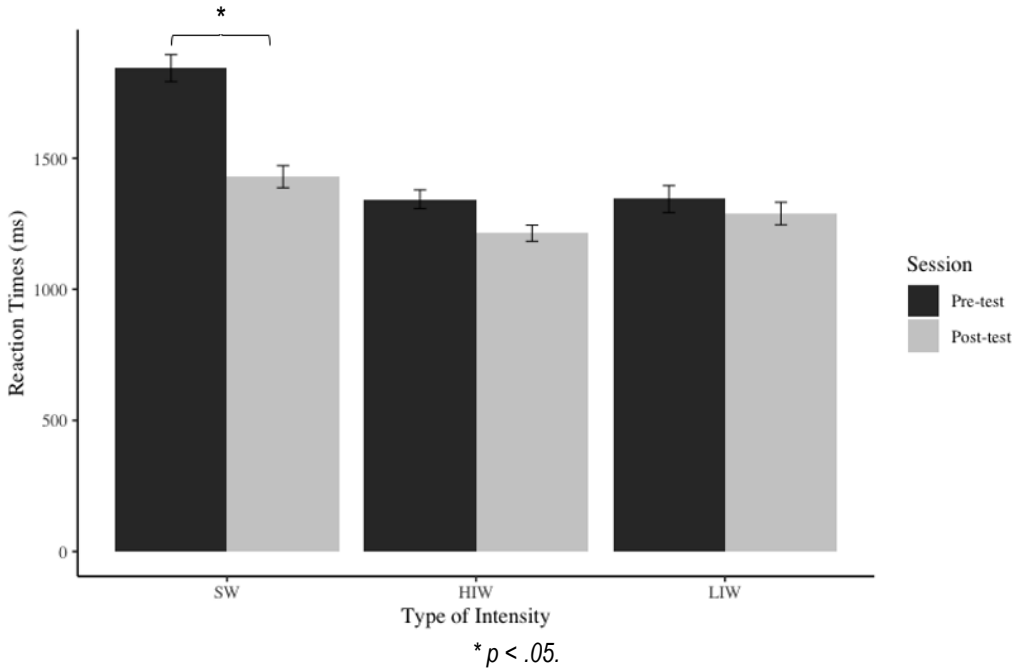

Figure 3. Means and error bars of the Pre and Post-tests RTs in the Visual Search task.

Table 1. Number of participants performed the tasks. Y= Yes.

Participant	WM-F						WM-B						Posner Cueing Task						Visual Search Task					
	SW		HIW		LIW		SW		HIW		LIW		SW		HIW		LIW		SW		HIW		LIW	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-Test	Pre-test	Post-test	Pre-test	Post-test
1	Y	Y	Y	Y			Y	Y	Y	Y			Y	Y	Y	Y			Y	Y	Y	Y		
2	Y	Y					Y	Y					Y	Y					Y	Y				
3	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
5	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
6	Y		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y		Y	Y	Y	Y
7	Y		Y	Y			Y		Y	Y			Y		Y	Y			Y		Y	Y		
8	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	
9	Y		Y	Y	Y		Y		Y	Y	Y		Y		Y	Y	Y		Y		Y	Y	Y	
10	Y		Y	Y			Y		Y	Y			Y		Y	Y			Y		Y	Y		
11			Y	Y	Y	Y			Y	Y	Y	Y			Y	Y	Y	Y			Y	Y	Y	Y

Table 2. Differences in RTs among the "T"s condition.

T Numerosity	RTs (Mean, SE, ms)	RTs (Mean, SE, ms)	t (df)	p-value
5 VS 10	1166.14, 30.00	1330.49, 28.88	3.22 (187)	= .007
5 VS 15	1166.14, 30.00	1542.56, 37.20	7.99 (187)	< .0001
5 VS 20	1166.14, 30.00	1694.40, 39.23	10.69 (187)	< .0001
10 VS 15	1330.49, 28.88	1542.56, 37.20	4.67 (187)	< .0001
10 VS 20	1330.49, 28.88	1694.40, 39.23	7.37 (187)	< .0001
15 VS 20	1542.56, 37.20	1694.40, 39.23	2.70 (187)	= .046

Table 3. Posner Cueing paradigm RTs of Invalid and Valid trials as a function of the Type of Intensity and Session.

