Original Article

Influence of highly motivational games on the executive function in adolescence

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Abstract

Introduction Today moving seems to have become a serious problem and yet we are predisposed to motion and activity, we interact with our environment through movement. The motivation to persevere is not related to external rewards, but rather to intrinsically generated emotions, furthermore, chronic aerobic exercise induces changes in brain regions that are functional to Executive Function (EF) and is important as a mediator of exercise-induced neurogenesis. In light of this, the purpose of this study is to determine whether a high-motivation protocol game based on EF development is capable of influencing a sample of adolescents aged 13-14 years-old in a secondary school. **Material and Methods** A sample of 75 students (39 girls; 36 boys) aged 12 – 13 years-old were involved in the study. Subjects were divided into control (football) and experimental (EF games) groups. Both groups were assessed with the Free Recall test. **Results** The results suggested that a physical activity based on intensity, enjoyment, and cognitive engagement is useful and transferable to school practice, in this case particularly in memory. **Discussion** This study suggested that the amount of qualitative physical activity should be evaluated when assessing the effect of physical activity on cognitive function. Physical activity should include an adequate amount of high intensity and cognitive involvement useful and transferable to school practice. **Conclusion** Educational value of physical education, in the school context this movement should not be confined to just two hours of physical education or sporadic projects but, on the contrary, it could become a fundamental choice of the whole system, through forms of motor involvement during the intervals, in the home-school paths and the high contexts of teaching.

Key Words: Cognitive Training, Working Memory, Adolescence, Games, Deliberate Play, Physical Education

Introduction

Latin expression “*Mens Sana in corpore Sano*” commonly indicates the relationship between physical and mental well-being. This condition of well-being is attainable through sports practice and health routine. According to the results of a recent study (Guthold R., Stevens G.A., Riley L. M., et al. 2019), today's youngsters are mostly inactive: on average 80% of them perform (87% in Italy), less than one hour of physical activity per day, below what is expected by the World Health Organization (60 min/day)(McMahon E.M, Corcoran P., O'Regan G., et al. 2017). Today moving seems to have become a serious problem and yet we are predisposed to motion and activity, we interact with our environment through movement. The school, as an educational place, should contribute to the lowering of this percentage, educating and promoting a healthy lifestyle, in which motor activity plays a fundamental role (Pesce C., Crova C., Cereatti L., et al. 2009; Håvard, L., Haga, M.,&Sigmundsson, H. 2020). Weekly hours of physical education (2h/week in Italy) certainly do not solve the problem of the physical inactivity of Italian adolescents, but maybe enough to convey the idea that the right dose of daily movement, carried out at a correct intensity (Pesce C., Faigenbaum A., Crova C. et al. 2013) leads to benefits not only at a physical level (Tomprowski, P. D., Davis, C. L., Miller, P. H., et al. 2008) but also a relational-cognitive level MandolesiL. (2017). The motivation to persevere is not related to external rewards, but rather to intrinsically generated emotions (Tomprowski P.D., McCullick B, Pendleton D.M., et al. 2015). To facilitate this transition, teachers should offer learning experiences that maintain the unique characteristics of free play, which at the same time go in the direction of organised and goal-oriented activities. For this to happen, the proposals should be appropriate to age and develop fundamental motor skills and cognitive characteristics must guarantee challenging and problem-solving situations. In previous years, it has highlighted the interest in the development of cognitive skills of the child through games and playful experiences. The survey focused in particular on the possibility of transference to other learning areas (Diamond A. & Lee B., 2011). The potential of transference in games based on motor activity is intrinsic to their nature. The movement game is based on

