ANALYSIS OF THE CORRELATION BETWEEN MOTOR ACTIVITY AND MATHEMATICAL COMPETENCE IN DEVELOPMENTAL AGE

ANALISI DELLA CORRELAZIONE TRA ATTIVITÀ MOTORIA E COMPETENZA MATEMATICA IN ETÀ EVOLUTIVA

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ABSTRACT

The research investigates the correlation between motor activities and cognitive development, taking as its reference the theoretical framework of embodied cognition and theoretical mathematics, which is based on the interpretation-procedure-number-fact sequence. Specifically, we focus on the relationship between corporeality, working memory and early mathematical abilities in primary school children

La ricerca indaga la correlazione tra attività motorie e sviluppo cognitivo, prendendo come riferimento il quadro teorico della cognizione incarnata e della matematica teorica, che si basa sulla sequenza interpretazione-procedura-numero-fatto. Nello specifico, ci si concentra sulla relazione tra corporeità, memoria di lavoro e abilità matematiche precoci in bambini della scuola primaria.

KEYWORDS
Motor activities; embodied cognition; working memory; mathematical skills; sports.

Attività motorie; cognizione incarnata; memoria di lavoro; abilità matematiche; sport.

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Introduction[1]

The research aims to investigate whether there is a significant difference in cognitive development, specifically of early logical-mathematical skills, between children who practice motor activity and those who do not, in the primary school context (classes I and II), to implement a motor-teaching methodology that can enhance these skills.

The theoretical foundation on which the research is based is the Embodied Cognition approach, which precisely focuses on the importance of the body as a mediator for learning processes. Embodied cognition, overcomes the idea of Cartesian dualism between mind and body, and believes that they are linked to each other in a retroactive feedback relationship, not considering the mind as a process of abstract information unconnected with the external world, but on the contrary, it speaks of the mind no longer just as a set of brain circuits, but that it should be analysed in the context of its relationship with a physical body. Thus the concept of the 'embodied' mind, embodied in an external bodily and relational context, begins to spread, and a connection between mental life events and sense-motor processes is sought, based on the idea that cognition depends on the body. "We perceive to act, and what we perceive depends on how we intend to act" (Glenberg, 2013).

Based on this premise, we can define the individual as a 'complex system', multi-componential, whose different elements interact with each other. Therefore, it is necessary to evaluate it through a holistic dimension, considering the interconnection between mind, body, and environment.

For some time, Embodied theories have correlated linguistic and computational abilities with corporeity and the connection with movement (Caruana-Borghi, 2013).

Specifically, a study by Fausto Caruana and Anna M. Borghi 2013, was taken into consideration, in which some of the most important results of Embodied Cognition in different areas of experimental research are presented and discussed: from the study of convenience to that of bodily experience, from the investigation of emotions to that of language. It is therefore of fundamental importance that during this educational experience, the child has the opportunity to integrate cognitive, perceptual and motor skills to develop competence (Ceciliani,2018).

1. Correlation between brain, physical activity and cognition

[1] Francesco Tafuri author of introduction and paragraph 2; Arianna Cittadini author of paragraph 1-3-4; Stefania Morsanuto author of 5 and discussiona and conclusion

For several years, the idea that physical activity is identified in the scientific literature as having significant potential to improve specific cognitive processes and corresponding neural substrates has been supported.

Neuroscience shows the benefits that exercise can bring to the brain. Firstly, physical activity allows greater oxygenation of tissues and consequently an increase in metabolic activity, which leads to changes in the brain allowing motor, cognitive, relational and emotional skills and abilities to mature (Olivieri,2017). Movement also triggers the release of certain hormones such as dopamine, which is involved in motivation and attention, and serotonin, which acts as a mood regulator. Physical activity allows the brain to work and, consequently, to implement and strengthen neuronal connections. In fact, although cerebral development is complete within the third decade, there are nevertheless certain areas, including the hippocampus, the area responsible for spatial memory and the consolidation of information from Short Term Memory (MBT) to Long Term Memory (MLT), which is subject to a process of neurogenesis. Several studies show that this process is favoured by various factors, including physical activity, which facilitates the production of brain-derived neurotrophic factor (BDNF), which acts on the survival and growth of neurons. This promotes learning and prevents various forms of dementia (Van,2009). Several researches support the idea that movement influences the neuroplasticity of brain structures, improving cognitive functions, and consequently the quality of learning (De Bruijn et al., 2019).

