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MOTOR COMPLEXITY AND LOGIC-MATHEMATICAL ABILITIES: PROPOSAL FOR INTERVENTION ON A VISUALLY IMPAIRED SAMPLE

ATTIVITA' MOTORIA COMPLESSA E ABILITA' LOGICO-MATEMATICHE: PROTOCOLLO DI INTERVENTO PER UN CAMPIONE CON DISABILITA' VISIVA

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Abstract

The interest of research focuses on the possibility of exploiting the benefits of complex motor activity on learning and cognitive development in a sample of children with visual impairment.
Scientific pieces of evidence point to the onset of certain difficulties in the cognitive development of children with visual impairment, particularly in the processes of seriation and classification. (Tobin, 1972; Warren, 1984; Macesic-Petrovic, 2010).
The analysis of the literature was made by comparing the benefits of aerobic activity and complex motor activity on cognitive functions, and subsequently, it was hypothesized that complex motor activity involves a greater benefit on mental functioning because coordination between thoughts and movement that characterizes it, makes the improvement more lasting in time and space. In order to do this, we propose an intervention protocol, which includes an evaluation with OLC TEST, at the beginning, at the end and in a third time, of the cognitive abilities concerning elementary logical operations, therefore tasks that include the activities of seriation and classification. The protocol provides for the insertion of three groups that will practice aerobic activity G1, complex motor activity G2, the third group will not practice any activity. The assessment will take place in 3 steps: T0 before the beginning of the protocol, T1 after 6 months of training and T2, 6 months after the end of workout.

L'interesse della ricerca verte sulla possibilità di sfruttare i benefici dell'attività motoria complessa sull'apprendimento e sullo sviluppo cognitivo in un campione di bambini con disabilità visiva.
Evidenze scientifiche indicano l'insorgenza di alcune difficoltà nello sviluppo cognitivo dei bambini con disabilità visiva, in particolare nei processi di seriazione e classificazione. (Tobin, 1972; Warren, 1984; Macesic-Petrovic, 2010).
L'analisi della letteratura si è focalizzata sul confronto dei benefici dell'attività aerobica e dell'attività motoria complessa sulle funzioni cognitive. Successivamente si è ipotizzato che l'attività motoria complessa comporti un maggior beneficio sul funzionamento mentale perché la coordinazione tra pensieri e movimento che la caratterizza, rende il miglioramento più duraturo nel tempo e nello spazio. Basandosi sui risultati emersi da alcuni studi in letteratura, viene proposto un protocollo di intervento che prevede l'inserimento di tre gruppi di bambini che praticheranno attività aerobica (G1), attività motoria complessa (G2), il terzo gruppo non praticherà alcuna attività (G3). La valutazione delle operazioni logiche elementari, quindi compiti che comprendono le attività di seriazione e classificazione, avverrà attraverso l'OLC TEST, avverrà in 3 fasi: T0 prima dell'inizio del protocollo, T1 dopo 6 mesi di allenamento e T2, 6 mesi dopo la fine dell'allenamento.

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Keywords:
Motor complexity, logic-mathematical abilities, visual impairment.
Attività motoria complessa, abilità logico matematiche, disabilità visive.