understanding, not on memorising rules (Giuriato M. & Lovecchio N. 2019). The more the child organises and restructures learning experiences, the greater the transfer will be. Games promote abstract knowledge, which in general situations these strategies can be used in different contexts (Pesce C., Marchetti R., Motta A., et al. 2015; Tomporowski, P. D., & Pesce, C. 2019). Furthermore, they create challenges that children will face, a cognitive challenge that should always be incremental (Diamond A., 2013) and at the same time adapted to the level of development of the child's ability (Pesce C., 2013; Diamond A., 2000) presented a description of several areas of research that suggest a narrow neuronal link, and a remarkable activation of the cerebellum, with complex and coordinated movement, concluding that the cerebellum seems to be important for complex cognitive functions as well as complex motor functions (Schmahmann J.D., 2019). Chronic aerobic exercise (i.e. football) also induces changes in brain regions that are functional to learning and memory (Best J.R., 2012) and it is important as a mediator of exercise-induced neurogenesis.

The developing brain "decides" to use and strengthen the most stimulated pathways and to "abandon" those not kept active. After the first phase of maximum production of the neurons (proliferation), one falls into a period of neuronal death (pruning) (Tomporowsky et al., 2015), and the neurons that made the connection between them proliferate and develop (synaptogenesis), however, the others die. In particular, Best (2012) suggests that exercise provided neuronal activation which, when combined with a challenging context, leads to robust and stable neurogenesis in the brain centers of learning and memory. From this, it is deduced that physical exercise in a complex and social environment, such as group games or team sports, can lead to greater morphological changes than an exercise in simpler contexts, such as walking or running (Berger N., Lewis D., Quartagno M., et al. 2020). From this it emerges that the preadolescence, can provide an opportunity to improve and maintain the fundamental capacities of movement of long duration, that would otherwise be canceled. Another intrinsic characteristic of the game is enjoyment, which seems to influence the development of EF (Diamond A., 2017). When having fun, the brain releases lipid mediators, endogenous cannabinoids, which in turn activate the ventral tegmental area of the brain. This area is the source of the dopamine that projects in the prefrontal cortex, which has the effect of making people more motivated and available for work. The purpose of this study is to determine whether a high-motivation protocol game based on EF development is capable of influencing a sample of adolescents aged 13-14 years-old in a secondary school; especially on specific working memory processes through physical education hours.

Table 1. Executive Function in children: tasks for children (Pesce et al., 2015)

EXECUTIVE FUNCTIONS	SIMPLE	TASK COMPLEX
INHIBITORY CONTROL	Simple tasks of inhibiting control	Keep in mind a rule and act upon it by inhibiting a response
WORKING MEMORY	Keep in mind some information over time	Keep information in mind, manipulate and update it
COGNITIVE FLEXIBILITY	Form an arbitrary association stimulus-answers, then move on to another	Moving from a stimulus-response association to another one shifts the focus on different sizes of stimuli

Material & methods

Participants

The study was conducted in four classes of a secondary school in Verona, on a sample of 75 students (39 girls; 36 boys). All students were healthy between the ages of 12 and 13. The parents (or legal guardians) gave written, informed consent after having received a detailed explanation of the study procedure and possible risks. The study protocol was conducted by current national and international laws and regulations governing the use of human subjects (Declaration of Helsinki II). The research took place from November (PRE) to December (POST). The subjects were involved in three weeks of the protocol (2 times/week). The first session was preceded by a familiarisation session in which the activity was presented.

Procedure

To evaluate memory the Free recall test was used (Nielson K.A., Radtke R.C., Jensen R.A., 1996). The test provides six lists of 20 entries each, for a total of 120 words in English, taken from (Paivio A., Smythe P.C., & Yuille J.C., 1968). The lists were made following the guidelines of Nielson et al. (1996) and Pesce et al., (2009). The test protocol is summarised in Figure 1.

Both in PRE and POST, the re-enactment test was carried out under three different conditions:

- First Hour (FH) of the morning, as soon as the pupils arrived at school,
- Physical Education (PE) at the beginning of the fourth hour after the lesson of PE
- Frontal Lessons (FL) at the beginning of the fourth hour after lectures.