Anatomically, the striatum thalamus system (or Basal Nuclei) and the Cerebellum are the main areas involved in the motor system, both receive impulses from the entire cerebral cortex, and in addition to being the regulators of movement execution, they are involved in higher order functions, cognitive in nature, such as planning and execution related control and motor strategies. As a matter of fact, several studies have highlighted the connection between the prefrontal cortex, the area deputed to executive functions, and the striatum (Elliott,2003; Heyder, 2004); this connection is made evident by studies regarding Parkinson's disease, where patients have executive deficits and motor disturbances. It has also been observed that such deficits in executive functions may be the consequence of impaired dopaminergic function (failure to release dopamine) in the striatum, which could result in reduced activity between the motor cortex and the cortical thalamus system (Sawamoto,2008).

Further studies have highlighted the close relationship between the cerebellum and the area responsible for executive functions, the prefrontal cortex. Thus, an inadequate functioning of the cerebellum would imply impaired executive functions, and vice versa, if the cerebellum works actively, this would favour executive functioning (Budde,2008). Therefore, it can be deduced that motor skills expand the connection between the cerebellum and other brain areas, thus favouring their functioning (Van,2012).

Executive functions (FE), are cognitive abilities required to achieve complex behaviour. They include a variety of processes such as: planning ability, inhibition, working memory, attentional flexibility and problem solving, which are prerequisites for learning processes in developmental age (Marotta,2013). In fact, the student needs good executive functioning in order to concentrate on multiple school tasks and to complete a goal and thus succeed academically. In light of what has emerged so far, it is hypothesised that there is a significant relationship between motor performance and the development of cognitive processes, in particular executive functions, in fact, when we perform an action, all those processes of information processing, very rapid decision-making, estimation, judgement, and inhibition of distracting stimuli or automatic responses that could lead to making mistakes are activated.

A study by Diamond 2012, shows, with regard to motor activity, that executive functions in children can be implemented by practising martial arts. The increase in these functions results in the development of selective attention and reasoning skills, which are responsible for an improvement in school learning.

The research results of Jäger et al. 2014, showed that intense physical activity, within which cognitive games are contained, leads to an implementation of inhibitory control. Possibly underlying this increase could be the increase in cortisol, which results precisely from physical activity.

Cortisol affects neurotransmitters that seem to intervene in certain cognitive processes, such as perception, selective attention and memory (Erickson,2003).

The function of the locus coeruleus (LC) is to be considered, as it plays an important role in the functioning of our central nervous system and is mostly made up of noradrenergic neurons. It is part of the ascending reticular activating system responsible for regulating physiological responses to stress and fear. It is the source of noradrenaline (NA) for the brain, brainstem, cerebellum and spinal cord, and integrates sensory information by regulating attention, sensory activation and some memory performance. Norepinephrine (NA) is produced in the LC, which influences different regions of the cortex and subcortical areas by regulating basal arousal, which is the state of temporary arousal of the central nervous system in response to significant stimuli of varying intensity, characterised by an increased attentional-cognitive state of vigilance and prompt reaction to external stimuli that variably facilitates behavioural and sensory-motor functions (Breton-Provencher, Drummond, Sur, 2021).

Thus, motor activity has for decades been the focus of scientific research which identifies it as a tool for developing and implementing cognitive processes (Latino,2020). Accordingly, it is to be hoped that physical education programmes will be systematised as a result of the concepts that have emerged to date, and that they will therefore be aimed at achieving specific objectives relating to the development of executive capacities, against a more general objective, i.e. the overall development of the child, who benefits from the practice of sport in physical, cognitive and also relational terms, thus responding to the new vision of the individual from a purely biopsychosocial perspective.

2. How to train and strengthen through physical activity?

The physical activity discussed so far and examined by the studies reported consists of a planned, structured, repetitive activity. It has the ultimate goal of improving one or more components of physical fitness. These are aerobic and anaerobic activities. They are characterized by a precise frequency, duration and intensity.

A new study (Schmitt,2019) showed for the first time that low and high exercise intensities affect brain function differently. The researchers used resting-state functional magnetic resonance imaging (Rs-fMRI) to find that low-intensity exercise activates brain networks involved in executive control and attentional processes.

In contrast, high-intensity exercise mainly activates networks involved in processing affect and emotion. This leads to a reduction in stress, for example. This is a particularly significant finding. Indeed, these data can be used to inform therapeutic plans that include motor activity in pathological cases.

Regarding type and duration, the greatest benefits of exercise on cognitive function were found in coordination-type exercises. Acute exercise training lasting 10, 20 or 30 minutes neither improved nor worsened cognitive performance. In contrast, with longer training durations, effectiveness increased.