Type of Intensity	Session	Invalid RTs (Mean, SE, ms)	Valid RTs (Mean, SE, ms)	t (df)	p-value
SD	1	644.37, 10.02	498.24, 7.08	7.08 (170)	< .0001
SD	2	664.47, 12.84	522.70, 8.31	8.78 (170)	< .0001
HIW	1	661.38, 10.02	518.90, 7.81	5.95 (170)	< .0001
HIW	2	598.62, 12.84	458.19, 5.82	7.71 (170)	< .0001
LIW	1	626.59, 9.57	512.91, 6.76	7.91 (170)	< .0001
LIW	2	700.80, 18.18	574.27, 9.98	6.04 (170)	< .0001

Posner Cueing Task

Analysis of Posner Cueing Task revealed significant interaction Type of Intensity X Session (F (5, 170.89) = 13.69, p < .0001) and the triple interaction Type of Intensity X Session X Cue Validity.

Post-hoc analysis on the Interaction Type of Intensity X Session (Fig. 4) test revealed that in SW, RTs were not different (t (171) = 0,29, p = 1, M = 529.93, SE = 6.39 ms VS M = 557.72, SE = 7.40 ms). In the HIW, participants were slower in Pre compared to Post test (t (170) = 5.68, M = 553.28, SE = 7.06 ms VS M = 487.96, SE = 5.39 ms). In low intensity week, instead, participants were faster in Pre compared to Post-test (t (170) = 3.53, p = .005, = 538.90, SE = 5.91 ms VS M = 601.53, SE = 9.02 ms, See Figure 4).

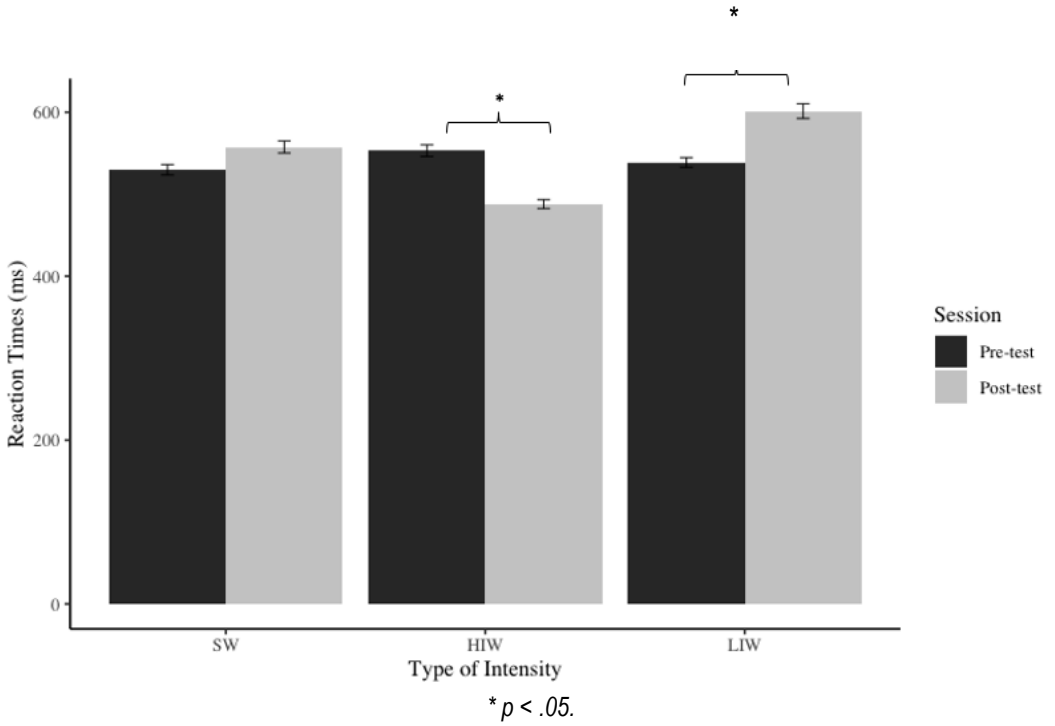

Figure 4. Means and error bars of RTs differences between Pre and Post-tests session in the three type of Intensity.