1. Introduction

During early childhood, the child knows the world through the sensory-motor channel, knowledge is therefore linked to the possibility of sensory and motor exploration of the environment. Interaction with the environment, made by the child throughout the body allows learning experiences, through which knowledge is acquired. This happens also thanks to the activation and choral integration of all sense organs at the moment of stimulation and consequent assimilation and internalization of the stimulus. In visually impaired children, environmental exploration lacks the choral aspect of the activation of sense organs, which is essential to making the exploration itself a moment of knowledge construction. Scientific evidence points to the emergence of some difficulties in the cognitive development of children with visual impairment (Tobin, 1972; Warren, 1984; Macesic-Petrovic, 2010), in particular limitations in elementary logical operations such as classification and serialization, which are components of numerical-mathematical intelligence (Macesic-Petrovic, 2010). Classification is the process of bringing together objects, visual elements or symbols according to their characteristics and dividing them into groups. Children learn to establish associations between similar objects through classification. The ability to classify, which is the basis of the concept and operation of the number, is also the prerequisite for the ability to compare and count (Platz, 2004; Smith, 2006) and necessarily involves experience and interaction with the environment. Serialization, on the other hand, is the process of ordering two or more objects, according to particular characteristics (Platz, 2004; Reys et al., 2009; Smith, 2006) These difficulties are the result of the quality of the experience acquired by visually impaired children, inasmuch as the nature of the concepts acquired by the individual depends to a large extent on the quality of the experience in the environment (Tobin, 1972; Warren, 1984). The limitations resulting from the child's disability thus lead to difficulties which become pervasive in the child's mature development and have a negative impact on his or her quality of life. Some research has shown that children develop greater cognitive and physical abilities through their sensory-motor interactions with the environment, which are identified with a greater capacity for conceptualization (Gibbs, 2006). In addition, Bornstein highlighted the link between advanced motor skills and exploratory behavior in childhood, the characteristics of which are correlated with positive academic outcomes (Bornstein et al., 2013). The importance of being active in the environment, particularly in the development phase, is evident, not only quantitatively but also qualitatively, in order to become protagonists of one's own experience. The visually impaired child builds the concepts of the world based on other senses to compensate for the missing sense of vision. The resulting limitation stems precisely from the fact that in the construction of concepts, experience and visual information are essential (Macesic-Petrovic, 2010). Based on what emerged from the literature review, the interest of the research stems from the desire to respond concretely to the difficulties encountered in children with visual impairments.

Sport is widely proven to be a major factor influencing learning processes. Exercise improves cognitive performance due to the strong neuronal connection between the cerebellum, which is responsible for motion, and the frontal cortex, which is largely responsible for cognitive functions (Budde, 2008). In addition, physical exercise promotes brain plasticity, an essential

skill for learning and cognitive development. We have seen how the difficulties of visually impaired children lead to a limiting experience of the world that involves smaller and qualitatively lower interactions with the environment than peers without visual impairment. The interest of the exploratory analysis has therefore focused on the benefits that motor activities of different kinds can have on learning, in order to define an intervention protocol that can support visually impaired children in learning the logical-mathematical abilities, which are more critical in this population group. On this basis, the research project has two main objectives. The primary objective is to investigate the relationship between the practice of a complex motor activity, which involves multi-limb activation, the activation of learning processes and the use of problem solving and decision-making strategies that require significant top-down control, and the consequent cognitive activation, in the specific domain of logical-mathematical abilities, within a sample of subjects with visual disabilities.
The secondary goal, which is necessary in order to complete the investigation, is the validation of the Vianello OLC test (Vianello R. et al., 1991), for the evaluation of logical and conservation thinking, for able-bodied children from four to seven years and eleven months, on a sample of visually impaired people.
The OLC test provides quantitative references on the level reached by the child in logical thinking both in terms of mental age and in terms of IQ (and its deviation). Through twenty-four tests of increasing difficulty, the areas of serialization, numbering, classification and conservation are considered.
On the basis of what has been said, we want to evaluate how aerobic and complex motor activity respond to the difficulties encountered by blind children, in terms of cognitive implementation, duration in time and space of any improvements deriving from physical activity and in terms of the possibility of generalization and therefore the transfer of cognitive improvement even outside the context in which it occurs, meaning that of training.

2. Learning and visual impairment

The interest of the research is to contextualize the cognitive dimension of motor activity, within a population with visual impairments.
According to Piaget's theory, concerning the cognitive development of the child, the concrete operative stage is the phase in which a series of complex cognitive functions are acquired, including the use of reversible mental operations, which in this stage are still very concrete operations, immediately applicable and relevant in the possibility of interaction. By concrete operations, the author means all mental processes performed on material and perceptible, non-abstract content, or manipulable objects (Piaget, 1973).
It is in this phase that operative thinking develops, therefore a thought thanks to which the child is able to perform mental operations of a certain complexity. Reference is made to logical but concrete operations, such as adding, subtracting, dividing, classifying, sorting, equating and matching, based on tangible data (Piaget, 1973).
It is always at this stage that the child begins to have the capacity to preserve the quantity, he is therefore able to understand that the quantity, for example, of a liquid remains the same even if the container is changed. This ability is also to be understood as a prerequisite for learning mathematics, as conservation is a necessary condition for arithmetic thinking. All these skills are the basis of mathematical calculation and these same skills are the ones that are lacking in children with visual impairment.
On the basis of a first analysis of the literature carried out, aimed at investigating the difficulties encountered by the children under examination, regarding cognitive functions, the research aims to investigate the relationship between motor activity and learning, already extensively