Figure1. Free recall test protocol(Pesce et al., 2009)

Test protocol

The four classes involved in the research were divided into one:

- Control group: the motor activity carried out for four weeks by the control group was mainly based on activities under the annual work plan, namely exercises on the fundamentals of football, only the final part of the lesson was dedicated to the game activity
- Experimental group: have followed lessons based on the model of lesson proposed in accord with the guideline of Biino V. (2018). The protocol it was based on motor skills (run, kick, throw, grab, ability to react, speed, dexterity), cognitive function (working memory, inhibition, flexibility), life skills (self-awareness, decision making, problem-solving, effective relationships, teamwork), EF (mental control, working memory)

The Free-recall test was preceded by a familiarisation session, during which the experimental procedure was explained, through the execution of the entire memory test, just as it would have been performed during the subsequent research sessions.

During each session, a different word list was used to reduce the effects of learning that could occur with the use of a single list for all sessions. However, to reduce potential threats to internal validity arising from the use of six different word lists, the same list was not used for all classes during the same session type. The assignment of word lists and session type to each class was randomised.

Statistical analysis

The data were analysed with SPSS vers 25. The possible differences between PRE and POST intervention were analysed through the T-test. Later, given the nature of the variables (discrete), to compare the results of the two groups (control, experimental), for analysis among the items of memory test (immediate recall task: primacy and recency; delayed recall task: primacy, recency) and the moments in which it was performed (1° now without physical education; now after physical education; 3° hour after lectures) the Friedman test was used (non-parametric) and the corresponding post-hoc (Wilcoxon). The statistical significance has been set at $p: 0.05$

Results

Pre – Post

The comparison between PRE and POST through the T-test suggests that after the First Hour (FH), there is no significance. After the hour of Physical Education (PE) a significance emerges in recency item ($p=.02$) of the experimental group is delayed task in the POST. Finally, the PRE-POST comparison after the Frontal Lessons (FL) reveals a significant difference in support in primacy items of the experimental group in the POST both in immediate ($p=.01$) and delayed ($p=.00$) task.

Control group

The comparison through the Friedman test suggests a significance within the control group particularly a significant difference was found in the primacy item during the delayed task (Figure 2) ($p=.003$), the post hoc test revealed a significant difference between PE and FH ($p=.034$) and between PE and FL ($p=.017$) in favor of the condition EF concerning both conditions: FH ($p=.034$) and FL ($p=.017$). A significant difference was found in recency item during the immediate task (Figure 3) ($p=.025$) the post hoc test reveals a significant difference in primacy item in the delayed task between PE and FL ($p=.009$). Furthermore, recency item in the delayed task it

was found significant (Figure 3) ($p=.017$), the post hoc test suggested a difference between PE and FH ($p=.019$) and between FL and PE ($p=.013$)

Figure2 Task of free recall test of Control group – primacy item

Figure3 Task of free recall test of control group – recency item

Experimental group

The analysis of the experimental group reveals a significance among the recency item in the immediate task (Figure 4) ($p=.0012$), in particular, the post hoc test reveals a significant difference between PE and FH ($p=.013$); while in the recency item during the delayed task emerged a significance (Figure 4) ($p=.002$), the post hoc test suggest a difference between PE and FH ($p=.004$); and between FL and PE ($p=.0049$). A significant difference was found, in the primacy item during the delayed task (Figure 5) ($p=.05$), the post-hoc test suggested that exists a significative difference between FH and FL condition ($p=.003$).