In fact, an extension of the exercise session to 30 to 60 minutes predicts a twofold increase in the size of the beneficial effect, provided, however, that the training sessions are continuous for a duration of at least 1-2 months. Motor activity also serves to engage the value dimension, engages recognition and respect for rules, and uses the cognitive system differently and originally.

The sporting discipline involves the logical-mathematical and spatial dimensions that are intentionally activated through the body and movement, in fact, with motor performance different cognitive schemes of a spatial and numerical nature are set in motion, of a strategic anticipatory type of action. 'With motor activity, the numerical concept implicit in the executive level is structured, the spatial dimension is represented and translated into dynamic actions, the relationship between space outside the body and one's own body is calculated' (Sibilio,2005).
In sports, cognitive schemes of a tactical and strategic nature and mental representations anticipating action are implemented, according to spatial and numerical principles.
In playing or practising sports, doing and thinking cannot rely solely on internal mental representations, concrete situations require a high level of kinesthetic and bodily awareness thanks to which one can activate and implement effective motor behaviours, both to respond flexibly to different environmental conditions, often under time pressure, and to reflect on the effects of the choices implemented in the situation (Sutton, 2007). Team confrontation games/sports, for example, are characterised by high degrees of variability that require continuous motor adaptation to situations made uncertain or unexpected by the actions of other players. In this context, awareness of oneself, one's own body, and one's actions become a determining element to be able to respond to the demands of the situation experienced, implementing appropriate and effective behaviour. Previous experience, one's sensorimotor history, therefore, becomes fundamental due to the greater possibility of performing perceptive discriminations between actions in progress or those to be undertaken: the more one has mastered or has experience of a given skill, the more one is able to discriminate it, for its effective use, thanks to the memory of situations experienced in the past (Beilock,2008; Calvo Merino,2005). Motor activity and sport, therefore, represent frames of experience in which sensory perception is phenomenologically embodied, that is, referred to the body as the starting point from which it is possible both to experience concrete situations in first person (first person perspective) and to experience the dialogical relationship between environment, body and consciousness(Allen-Collinson,2009).

3. Study and research hypothesis

Starting from these assumptions, the intention is to exploit the intrinsic potential of motor activity by planning an intervention protocol aimed at stimulating the executive system, hypothesizing the consequent presence of positive cascading benefits for learning processes, the development of which is closely related to the aforementioned area. In particular, the correlation between mathematics, movement and physical education was observed (Reilly,2012), with the aim of demonstrating how the mathematical skills of estimation, numeracy and evaluation, which are innate, can be trained through corporeity, hence motor

activity. The present study aimed to investigate the correlation between working memory, logical-mathematical skills and motor activity.
The research was carried out through a school screening in primary and secondary school children.

4. Methodology

Two tests were administered to the children: WISC-IV - Wechsler Intelligence Scale for Chíldren - Fourth Edition (David Wechsler, 2003; available in Italy since 2012, Orsini, Pezzuti, & Picone) and Test of Early Assessment of Mathematical Competence - VPCM (G. Benvenuto; I. Gonzàlez S.M.; N. Lanciano; M.C. Passolunghi; 2018).

The WISC-IV Scale is used to assess Intelligence Quotient (IQ) which is derived from the sum of four composite scores, each formed by specific subtests and can be administered from 6 to 16 years of age.

Specifically for this research, two subtests are used whose sum of their weighted scores gives us the Index of Working Memory (IML), i.e. the measure of learning, retention and information processing capacities that allow us to store and then reuse information. The subtests used are:

- "Digit memory", consisting of two tasks, a direct digit memory task, in which the child is asked to repeat the numbers in the same order as they are read aloud by the examiner, and a reverse digit memory task, in which the child is asked to repeat the numbers in the reverse order as they are read aloud by the examiner;

- "Letter and number reordering", where the examiner reads the child a sequence of numbers and letters in random order and the child's task is to first repeat the numbers in ascending order and then the letters in alphabetical order.

The Early Assessment Test of Mathematical Competence - VPCM allows a non-specific determination of a level of mathematical competence in children aged 4 to 8 years in order to identify risk factors with the aim of enhancing the strengths and weaknesses of such children. The version used is a revision of the Early Numeracy Test - Revised -ENT-R (Van,2018). The test consists of 45 items subdivided into 9 sub-components that investigate logical and cognitive numeracy skills. Specifically: logical skills are assessed by the sub-components: concept of comparison, classification, one-to-one correspondence and seriation. Numerical skills are assessed by the sub-components: structured counting, resulting counting, general knowledge of numbers and number estimation.