investigated in samples of able bodied, specifically by doing reference to the logical and mathematical abilities of visually impaired children.
The analysis of the literature that followed was made on the basis of a parallelism between aerobic motor activity and complex motor activity.

2.1 Aerobic motor activity

The literature widely suggests the positive influence of physical activity on cognitive functions. The influence on cognitive functions is linked to the basic concept according to which motor activity involves physiological activations in terms of increased blood flow, increased cerebral oxygenation, thus favoring the processes of synaptogenesis and neurogenesis. On the basis of this foundation, several studies have been conducted analyzing the variable of movement in association with cognitive functions and also specifically with logic-mathematical abilities.
Hillman's experiment (Hilmann et al., 2008) provides an example of a quantitative intervention based on aerobic exercise. In the experiment, 20 children (average age: 9.5 years) performed a modified Flanker Test and a school performance test after 20 minutes of sitting exercise or rest. The exercise involved solitary treadmill walking at 60% of the child's estimated maximum heart rate, which presumably did not require significant mental effort, as the child's only requirement was to maintain a certain walking pace. The results showed greater precision of response after exercise, suggesting an improvement in inhibitory control, and a selective improvement in children's performance on the Wide Range Achievement Test.
Also from the Donnelly study (Donnelly JE. Et al., 2011), a cognitive advantage emerged, following the integration of physical education hours in schools. The survey found that adding 90 minutes of moderate to vigorous physical activity during the weekly school hours in 10-minute sessions leads to improved results in specific math, reading, spelling and composition tests over the period of three years in primary school children.
Another example of improvement in cognitive functions resulting from the integration of motor activity in physical education programs is provided by Reed and coll., (Reed et al., 2010).
The study, done on a sample of 155 elementary school students, showed how integrating 30 minutes of physical activity into the school timetable for three days a week over a four-week period leads to an improvement, compared to the control group, on standardized tests of humanities and social subjects, as well as a positive correlation with fluid intelligence that defines the ability of abstract and fast reasoning. The Davis study (Davis, 2011) also showed a positive impact on cognitive functions, following an increase in motor activity. The study was conducted on boys aged 7 to 11, divided into 3 groups (a control group, a group with 30 minutes of daily aerobic activity and a third group with 40 minutes of daily aerobic activity) showed a positive correlation between increased aerobic activity, 40 minutes, and better results in math but not in the mother tongue.
Several studies then specifically investigated the improvement in logical-mathematical skills, as a result of the performance of motor activity.
A study by Sanchal (Sanchal A. et al., 2017) investigated the impact on students' attitudes towards mathematics when it is acquired in a sports context. In this study, students' attitudes included their confidence, math awareness, and commitment. The study suggests that when students learn mathematics within a physical exercise context, the constructs of awareness, trust and commitment regarding the subject increase.
The same integrated approach between teaching mathematics and physical exercise was considered by Jansen et al. (Jansen et al., 2020), who examined the relationship between sport activities, spatial and mathematical skills in primary school children. The research sample carried out spatial and sporting tasks, which can be differentiated into: intrinsic-dynamic,