Figure 4 Task of free recall test of experimental group – recency item

Figure5. Task of free recall test of experimental group – primacy item

Discussion

The objectives of this study were to assess whether PE has beneficial effects on the memorisation processes and to determine whether these processes were influenced positively by games. The first and last words of a list to be memorised are those that are best remembered, compared to the information in the middle of the list, according to an ad U function. This advantage has been defined respectively, primacy effect (long-term memory) and recency effect (short-term memory) (Atkinson R. & Shiffrin R., 1968). However, explaining the effect of recency only in terms of the availability of information in short-term memory is not entirely correct, considering that in this study in line with Pesce et al., (2009) the positive effects of recency have emerged both in the control group (football) (Figure 3) and in a more accentuated form in the experimental group (high motivated games) (Figure 4) during the delayed recall task, where the memory has been disturbed by the interferences of the discussion in class, which did not allow reiterating the word for a time necessary for stabilization in memory (Tan L. & Ward G., 2000). According to some studies, this positive effect of the PE before the task of memory depends on the physical effort in physical activity that causes an increase in physiological activation which, facilitates the consolidation in working memory (Nielson et al., 1996). The physiological activation and the increase of available mental resources, induced by the physical exercise also verified during childhood (Cereatti L., Casella R., Manganelli M. et al. 2009), shorten the consolidation time, favoring the faster passage in the long-term memory. Also, in the recency item during the immediate task, the results were better when the test was preceded by the EF lesson, regardless of the type of activity (experimental: high motivated games; control: football). Furthermore, Pesce et al, (2009) found that only motor activities with cognitive and interaction characteristics had resulted in statistically significant improvements.

Conclusions

The results of this study suggested that the amount of qualitative physical activity should be evaluated when assessing the effect of physical activity on cognitive function. Physical activity should include an adequate amount of high intensity and cognitive involvement useful and transferable to school practice. Moreover, enjoyment is among the main reasons why individuals, at all ages, engage in motor and sports activities. In particular, enjoyment is the central component of intrinsic motivation (VazouS. & Smiley-Oyen A., 2014; van den BergV., Singh A.S., KomenA. et al., 2019; Have M., Nielsen J.H., Ernst M.T, 2018). Stimulating enjoyment within physical education programs can increase arousal and thus active participation. The football lessons (control group) and high motivated games (experimental group) have favored active participation in this search and have motivated perseverance in the engagement. Unfortunately, many of the physical education interventions on executive functions are focused only on the improvement of aerobic efficiency, ignoring the powerful emotional factors. These results suggested the existence of an exercise-induced benefit when it is based on a high-intensity aerobic component, complex coordinative skill, and enjoyment, which translates into the practical application for a greater availability on the part of pupils to store the information of the next class time after the PE time. It can, therefore, be concluded that, given the educational value of physical education, in the school context this movement should not be confined to just two hours of physical education or sporadic projects but, on the contrary, it could become a fundamental choice of the whole system, through forms of motor involvement during the intervals, in the home-school paths and the high contexts of teaching.

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The contribution is the result of a joint work by the four authors and the result of their common reflection, however V.B. wrote Discussion and Conclusion, L.B. wrote Material and Methods and Results included part of statistical analyses; P.R. collected the data; M.G. wrote Introduction and part of statistical analyses