5. Data analysis

5.1 Sample analysis

The sample consists of 137 statistical units, which were tested

Statistics

		Classroom	Age groups	Sport (Y/N)	Gender
N	Valid	137	137	137	137
	Missing	0	0	0	0

Table 1 - Statistics

Children are distributed fairly proportionally between first (43.8 percent) and second grade (56.2 percent)

Classroom

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1st elementary school	60	43.8	43.8	43.8
	2nd elementary school	77	56.2	56.2	100.0
	Total	137	100.0	100.0	

Table 2 - Classroom

Considering age, the distribution is homogeneous, in relation to what was highlighted above, with the presence of two children with ages much lower than average.

Age groups

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	66-71 months	2	1.5	1.5	1.5
	72-77 months	26	19.0	19.0	20.4
	78-83 months	34	24.8	24.8	45.3
	84-89 months	31	22.6	22.6	67.9
	90-96 months	44	32.1	32.1	100.0
	Total	137	100.0	100.0	

Table 3 - Age groups

Instead, the number of children who do not play sports prevails (71.5 percent) versus those who do (28.5 percent).

Sport (Y/N)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	98	71.5	71.5	71.5
	Yes	39	28.5	28.5	100.0
	Total	137	100.0	100.0	

Table 4 - Sports (Y/N)

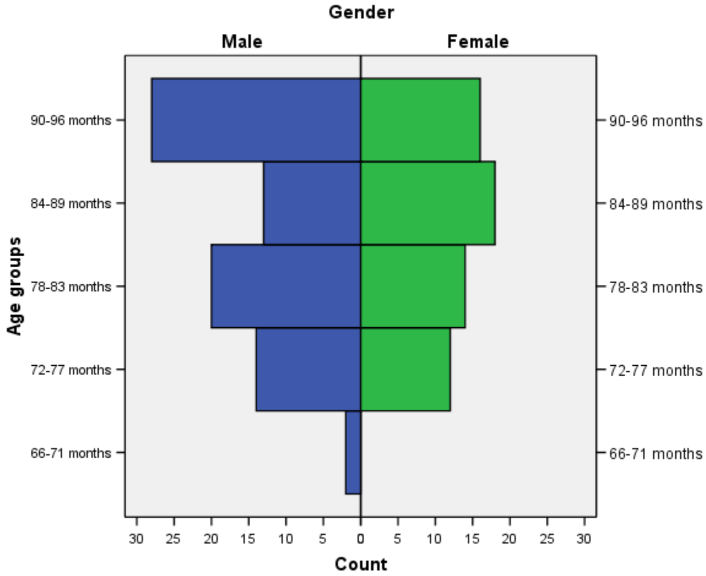
Finally, there is a preponderance of the male gender (56.2%) versus the female gender (43.8)

Gender

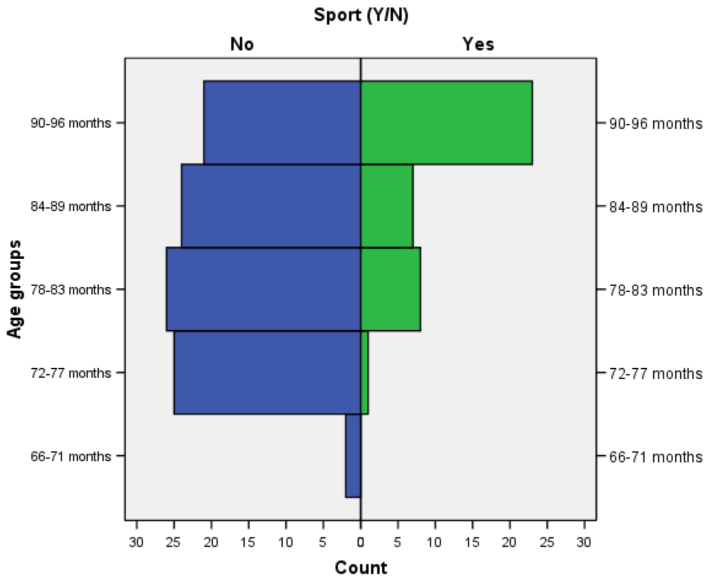
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	77	56.2	56.2	56.2
	Female	60	43.8	43.8	100.0
	Total	137	100.0	100.0	

Table 5 - Gender

The pyramid graph shows the age distribution by gender.



The pyramid graph shows the distribution between age and playing or not playing sports.



Figures 1 - Gender vs Age groups

The tests used

To analyze the data and determine whether the mean difference between paired observations for 2 categories (e.g., gender M/F, sport Y/N) is statistically significant, the **Independent Samples T-Test (SPSS)** was used**.**

The null hypothesis H_0 is therefore that there is no statistically significant difference between the mean value obtained from the sample by category in the different tests.