Analysis on differences among Pre-test sessions among the three intensities revealed no difference between SW and HIW (t (171) = 0.88, p = 1, M = 529.93, SE = 6.39 ms VS M = 553.28, SE = 7.06 ms). However differences between SW and LIW and between HIW and LIW and were found (t (172) = 3.61, p = .004, M = 529.93, SE = 6.39 VS M = 533.28, SE = 7.06 ms; t (170) = 3.25, p = .01, M = 553.28, SE = 7.05 ms VS M = 538.90, SE = 5.91 ms, respectively).

Analysis of differences among Post-test sessions revealed faster RTs for HIW compared to SW and LIW (t (171) = 6.08, p < .0001, M = 487.96, SE = 5.39 ms VS M = 557.72, SE = 7.40 ms; t (171) 5.45, p < .0001, M = 487.96 SE = 5.38 VS M = 601.53, SE = 9.02 ms, respectively). No differences between SW and LIW (t (171) = 0.42, p = 1, M = 557.72, SE = 7.40 ms VS M = 601.53, SE = 9.02 ms) emerged.

Triple interaction analysis revealed difference between valid and invalid trials in all the measurements. Specifically, children were faster in valid trial than invalid trial (see Table 2 and Figure 5).

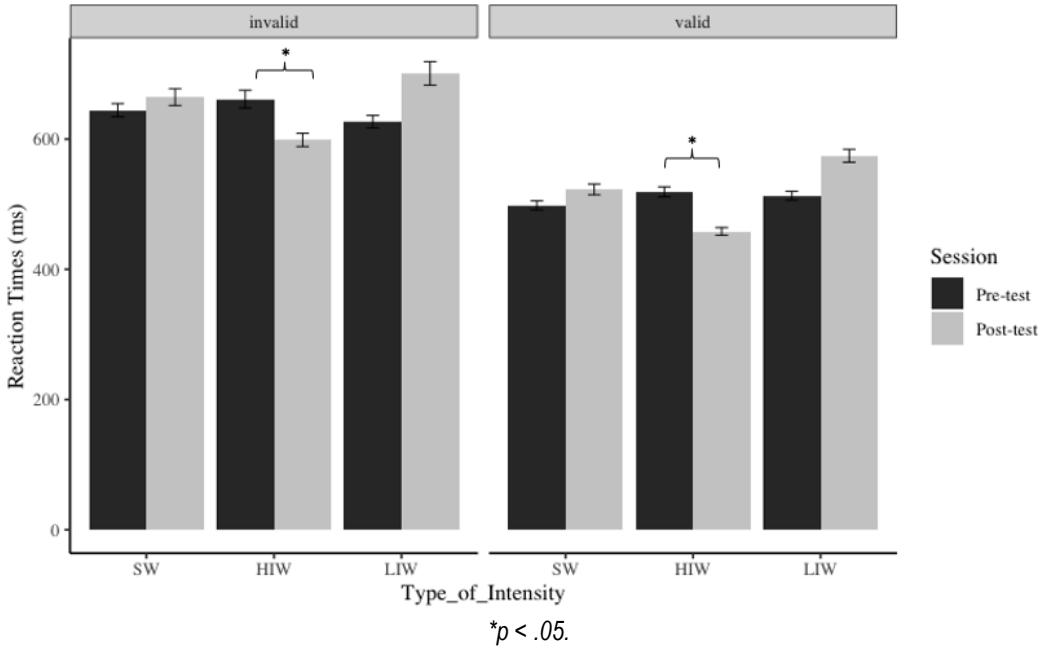

Figure 5. RTs means and their error bars for Invalid and Valid trials and the differences between Pre and Post-session.

Analysis on differences between the two test sessions for invalid and valid trials revealed some differences. Specifically, in invalid trial, no-differences between the two sessions in SW and LIW emerged ($t(170) = 0.52$, $p = 1$; $t(170) = 4.45$, $p = .08$, respectively), but in HIW children were faster in post-test session compared to pre-test session ($t(170) = 4.45$, $p = .0004$). Regarding valid trials, similar results were found. Specifically, in SW and LIW no difference between pre and post-tests emerged ($t(179) = 0.10$, $p = 1$, $t(170) = 2.1$, $p = 1$, respectively, Figure 5). In HIW participants were faster in post compared to pre-test session ($t(170) = 3.58$, $p = .011$).

