

A Study on the Correlation between Intelligence and Spatial Orientation in Children Who Practice Chess at School

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Abstract: *The game of chess requires many hours of training in order to achieve the title of FIDE Master. The complex nature of the game requires higher cognitive skills and implicitly helps their development. We selected 2 third grade classes that have a total number of 67 pupils. They were assessed initially and finally to measure the intelligence quotient (I.Q.) and the level of spatial orientation. For testing the I.Q., we used the Raven Progressive Matrix and for the level of spatial orientation, the Bender-Santucci test. To check if the progress is statistically significant, we used paired samples t-test and calculated Cohen's d to quantify how large the difference between the two tests is. We performed a simple linear regression between intelligence and spatial orientation to see if the intelligence quotient is a predictor of the level of spatial orientation. We discover an upward regression line between I.Q. and spatial orientation. In conclusion, the level of spatial orientation can be improved through chess and this will positively influence the student's academic progress.*

Keywords: *psychomotor intervention; childhood; primary school childhood; psychomotor development.*

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Introduction

Chess is a sport that requires higher cognitive processes (Blanch et al., 2020) where the alternation of logical and analytical thinking is essential. It represents the ideal tool for studying cognitive processes such as: anticipation (Sala et al., 2016), distribution of attention (Guntz et al., 2019; Velea & Cojocaru, 2018) pattern recognition (Gobet & Simon, 1998), creativity (Gliga & Flesner, 2014; Ayperi & Sigirtmac, 2016), speed information processing (Joseph et al., 2018), working memory (Joseph et al., 2019), analytical thinking (Stegariu & Iacob, 2020), problem solving abilities (Unterrainer et al., 2006) or stress resistance (Guntz et al., 2018). The main correlation that represents the foundation of re-search with the independent variable chess, is the one between chess practice and intelligence (Bilalic et al., 2007; Kazemi et al., 2012; Grabner, 2014; Hong & Bart, 2006; Milat, 1997; Mirzakhanyana et al., 2016; Wessel & Aciego, 2017). Reference studies have been carried out since 1973 when Dr. Frank (Frank & D'Hondt, 1979) made the first exper-imental research on chess players. The favorable results encouraged Ferguson (1986) to initiate a research program started in 1979 with the aim of providing challenges designed to stimulate the development of students' critical and creative thinking. Based on these results, F.I.D.E. (Fédération Internationale des Échecs) organized a meeting to discuss the issue of introducing chess into schools. The main arguments highlighted were that chess improves memory, enhances creativity and develops higher cognitive processes. This evolution culminated with the decision of the European Parliament on March 13, 2012 to promote chess as a pedagogical tool in the educational system (De Jorge-Moreno, 2020).

The justification by which chess is considered a sport is given by the fact that there are many similarities at the level of training and competition. The only difference is that the chess game does not involve physical effort, but the physiological effects are similar to those of a marathon runner (Golf, 2015). This aspect shows us that it is physically demanding to maintain the same level of concen- tration during a classical chess game (Gentile et al., 2018).

Chess represents the ideal environment to observe how an individual evolves in the process of reaching high performance, especially since in this sport there are no stereotypes (Blanch, 2016; Stafford, 2016), age, gender, background do not influence the course chess, on the contrary, it has been shown that, from a statistical point of view, female subjects perform better than male subjects (Stafford, 2018). Therefore, this is the environment in which the interaction between intellectual abilities and

emotion management can be analyzed (Avni et al., 1990). There are few studies that have focused on identifying the chess player's personality (Klein-Vollstädt et al., 2010), and one of the reasons may be the existence of the chess value measurement method (Elo, 1978) that quantifies this skill in an objective way. The relative scaling of the players masks the importance of some skills essential to achieving performance, such as: spatial orientation, attention, concentration, courage, etc.

Success in fields where the amount of information is huge depends on several specific but also non-specific skills (Ackerman, 1996). In the case of chess, the main notions to be assimilated are those over which the player has no substantial influence, such as: the early phase of the openings and the last part of the endgames (Blanch & Llaveria, 2021). Here the notions are clear and their validation has been seen in grandmaster games and with the help of engines that clearly highlight the correct sequence of moves. Also, many webpages have appeared recently (2020-2022) that allow practicing and playing chess online in an environment that simulates the classic version of training (Fuentes-Garcia et al., 2019). We can say that there is a parallel between the general development of the child and the chess player, because in the early phase it is based on non-specific skills such as: managing emotions, courage/fear, impulsiveness etc. The first specific skills are rudimentary and the formation of representations is precarious, taking on a form different from the real one. In the case of chess, there are valuable principles that apply to all players, but their interpretation and use is subject to individual understanding. One such principle was enunciated by Siegbert Tarrasch: "Every move creates a weakness!". By simply moving any piece, a movement of forces is generated. Smaller if a pawn is moved, or larger if the queen is moved, and this generates tension in one point of the board, but leaves defenseless another. It should also be noted that the pawn is the only piece that is not allowed to move backwards which means that the weaknesses created are permanent. If in the case of beginners, the moves are made based on superficial thinking, in that of the grandmasters, they are based on a thought process well anchored in the particularities of the position on the board. Even in the case of blitz games where thinking time is limited (around 5 minutes for each player), the principles are strictly respected, and the time scramble does not affect the thinking process (Chang & Lane, 2016; Van Harreveld et al., 2007).