The conditions for applicability of the test are.

1. Independent observations

Each statistical unit represents a different person. The condition applies to our data.

2. Normality

The dependent variable must follow a normal distribution in the population. This is only necessary for samples smaller than about 25 units. Having 137 statistical units makes the normality test unnecessary.

3. Homogeneity: the standard deviation of our dependent variable must be equal in both populations. We need this assumption only if our sample size is (sharply) unequal. SPSS checks whether this holds when we run our t-test. If it does not, we can still report the correct test results.

In conclusion, we can consider the conditions verified.

To analyze the data and determine whether the mean difference between paired observations for more than two categories (e.g., age groups) is statistically significant, the **One-Way ANOVA- Test** (SPSS) was used.

The condition that there is homogeneity among the variances will be tested with Levene's test. If the result is affirmative, the One-Way Anova test can be used, otherwise the **WELCH** test should be used.

Statistical analysis between test results and gender

The sample has different averages for males and females in the different tests, although minimal. It is intended to test whether these differences are statistically significant.

Inferential statistics shows us the following results

Independent Samples Test - Gender

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Calculation memory	Equal variances assumed	.001	.981	1.740	135	.084	.921	.530	-.126	1.969
	Equal variances not assumed			1.740	126.960	.084	.921	.529	-.126	1.969
Letters and numbers reordering	Equal variances assumed	.469	.495	.531	135	.596	.304	.572	-.827	1.434
	Equal variances not assumed			.535	130.314	.593	.304	.567	-.819	1.426
Total score	Equal variances assumed	.004	.947	1.458	135	.147	3.870	2.655	-1.380	9.121
	Equal variances not assumed			1.454	125.571	.149	3.870	2.662	-1.399	9.139
Mathematical skills	Equal variances assumed	.100	.752	.676	135	.501	2.311	3.421	-4.454	9.075
	Equal variances not assumed			.674	125.683	.502	2.311	3.429	-4.476	9.097

Table 6 - Indipendend Sample Test - Geneder

Levene's test of equality of variances gives a p-value (Sig) always greater than 0.05. So we can consider the variances to be equal and consequently consider only the first rows of the table.

Considering the T-Test of equality between averages (Null Hypothesis), we see a p-value always greater than 0.05 (Mr. 2-tailed). Consequently, we cannot reject the null hypothesis of equality between sample averages by gender. The fact that 0 is within the confidence interval also reinforces this conclusion.

From the inferential statistics, therefore, it is derived that the mean of values obtained by males and females in the sample is yes different, but this difference is not statistically significant.

Statistical analysis between test results and who does or does not play sports

The sample has different averages between those who play sports and those who do not in the different tests. It is intended to test whether these differences are statistically significant.

Inferential statistics shows us the following results

Independent Samples Test - Sports

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Calculation memory	Equal variances assumed	2.448	.120	-1.752	135	.082	-1.020	.582	-2.171	.131
	Equal variances not assumed			-1.635	61.104	.107	-1.020	.624	-2.267	.228
Letters and numbers reordering	Equal variances assumed	1.044	.309	-.954	135	.342	-.598	.627	-1.839	.642
	Equal variances not assumed			-1.021	81.180	.310	-.598	.586	-1.765	.568
Total score	Equal variances assumed	.650	.421	-1.651	135	.101	-4.809	2.913	-10.569	.951
	Equal variances not assumed			-1.619	67.137	.110	-4.809	2.971	-10.739	1.121
Mathematical skills	Equal variances assumed	1.569	.212	-4.847	135	.000	-16.851	3.477	-23.727	-9.975
	Equal variances not assumed			-5.099	78.131	.000	-16.851	3.305	-23.430	-10.272

Table 7 - Independent Sample Test - Sports

Levene's test of equality of variances gives a p-value (Sig) always greater than 0.05. So we can consider the variances to be equal and consequently consider only the first rows of the table.

Considering the T-Test of equality between averages (Null Hypothesis), we see a p-value always above 0.05 (Mr. 2-tailed), except for the **Mathematical Skills** test. Consequently, we cannot reject the Null Hypothesis of equality between the sample averages between those who play sports (who always performed better) and those who do not for the first 3 tests (the fact that the 0 is within the confidence interval also reinforces this conclusion), but we can reject the Null Hypothesis for the 4 test (Mathematical Skills), also considering that the 0 falls outside the confidence interval.

Thus, inferential statistics show that the mean values obtained between those who play sports and those who do not in the sample are different, but this difference is statistically significant only in the case of the Mathematical Skills test. In particular, those who play sports obtained higher scores on average.