In the Pre-test sessions, no differences in term of RTs between SW and HIW in invalid trials ($t(171) = 0.47$, $p = 1$) were found. Whereas differences in invalid trials between SW and LIW and between HIW and LIW emerged ($t(171) = 3.40$, $p = .02$, $t(170) = 3.31$, $p = .03$, respectively). In particular, RTs were longer in HIW compared to SW and LIW. Post-test analysis on invalid trials revealed differences between SW and HIW and between HIW and LIW ($t(171) = 4.99$, $p < .0001$; $t(170) = 3.87$, $p = .004$). In particular, RTs were short for HIW compared to SW and LIW.

In the pre-test sessions for valid trial no difference among the three type of intensity emerged ($t < 1.90$, $p = 1$). In valid trials Post-test sessions instead, difference between SW and HIW and between HIW and LIW emerged ($t(171) = 3.83$, $p = .004$; $t(170) = 3.96$, $p = .003$, respectively). HIW's RTs were shorter compared to SW and LIW. No differences between SW and LIW emerged ($t(170) = 0.25$, $p = 1$).

DISCUSSION

In the last years the relation between physical activity and cognitive functions has been widely studied both children and adults (Biddle et al., 2011; Biddle at al., 2019; Tomporowski, Lambourne & Okumura, 2011). Much research has been developed and the results were summarised in several meta-analysis, systematic

reviews and literature reviews (Biddle et al., 2011; Biddle at al., 2019; Tomporowski, Lambourne & Okumura, 2011). The results agreed with the fact that physical activity can increase the cognitive functions of children and adults. However, it seems that increment of the cognitive function could be due to only with some intensity of physical activities (Angervaren et al., 2007; Brown et al., 2012). Specifically, according to some research, high intensity physical activities may produce an increment of cognitive functions than low intensity ones (Brown et al., 2012).

In the present study we investigated the effect of physical activity intensities on different cognitive functions such as Working-Memory and Attention during a summer camp. According to our results on CERT it is possible to conclude that the experimental manipulation worked. Indeed, participants reported a higher effort in HIW compared to the other two experimental conditions as well as the physical of LIW was the smallest. Regarding cognitive functions analysed (e.g. Working-Memory and Attention) our results highlighted that both DS-F and DS-B were not affected by the intensity of physical activity in all the three experimental conditions as well as no effect emerged in the Visual Search task. Posner Cueing task results, instead, highlighted an effect of the physical activity intensity on the cognitive functions. Indeed, only in HIW children performed better in post-test than pre-test as well as the RTs were faster compared in post-test HIW compared to SW and LIW. Our results indicated an effect of the physical activity intensity producing an enhancement of some cognitive functions, but not for all those analysed. For instance, WM tasks revealed a moderate effect of physical activity. According to some research (de Greef, Bosker, Oosterlan, Visscher, Hartman, 2019), WM span should not be influenced by the acute physical activity thus if we consider our experiment as acute intervention our results are in line with previous investigations and the results supported the idea that acute physical activity and the related intensity does not increase the memory span. Differently, if we consider our intervention as chronic, it is possible to assume that the time is not enough to produce significantly increments of WM span. Regarding visual search results, it is very likely that task is characterised by low difficulty and low learning process of the task. To corroborate this hypothesis, it is possible to notice that there is a decrement of RTs in SW post-test compared to pre-test, while the other two experimental week the RTs were not different. This could be due to the learning effect, where in the firsts sessions participants were not confident with the task compared to the other sessions in which they learn how perform the task. Posner Cueing results, instead, revealed a clear effect of physical activity and its intensity. Probably, this task is characterized by higher difficulty compared to Visual search task, thus the learning process influenced less the performance. Our results suggested that it is possible to claim that the physical activity may enhance attention, but its intensity could be particularly important. Some evidences shown that adult athletes had better attentional skills than sedentary people (Pesce & Busel, 2001). Thus, it is possible to assume that when children are trained at high intensity, they should switch frequently their attention to the most important cues and consequently they increase their ability in a task such as the Posner Cueing task.

CONCLUSION

Physical activity is an important tool for the development of human cognition, however, not all cognitive functions are affected at the same level. Moreover, with the present research we give some suggestions for teachers and educator in developing physical education lessons: specifically, the high intensity activities should be promoted especially when time devoted to physical activity is scarce.

LIMITATIONS

Unfortunately, even if our study is interventional/longitudinal, due to COVID-19 limitations, the sample size was low, and we did not have the opportunity to recruit a control group. A next investigation with a large

sample size and with a control groups, when the COVID-19 restrictions no longer will be placed, will be performed.

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