After presenting some aspects specific to the game of chess and how they influence and are influenced by intelligence, in the following paragraphs we will analyze one of the psychomotor skills, spatial orientation, from two perspectives: chess - spatial orientation and education - spatial orientation.

Psychomotricity is a complex process through which the education and development of motor functions is carried out simultaneously with mental ones, resulting in the dynamic integration of the individual in the surrounding environment (Abălașei, 2011). Even if until recently psychomotricity belonged to the field of psychology, starting from the first half of the 20th century, the importance of motor function was highlighted (Bălănean et al., 2022). It should be noted that it is not limited to motor activity but includes the entire scheme of adaptation of the individual to the demands of life, observing and analyzing the manifestations of the perceptive functions coordinated by the intellect in response to the excitation of stimuli (Stegariu & Abălașei, 2022). Basic psychomotor skills are constantly evolving, being strongly influenced by the input of education, physical and intellectual development and habitual actions. An effective development of the child gives him a good overall dynamic coordination and spatial orientation (Pacheco et al., 2022). In the preschool phase, the child discovers the world using motor acts as the main means. A lack of coordination between intellectual and motor skills can be seen. Thus, the motor act is a reflex to various stimuli, later coming under the tutelage of the psyche. With the transition to school life, we witness an acceleration of the development of intellectual functions, and in this phase, we can observe a detachment of the intellectual component because most of the motor activity becomes automatic. The development of cognitive functions in children is closely related to the evolution of sensori-motor structures because they represent the foundation for using the fundamental operations of thinking. We can say that intelligence arises from action, based on the transformations of perception of objects and phenomena in the environment. Therefore, it is necessary to observe and analyze the evolution of perceptions in order to understand the overall development of children. Space and time are the benchmarks to which we relate any activity carried out, either by the objects in the environment (Morawietz & Muehlbauer, 2021) or by the person himself. These two elements define the structure of the environment within which people operate. The spatial relationships already known to children are general: near, next to, above etc, but they become clear when the units of measurement are included in school activities, thus creating spatial representations (Fernandez-Baizan et al., 2021). In the first phase, the estimation will be deficient through addition, and towards the end of the primary cycle, students will underestimate distances and sizes (Schiopu & Verza, 1997).

The importance of spatial orientation is given by the daily use of spatial concepts in various areas of their lives (Bălănean et al., 2022), and the

most important aspect is used at school where it plays an essential role in learning the skill of writing. According to Muntianu et al., (2022), there is a close relationship between spatial orientation, eye-hand coordination and general dynamic coordination, a fact that increases the importance of developing spatial orientation during the primary cycle.

During the chess game we can talk about two spatial aspects: the placement of the pieces in the center of the square and the distribution of forces in certain areas of the board to serve specific purposes (Stegariu and Abălașei, 2022). During the learning period, the movement, value and way of capturing the pieces is presented in the absence of adversity thus, spatiality and spatial orientation is wrongly perceived. The next stage involves understanding the nature of the game of chess, and the fact that the opponent has exactly the same goal generates a series of critical thoughts. The first reflex, similar to that of conservation, is triggered when an opposing piece enters its own half to attack. The child tends to make chaotic moves wanting to get away from the danger. Simultaneously with the evolution of chess, the spatial orientation develops, which involves the awareness of important squares, the way of exploitation, but also the dynamics of the pieces in this context. The need to control all of your own side of the board disappears, and breaking into the enemy camp will not be scary.

Due to the complex nature of the chess game, we assume that higher cognitive processes are required, generating a clear definition of spatiality, and this evolution is essential in the child's maturation process.

Materials and Methods

The purpose of this study is to observe the evolution of two primary school classes that study chess as an optional subject since the First Grade. The observed abilities are spatial orientation and intelligence quotient (IQ) and to determine whether intelligence can be considered a predictor of spatial orientation, we performed a simple linear regression. In order to check if the differences between the initial and final tests are statistically significant, we used Paired samples t-test and the probability of superiority was revealed using Cohen's d. This is used complementary to ANOVA or t-test to quantify how large the difference between the two tests is.