Statistical analysis between test results and age groups

We now want to test the null hypothesis H_0 that the mean results for age groups are the same in the various tests administered to the sample.

The One-Way Anova test is used (the independent variable being qualitative and having a number of values greater than 2).

1. A requirement for the ANOVA test is that the variances of each comparison group be equal. This condition is tested using the Levene statistic. What is sought here is a significance value greater than 0.05, since a different result would suggest a real difference between the variances (**Homogeneity of Variances**).

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
Calculation memory	.341	4	132	.850
Letters and numbers reordering	1.191	4	132	.318
Total score	.808	4	132	.522
Mathematical skills	.323	4	132	.862

Table 8 - Test of Homogeneity of Variances - Age groups

In our sample, the significance value of Levene's statistic based on a comparison of medians is always greater than 0.05. This is not a significant result, which means the requirement of homogeneity of variance was met and the ANOVA test can be considered robust.

2. To obtain the result of the **ONEWAY ANOVA test, one** looks for whether the value of F, which appears in the row between the groups, reaches the level of significance (Sig. <0.05). Otherwise, the null hypothesis cannot be rejected.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Calculation memory	Between Groups	20.168	4	5.042	.518	.723
	Within Groups	1284.971	132	9.735		
	Total	1305.139	136			
Letters and numbers reordering	Between Groups	51.227	4	12.807	1.174	.325
	Within Groups	1439.853	132	10.908		
	Total	1491.080	136			
Total score	Between Groups	808.439	4	202.110	.839	.503
	Within Groups	31785.356	132	240.798		
	Total	32593.796	136			
Mathematical skills	Between Groups	11299.243	4	2824.811	8.847	.000
	Within Groups	42146.655	132	319.293		
	Total	53445.898	136			

Table 9 - Anova test - Ages groups

In our sample, we obtain that F achieves a significant p-value (Sig.) (below the .05 alpha level) in the test related to Mathematical Skills. This means that there is a statistically significant difference in this test for different ages. However, we do not yet know for which of the specific age groups this difference is significant. We can find out in the table of multiple comparisons that contains the results of Tukey's post hoc test.

Multiple Comparisons

Dependent Variable: Mathematical skills
Tukey HSD

(I) Age groups	(J) Age groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
66-71 months	72-77 months	-7.077	13.112	.983	-43.34	29.19
	78-83 months	-4.382	13.001	.997	-40.34	31.58
	84-89 months	-21.629	13.036	.463	-57.69	14.43
	90-96 months	-24.568	12.919	.322	-60.30	11.16
72-77 months	66-71 months	7.077	13.112	.983	-29.19	43.34
	78-83 months	2.695	4.655	.978	-10.18	15.57
	84-89 months	-14.552*	4.752	.022	-27.70	-1.41
	90-96 months	-17.491*	4.420	.001	-29.72	-5.27
78-83 months	66-71 months	4.382	13.001	.997	-31.58	40.34
	72-77 months	-2.695	4.655	.978	-15.57	10.18
	84-89 months	-17.247*	4.437	.001	-29.52	-4.97
	90-96 months	-20.186*	4.080	.000	-31.47	-8.90
84-89 months	66-71 months	21.629	13.036	.463	-14.43	57.69
	72-77 months	14.552*	4.752	.022	1.41	27.70
	78-83 months	17.247*	4.437	.001	4.97	29.52
	90-96 months	-2.939	4.190	.956	-14.53	8.65
90-96 months	66-71 months	24.568	12.919	.322	-11.16	60.30
	72-77 months	17.491*	4.420	.001	5.27	29.72
	78-83 months	20.186*	4.080	.000	8.90	31.47
	84-89 months	2.939	4.190	.956	-8.65	14.53

*. The mean difference is significant at the .05 level.

Table 10 - Tukey HSD - Age groups

It can be seen from the table that: for the Mathematical Skills test there is a statistically significant difference between the averages of the 72- to 83-month age groups and the 84- to 96-month age groups (older children performed better on average than younger children).

Correlations between tests

From the correlation matrix between the different tests, it can be seen that we have a strong positive correlation between all the tests. So improving in the results of one of the tests also gives positive results in all the others.