intrinsic-static and extrinsic-static. Performance in mathematical skills (separated into numerical / arithmetic and geometric) was analyzed. The results showed significant correlations between static and sport space activities. Furthermore, a good performance in intrinsic-spatial ability was correlated with a high geometrical performance in children, especially in boys.
Mikkel's study (Mikkel et al., 2016) also reports the positive response that can be found from the integration between mathematics and motor activity. The study in question highlighted how fine or coarse motor activity built in mathematics lessons improve mathematical performance in students.
Furthermore, Hraste's study aimed (Hraste et al., 2018) to examine the effectiveness of an integrated math / geometry and physical activity program, specifically designed to increase learning in fourth grade pupils. The experimental group of subjects learned mathematics and geometry through the integrated teaching method, while the control group of subjects learned through traditional teaching methods. The results indicated that the group of subjects who acquired knowledge of mathematics and geometry with the integrated teaching method were significantly more successful than the control group. The results therefore suggest that the integrated teaching method could be considered a useful and effective method for teaching mathematics and geometry if motor tasks are integrated to this. Growing evidence suggests that aerobic fitness improves mental function in terms of cognitive function during childhood, in particular positively influencing academic performance, specifically that of mathematics. (Chaddock-Heyman L., 2015)

2.2 Complex motor activity

There is recent literature that investigates interventions that focus specifically on the role of task complexity and, consequently, of the mental effort and cognitive effort required. Common to these studies is the practice of motor activities involving complex sequences of multiple limbs, a rapid decision-making process due to the presence of tasks that involve a time pressure, the implementation of learning processes for specific skills and problem solving strategies.
A study by Kim and collaborators investigated the relationships between motor and cognitive processes and mathematical skills, exploring the associations between visuomotor integration, attention, fine motor coordination and mathematical skills in a sample of preschool children, demonstrating that the motor development and cognitive development are already strongly and dynamically correlated in early childhood (Kim, 2017).
This study once again underlines the importance of environmental exploration done in early childhood, in support of the fact that the presence of limitations in this context negatively affects the cognitive development of the child. At the same time, the possibility of giving an important role to complex movements, specifically of fine motor coordination, as a variable influencing cognitive functions, is confirmed. Contextualizing this study in the field of visual impairment, think of visuomotor integration, as a criticality of our research sample, which is however an essential factor for the development of the child, and in this criticality we find confirmation and response of the difficulties encountered by visually impaired children in the domain of logic-mathematical skills
Complex motor movement has also been focused on in terms of multi-limb coordination in a study conducted by Budde (Budde et al., 2008). In this study, a 10-minute coordinative intervention based on football training was proposed, whose complexity of movement was based on the ability to balance and adapt, effectively responding to changing conditions (for example, bouncing a volleyball ball by alternating right hand and left hand while standing on a moving platform). The results showed that the experimental group, which carried out the

complex motor activity, performed better in an attention test than the children who participated in a normal physical education lesson in which the students practiced with a moderate intensity for 10 minutes without specific coordination requests and therefore without significant cognitive commitment.
The study which was particularly relevant for our research was that conducted by Pesce et al. (Pesce C. et al., 2009). This research group proposed to the sample under examination a 40-minute protocol that included team games and circuit training characterized by rapidly changing conditions that required decision-making responses taken under time pressure. The results obtained after training, on the experimental group, showed an improvement in memory, in the coding phase, compared to the control group in which the memory test was not preceded by any physical or mental activity.
We find in the study by Lakes (Lakes et al., 2004), the voluntariness of approaching an innovation from the didactic point of view, in the teaching of physical education, always by virtue of the fact that the complexity of the movement can be a variable that has a positive impact on the cognitive functioning of the pupil. The author conducted a study focused on modifying physical education programs in primary schools. A traditional martial arts program was used in the study, to be offered in place of conventional physical education classes. The intervention protocol, which lasted 3 months, included instructions on body control during strikes, kicks and blocks. Compared to the children in the control group, the experimental group, who instead carried out the martial arts program, showed an improvement in math tests, in cognitive and affective regulation of the self and in behavior in the classroom.
The focus of interest that emerges from this analysis is not limited to the cognitive implementation that derives from physical exercise, as has already been widely proven in the literature, but we focus on how much this implementation is then transferable and generalizable in all environments academics, providing a broader and long-term benefit, not contextualized only in the moment of training.