References

- Guthold R., Stevens GA., Riley LM., et al. (2019) Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants, *Lancet Child Adolesc Health*; 4: 23–35.
- McMahon EM, Corcoran P., O'Regan G., et al. (2017) Physical activity in European adolescents and associations with anxiety, depression and well-being. *Eur Child Adolesc Psychiatry*.26(1):111-122. doi:10.1007/s00787-016-0875-9
- Pesce C., Crova C., Cereatti L., et al. (2009). Physical activity and mental performance in preadolescents: Effects of acute exercise on free-recall memory. *Mental Health and Physical Activity*, 2: 16-22.
- Håvard L., Haga M., & Sigmundsson H. (2020) Effect of different exercise modes at high intensity on immediate learning and arousal, *International Journal of Sport and Exercise Psychology*, 18:1, 33-45,
- Pesce C., Faigenbaum A., Crova C. et al. (2013). Benefits of multi-sports physical education in the elementary school context. *Health Education Journal*, 72, 326 – 336.
- Tomprowski PD., Davis CL., Miller PH., et al. (2008). Exercise and children's intelligence , cognition, and academic performance. *Educational Psychology Review*, 20, 2008,111–131.
- Mandolesi L. (2017). *Handbook of general sports psychology*. Il Mulino.
- Tomprowski PD., McCullick B., Pendleton DM., et al. (2015). Exercise and children's cognition: The role of exercise characteristics and a place for metacognition. *Journal of Sport and Health Science*, 4:47-55, 2015. 21.
- Diamond A. & Lee K. (2011) Interventions shown to aid executive function development in children 4 to 12 years old. *Science*. 2011;333(6045):959–964. doi:10.1126/science.1204529
- Giuriato M. & Lovecchio N. (2018) Cognitive Training in Soccer: Where Is the Key Point?. *Open Access Library Journal*, 5, 1-6. doi: 10.4236/oalib.1104333.
- Pesce C., Marchetti R., Motta A, et al. (2015). Joy of moving. Movement and Imagination. Calzetti Mariucci editori.
- Tomprowski PD., & Pesce C. (2019). Exercise, sports, and performance arts benefit cognition via a common process. *Psychological bulletin*, 145(9), 929–951.
- Schmahmann JD. (2019) The cerebellum and cognition. *Neurosci Lett*; 688:62-75.
- Berger N., Lewis D., Quartagno M., Njagi EN., & Cummins S. (2020). Longitudinal associations between neighbourhood trust, social support and physical activity in adolescents: evidence from the Olympic Regeneration in East London (ORiEL) study. *Journal of epidemiology and community health*, jech-2019-213412. Advance online publication.
- Diamond A. (2013). Executive Functions. *Annual Review of Psychology*, 64: 135-68.
- Diamond A. (2000). Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. *Child Development*, 71, 44–56.
- Diamond A. (2017). What characteristics might physical activities need so they yield the most benefit to executive functions? Unpublished oral presentation presented at International Seminar & Workshop University of Rome – Foro Italo.
- Best JR. (2012). Exergaming immediately enhances children's executive function. *Developmental psychology*, 48(5), 1501-1510.
- Nielson KA., Radtke RC., Jensen RA. (1996). Arousal-Induced Modulation of Memory Storage Processes in Humans. *Neurobiology of Learning and Memory* 66: 133-142.
- Paivio A., Smythe PC., Yuille JC. (1968). Imagery versus meaningfulness of nouns in paired-associate learning. *Canadian Journal of Psychology/Revue canadienne de psychologie*, 22(6), 427–441. <https://doi.org/10.1037/h0082782>
- Biino V. (2018). Playfully on the move. Calzetti e Mariucci editori.
- Atkinson R. & Shiffrin R. (1968). Human memory: A proposed system and its control processes. *The Psychology of Learning and Motivation: Advances in Research and Theory*, vol. 2, New York, Academic
- Tan L. & Ward G., (2000). A recency-based account of the primacy effect in free recall. *J Exp Psychol Learn Mem Cogn*. Nov;26 (6):1589-625.
- Cereatti L., Casella R., Manganelli M. et al. (2009), Visual attention in adolescents: facilitating effects of sport expertise and acute physical exercise, *Psychology of Sport and Exercise*, 10, 136-145.
- Vazou S. & Smiley-Oyen A. (2014). Moving and academic learning are not antagonists: acute effects on executive function and enjoyment. *Journal of Sport and Exercise Psychology*, 36(5), 474-485.
- van den Berg V., Singh AS., Komen A., Hazelebach C., van Hilvoorde I., Chinapaw M. (2019). Integrating Juggling with Math Lessons: A Randomized Controlled Trial Assessing Effects of Physically Active Learning on Maths Performance and Enjoyment in Primary School Children. *International journal of environmental research and public health*, 16(14), 2452
- Have M., Nielsen JH., Ernst MT., Gejl AK., Fredens K., Grøntved A., Kristensen PL. (2018). Classroom-based physical activity improves children's math achievement - A randomized controlled trial. *PLoS one*, 13(12), e0208787.