Correlations

		Calculation memory	Letters and numbers reordering	Total score	Mathematical skills
Calculation memory	Pearson Correlation	1	.296**	.785**	.431**
	Sig. (2-tailed)		.000	.000	.000
	N	137	137	137	137
Letters and numbers reordering	Pearson Correlation	.296**	1	.820**	.376**
	Sig. (2-tailed)	.000		.000	.000
	N	137	137	137	137
Total score	Pearson Correlation	.785**	.820**	1	.493**
	Sig. (2-tailed)	.000	.000		.000
	N	137	137	137	137
Mathematical skills	Pearson Correlation	.431**	.376**	.493**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	137	137	137	137

**. Correlation is significant at the 0.01 level (2-tailed).

Table 11 - Correlations - Tests

Discussions and conclusions

From the analysis of the data, of this exploratory research, we found positive elements that can confirm our initial hypothesis. Basically, it prevails that the number of children who do not participate in sports (71.5%) is greater than those who do (28.5% - Tab. 3), and in the sample, there is a preponderance of the male gender (56.2%) against the female gender (43.8 - Tab. 4), which presents different averages (for males and females) in the different tests, although minimal.

In the T-Test of equality between the averages (Null Hypothesis), we note a p-value always above 0.05 (Mr 2-tailed). Consequently, we cannot reject the null hypothesis of equality between the sample averages by gender. The fact that 0 is within the confidence interval also reinforces this conclusion.

From the inferential statistics, we, therefore, conclude that the mean values obtained by males and females in the sample are indeed different, but this difference is not statistically significant (Tab. 6). The sample presents different averages between those who practice sport and those who do not in the different tests. Considering the T-Test of equality between the averages (Null Hypothesis), we note a p-value always above 0.05 (Mr 2-tailed), except for the Mathematical Skills test. Consequently, we cannot reject the null hypothesis of equality between the sample's averages between those who practice sports (who always obtained better results) and those who do not for the first three tests (the fact that the 0 is within the confidence interval also reinforces this conclusion), but we can reject the null hypothesis for the fourth test (Mathematical Skills - Tab. 7), also considering that the 0 falls outside the confidence interval.

Inferential statistics thus show that the mean values obtained between those who practice sports and those who do not in the sample are different, but this difference is only statistically significant in the case of the Mathematical Skills test. In particular, those who practice sports obtained higher scores on average.

When testing the null hypothesis H0 that the average results for age groups are equal in the various tests administered to the sample, there is a statistically significant difference in this test for the different ages. for the Mathematical Skills test, there is a statistically significant difference between the averages of the age groups 72 to 83 months and the groups 84 to 96 (older children scored better on average than younger children). The correlation matrix between the different tests shows that there is a strong positive correlation between them.

Thus, improving the results of one of the tests also leads to positive results in all the others (Tab. 11).

A significant finding that emerges is the very high percentage (71.5%) of the sample, at a developmental age, who do not practice any type of motor/sporting activity. In light of this important data, it is planned to investigate the reasons why children do not practice sports and, conversely, to analyse the types of sports played by the selected sample. It is crucial to understand whether there are significant differences in academic performance between the two groups and to understand whether one type of sport influences logical-mathematical skills more than another. Mathematics is a workshop activity that aims to develop mathematical thinking from experiences with the body and movement and to develop a specific teaching intervention. The methodology should exploit the motivation induced by play-motor activities, selecting and creating new games that engage the body and perception, researching and realizing the transposition of experience from a concrete level to a level of graphic and verbal abstraction developing mental representation. The 'motor mathematics' approach should be a didactic tool in the logic-mathematics area that, starting from pre-school age, selects play-motor activities on the basis of the possibility of synthesizing the original concepts of mathematical thought underlying the motor experiences themselves.

References

ALLEN-COLLINSON, J., & HOCKEY, J. (2009). *“The essence of sporting embodiment: Phenomenological analyses of the sporting body”.* The International Journal of Interdisciplinary Social Sciences, 4 (4), 71-81.

BEILOCK S.L. (2008). *“Beyond the playing field: sport psychology meets embodied cognition, International Review of Sport and Exercise Psychology*”, 1(1), 19-30.

BRETON-PROVENCHER V., DRUMMOND G. T., SUR M., (2021). *“Locus Coeruleus Norepinephrine in Learned Behavior: Anatomical Modularity and Spatiotemporal Integration in Targets”.* Frontiers in Neural Circuits, V. 15.

BUDDE, H., VOELCKER-REHAGE, C., PIETRAßYK-KENDZIORRA, S., RIBEIRO, P., & TIDOW, G. (2008). *“Acute coordinative exercise improves attentional performance in adolescents”. Neuroscience letters*, *441*(2), 219-223.

CALVO MERINO, B., GLASER, D.E., GREZES, J., PASSINGHAM, R.E., & HAGGARD, P. (2005). *“Action observation and acquired motor skills: an FMRI study with expert dancers”.* Cerebral Cortex, 15, 1243-1249.