2.3 Motor activity and visual impairment: proposal for an intervention protocol

The basic concept that explains the positive correlation between aerobic motor activity and cognitive improvement is identified in the physiological activation resulting from training: in summary, the practice of physical exercise involves greater blood flow with consequent greater supply of oxygen to the brain, favoring thus the processes of neurogenesis and synaptogenesis and improving cognitive functions (Churchill JD. et al., 2002).
The resulting cognitive implementation of a complex motor activity is of a different nature, it is not only and strictly linked to the physiological activation deriving from physical exercise, but also largely depends on the coordination between movement and thought, which is necessary for carrying out this type of discipline. The complexity of movement required for these types of training involves an interaction between top down and bottom up processing, since the request made to the subject implies at the same time a significant cognitive effort and motor activation; therefore the subject is required to simultaneously activate their motor skills during the specific execution of a complex and multi-limb motor sequence, as well as their problem solving skills, processing and decision-making speed, learning processes for specific skills.
What emerges, therefore, is that the practice of a complex motor activity requires a greater cognitive effort, compared to aerobic activity, and that by its nature and for the benefits it brings, the resulting cognitive implementation has greater possibilities of duration in time and space, also emerging in contexts other than that of training, responding positively to the pervasiveness of the limitations deriving from visual impairment.

The line of thinking of the scientific community regarding the relationship between aerobic activity and cognitive function is that, as cognitive functions improve with physiological changes, the cognitive gains obtained with exercise decrease if exercise is reduced or shortened. Consequently, the maintenance and duration of cognitive benefits derived from exercise will require individuals to maintain the same regimes indefinitely (Hertzog C. Et al., 2008).
The strength of complex motor activity lies in the metacognition that is inherent in carrying out the practice. Trainings that intentionally include problem solving requests that lead to the acquisition of declarative and procedural knowledge, as well as response strategies, could conceivably lead to the long-term development of the ability to exercise control over thought and action by developing metacognition (Tomporowski P. et al., 2015). Children who are asked to coordinate their thoughts and movements should retain and therefore also have the possibility of transferring and generalizing the knowledge of the context in which they have performed, the actions taken for any technical gesture and their consequences as responses of the environment. The metacognitive processes that are involved in the practice of complex motor activity, in all its phases, from the preparation of the action, to the actual implementation, even to the environmental feedback, can persist over time, not necessarily decreasing, if the training was reduced or stopped.
The literature concerning motor activity and visual impairment, in general, mainly refers to the concept of inclusion, to the extent that children with visual impairments experience numerous barriers concerning physical activity in recreational activities and personal fitness programs at the outside the school environment and this often means that these children often lag behind their peers in participation in physical activity and motor skills (Lieberman L., 2018). The research project presented, on the other hand, wants to respond in a wide-ranging way to the difficulties encountered by these children, and therefore not focus only on the critical issues in terms of inclusion or usability of the materials, but shifting the focus on the difficulties encountered in the cognitive processes and in the specific in learning processes.
The literature cited so far has investigated the relationship between motor activity and logical mathematical skills in samples of able-bodied children and adolescents. This analysis shows a positive influence, deriving from physical exercise, not only on learning processes in general, but in the specific context of mathematics learning. The interest of the research group, based on the results that emerged from the exploratory survey, turns towards investigating the impacts of a complex motor activity protocol on the cognitive functions of a sample of subjects with visual disabilities.
It is hypothesized an improvement in cognitive functions, in particular in learning, with relatively permanent effects on mental functioning, and also a greater possibility of transferring the skills acquired in different areas of application that go beyond the training context alone. We have seen how an experience of the environment, qualitatively deficient and limiting, such as that experienced by a child with visual disabilities made in early childhood, then negatively affects the articulation of the child's cognitive profile (Macesic-Petrovic D., 2010). This, to the extent that the skills acquired in the preoperative and operative period, which are also the basis for learning mathematics, necessarily pass from a complete experience of the environment in the sensorimotor period. The research aims to investigate the relationship between motor activity and cognitive activation in the domain of logical-mathematical abilities, contextualized in a population of subjects with visual disabilities.
The research design is aimed at children from four to seven years and eleven months and provides for a survey period of 12 months. The sample consists of three groups: a first group that will perform an aerobic activity, a second group that will perform complex motor activity and a third control group that will not perform any activity. The evaluation of the logical-mathematical skills will take place in three stages; at the beginning of the protocol, i.e. T0, at

the end of the protocol, i.e. T1 and six months after the end of the protocol, i.e. T2. The presence of the three groups responds to the parallelism made during the analysis of the literature, to evaluate the possible greater effectiveness of the practice of a complex motor activity, compared to the aerobic one, in quantitative and qualitative terms, assuming that the complex motor activity results in a greater and relatively permanent cognitive benefit over time and space.
The test administered is the OLC: Logical Operations and Conservation (Vianello R., Marin M.L.). The tool measures the use of concrete operative thinking; in particular, it includes tests relating to the following four areas: serialization (tests 1-6), numbering (tests 7-12), classification (tests 13-18) and conservation (tests 19-24). The receivers are children between four years and seven years and eleven months. The times of administration vary from twenty-five to thirty minutes and the method of administration is individual. It can be administered in short form with only 18 trials or in standard form with all 24 trials.

3. Conclusions

In the light of what emerged from the analysis of the literature, regarding the relationship between motor activity and cognitive functions, it appears that the benefits of physical exercise to cognition have been widely investigated and found by numerous authors.
The parallelism that this research group has followed, has reason to exist for the need to evaluate the possibility of using the cognitive advantages deriving from motor activity in a relatively permanent way, thus trying to understand what are the variables that affect quality and quantity of cognitive implementation. An attempt is made to respond more effectively to the pervasiveness with which the difficulties encountered by people with visual impairments present themselves in the lives of these people, inevitably and negatively affecting the quality of life. Even if in this context we have focused on the difficulties that have emerged in the learning processes, it is also good not to underestimate the other dimensions of sport, from the social to the emotional one, in addition to the cognitive one analyzed here. It is therefore desirable to carry out research with the ultimate goal of improving the quality of life of this population, and therefore to carry out investigations bearing in mind the pervasive characteristic of the difficulties that characterize visual disability, which negatively impact on multiple domains of development of the person and in the which sport can play an important role. On the basis of this and the results reported by the scientific literature, we focused on the possibility that a complex motor activity, which involves the execution of multi-limb motor sequences and at the same time a top down activation to activate problem solving strategies and decision-making and the implementation of learning processes, involve a greater cognitive effort, compared to the aerobic one, but above all a plausible possibility about the relatively permanent duration of the cognitive advantages, which therefore persist over time and space, also appearing in different contexts from that of training. In this way, the limitation of the resulting cognitive benefit of aerobic practice is overcome, to the extent that this benefit is contextualized only at the time of training and therefore of the resulting physiological modification.
Future perspectives move towards innovation and improvement of the educational experience of the child with visual impairment. If future research were to confirm the research hypothesis, and therefore the validity of the complex movement for cognitive implementation in terms of permanence of the cognitive advantage over time and space, work should be done on the construction of educational programs that give this particular type of training an important role within the programming itself. The importance of the body and its centrality in the cognitive development of the child, as well as the importance of using and activating the sense organs to

create experiences and build knowledge, gives rise to the need to find an answer to all those that are limitations resulting from visual impairment. In this sense, the complexity of movement can be identified as a valid possibility of improvement for the child's learning processes and innovation is identified in the possibility of considering complex motor movement, as a means to generalize the skills and knowledge learned in the context of training, bringing benefits in the various circumstances that characterize the life of the subject.

References

Bornstein, M. H., Hahn, C.-S., Suwalsky, J. T. D. (2013). Physically developed and exploratory young infants contribute to their own longterm academic achievement. Psychol. Sci. 24, 1906–1917.

Budde H, Voelcker-Rehage C, Pietrassyk-Kendziorra S, Ribeiro P, Tidow G. (2008) Acute coordinative exercise improves attentional performance in adolescents. Neurosci Lett; 441:219-23.