CAPPUCCIO M.L. (2019), (edited by). “*Handbook of Embodied Cognition and Sport Psychology”*. Cambridge: MIT Press.

CECILIANI, A., (2018) *“Dall’Embodied Cognition all’Embodied Education nellescienze dell’attività motoria e sportiva”*, Journal of Phenomenology and Education. Vol.22 n.51.

DE BRUIJN, A., KOSTONS, D., VAN DER FELS, I., VISSCHER, C., OOSTERLAAN, J., HARTMAN, E., & BOSKER, R.J., (2019). *“Importance of aerobic fitness and fundamental motor skills for academic achievement”.* Psychology of Sport and Exercise, 43, 200–209

DIAMOND, A. (2012). Activities and programs that improve children’s executive functions. Current Directions in Psychological Science, 21, 335 – 341.

ELLIOTT R. (2003) "*Executive functions and their disorders"*. Br Med Bull 65: 49-59.

ERICKSON, K., DREVETS, W. & SCHULKIN, J. (2003). *"Glucocorticoid regulation of diverse cognitive functions in normal and pathological emotional states".* Neuroscience Biobehavioral Review, 27, 233 – 246.

FAUSTO CARUANA, ANNA M. BORGHI, (2013), "*Embodied Cognition: una nuova psicologia"*, in Giornale italiano di psicologia, Rivista trimestrale, pp. 23-48.

GLENBERG, A., M., WITT, J., K., and METCALFE J., (2013). *"From the Revolution to Embodiment: 25 Years of Cognitive Psychology",* Perspectives on Psycholofical Science 8(5) 573-585.

HEYDER K ET AL. (2004) *"Cortico-subcortical contributions to executive control".* Acta Psychol 115: 271-289.

JÄGER, K., SCHMIDT, M., CONZELMANN, A. & ROEBERS, C., M. (2014). *"Cognitive and physiological effects of an acute physical activity intervention in elementary school children".* Frontiers in Psychology, 5, 1.

LATINO, F., FISCHETTI, F., COLELLA D., (2020), *"The influence of physical activity on school-age children's cognitive function and academic performance: a review of the literature*". Formazione & Insegnamento XVIII – 3 – 2.

MAROTTA, LUIGI, AND PAMELA VARVARA. (2013), "*Funzioni esecutive nei DSA. Disturbo di lettura: valutazione e intervento"*. Edizioni Erickson.

OLIVIERI, D., (2017), *"Mente-corpo, cervello, educazione: L'educazione fisica nell'ottica delle neuroscienze Mind-body, brain, education: A neuroscience perspective about physical education".* Formazione & Insegnamento XIV – 1 – ISSN.

ORSINI, A., PEZZUTI, L. E PICONE, L. (2012). *"WISC-IV. Contributo alla taratura italiana*". Giunti O.S. Organizzazioni Speciali, Firenze.

REILLY, E., BUSKIST, C., GROSS, M. K. (2012), *"Movement in the classroom: Boosting brainpow-er, fighting obesity Kappa Delta Pi Record*". 48 (2), 62-66.

SAWAMOTO N, PICCINI P, HOTTON G, PAVESE N, THIELEMANS K, BROOKS DJ. (2008), *"Cognitive deficits and striato-frontal dopamine release in Parkinson's disease"* May;131(Pt 5):1294-302.

SCHMITT, A., UPADHYAY, N., MARTIN, J. A., ROJAS, S., STRÜDER, H. K., & BOECKER, H. (2019). *“Modulation of distinct intrinsic resting state brain networks by acute exercise bouts of differing intensity*”. Brain Plasticity, 5(1), 39-55.

SIBILIO, M., (2005) *“Lo sport come percorso educativo: attività sportive e forme intellettive”,* Guida Editori.

SUTTON, J. (2007). *“Batting, Habit and Memory. The Embodied Mind and the Nature of Skill*”. *Sport and Society*, *10*(5), 763-786.

VAN LUIT, J.; VAN DE RIJT, B.; BENVENUTO, G.; GONZÁLEZ, S. M.; LANCIANO, N.; PASSOLUNGHI, M. C. (2018) *"Il test: Valutazione Precoce della Competenza Matematica (VPCM). Come è fatto e come utilizzarlo".*

VAN PRAAG, H. (2009). *“Exercise and the Brain: Something to chew on”.* Trends in Neuro-science, 32 (5), 283-290.

VAN, M. (2012). *“Movement in learning: Revitalizing the classroom”.* Brattleboro, VT: SIT Grad- uate Institute.