Chaddock-Heyman L., Erikson KI., Kienzler C., King M., Pontifex MB., Raine LB., Hillman CH., Kramer A. (2015) The role of aerobic fitness in cortical thickness and mathematics achievement in preadolescent children. Plos one.

Churchill JD, Galvez R, Colcombe S, Swain RA, Kramer AF, Greenough WT. (2002) Exercise, experience and the aging brain. Neurobiol 127 Aging; 23:941-55.

Davis, L.C., Tomporowski, P.D., McDowell, J.E., Austin B.P., Miller, P.H., Yanasak, N.E., Allison, JD., Naglieri, J.A. (2011). Exercise Improves Executive Function and Achievementand Alters Brain Activation in Overweight Children: A Randomized Controlled Trial. He-alth Psychology, 30(1), 91-98.

Donnelly, J.E., Lambourne K. (2011). Classroom-based physical activity, cognition and aca-demic achievement, Preventive Medicine, 52, 36-42

Gibbs, R. W. (2006). Embodiment and Cognitive Science. New York: Cambridge University Press.

Hertzog C, Kramer AF, Wilson RS, Lindenberger U. (2008) Enrichment effects on adult cognitive development. Psychol Sci Public Interest:1-65

Hillman CH, Pontifex MB, Raine LB, Castelli D, Hall EE, Kramer AF. (2009) The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children. Neuroscience; 159:1044-54

Hraste M., De Giorgio A., Mandic Jelaska P., Padulo J., Granic I. (2018) When mathematics meets physical activity in the school-aged child: the effect of an integrated motor and cognitive approach to learning geometry.

Jansen P., Pietsch S. (2020) Sports and mathematical abilities in primary school-aged children: how important are spatial abilities? An explorative study. Current Psychology.

Kim H., Duran C., Cameron C., Grissmer D. (2018). Developmental Relations Among Motor and Cognitive Processes and Mathematics Skills. Child Dev

Lakes KD, Hoyt WT. (2004) Promoting self-regulation through school-based martial arts training. Appl Dev Psychol; 25:283-302.

Lieberman L., Lepore M., Lepore-Stevens M., Ball L. (2018) Physical Education for Children with visual impairment or blindness.

Macesic-Petrovic D., Vucinic V., Eskirovic B. (2010). Cognitive development of the children with visual impairment and special educational treatment. Procedia Social and Behavioral Sciences.

Mikkel M., Rune R., Ritz C., Jesper Lundbye-Jensen J., Wienecke J. (2016) Motor-enriched learning activities can improve mathematical performance in preadolescent children. Front. Hum. Neurosci.

Pesce C, Crova C, Cereatti L, Casella R, Bellucci M. (2009) Physical activity and mental performance in preadolescents: effects of acute, exercise on free- recall memory. Ment Health Phy Act ;2:16-22.

Piaget, J. (1973). La nascita dell'intelligenza nel bambino. Firenze: La Nuova Italia.

Platz, D. L. (2004). Challenging young children through simple sorting and classifying: A developmental approach. Education, 125(1), 88-97.

Reed, J.A., Einstein, G., Hahn, E., Hooker, S. P., Gross, V.P., Kravitz, J. (2010). Journal of PhysicalActivity and Health, 7, 343-351.

Reys, R., Lindquist, M. M., Lambdin, D. V., Smith, N. L. (2009). Helping children learn mathematics. Hoboken, NJ: John Wiley & Sons, Inc.

Sanchal A., Sharma S. (2017) Student's attitudes towards learning mathematics: impact of teaching in a sporting context

Smith, S. (2006). Early childhood mathematics. Needham Heights

Tobin, M. J. (1972). Conservation of substance in the blind and partially sighted. British Journal of Educational Psychology.

Tomporowski P. et al. (2015) Exercise and children's cognition: The role of exercise characteristics and a place for metacognition. Journal of Sport and Health Science

Vianello R. e Marin M.L. (1991) OLC: Operazioni logiche e conservazione. Juvenilia

Warren, D. H. (1984). Blindness and Early Childhood Development. New York: American Foundation for the Blind.