The research subjects are the same as in Stegariu et al., (2022), only the psychomotor abilities differ. That article was focused on the analysis of the body schema, a psychomotor ability that is necessary for the process of growth and development, while in this research our attention was directed towards spatial orientation. Sixty-seven students from the third-grade who studied chess once a week were retested. Of the 67 students, 31 were boys and

36 were girls. The activity is included in the school curriculum as an optional subject at the school's decision, and each class is responsible for choosing the subject they will study. In the case of these two classes, the decision was taken by unanimous vote each year so students have studied chess since first grade. Testing took place at the end of the first semester of third and fourth grade respectively. This decision was made because it was desired to include the summer vacation between the two tests so we can talk about a 12-month period between the two tests.

We chose these two classes because they had the same teacher from the first lesson until the end of primary school. Also, absolutely all students in the two classes were included regardless of gender, background, grades or chess value. We mention that no child has any special condition so we can state that there was no selection bias that could have influenced the results [38]. We did not do a power analysis to validate the sample size because we were interested in presenting an overview of a group of pupils studying chess in school.

According to Sala et al., (2016), the ideal design for experimental research involves the selection of three groups, control, experimental and placebo. The control group does not perform any activity, they follow the normal course. The experimental is the essence, they study chess and their results are what we are looking for and the placebo group is used to counteract the situation where a group of students perform better because they have inoculated the idea that they are better prepared, thus generating better concentration and desire to solve the tests.

To quantify the level of intelligence and spatial orientation, we used the Raven's Progressive Matrices test and the Bender-Santucci test. Raven progressive matrices is a test that involves solving five sets of multiple-choice items of abstract reasoning. Each exercise has an abstract pattern presented as a matrix where the piece in the bottom right corner is missing and underneath there are several pieces that can complete the figure (Brouwers et al., 2009). The student has to choose the one that completes the figure while respecting the rule of unfolding the elements inside. In order not to affect performance, students must provide the solution without presenting their thought process (Song et al., 2021). Raven's Progressive Matrices are divided into 5 sets of 12 items, ordered from simple to complex both within the series and overall (Qiu et al., 2020). The first three series (A, B, C) offer 6 possibilities to complete the item's figure, and the last two (D and E) have 8. Each series imposes a different pattern that is not presented or described above and these are described by Stegariu et al., (2022). To understand how this test should be applied, we recommend consulting the

following articles: Kunda et al., (2016), Malkinski & Mandziuk (2022), Song et al., (2021) and Waschl et al., (2016).

The Bender-Santucci test assesses perceptual-motor function which refers to the child's ability to correctly perceive spatial details in order to compare and reproduce them (Vrasmas, 2003). Thus, we can speak of a practical intelligence essential in the teaching process. This test requires to duplicate five graphic models (Figure 1) without any help.

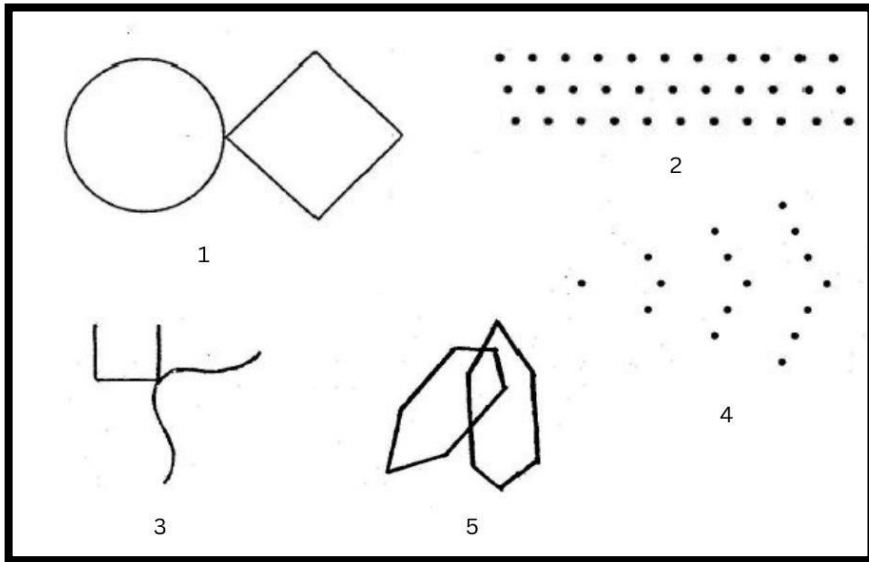


Figure 1. Bender-Santucci test (Vlad, 1999)

The drawings are shown in sequence without imposing a working time, but this can be timed to get a better overview. The child is given an A4 sheet and a writing instrument and no eraser or ruler. He has to fit all 5 drawings on one sheet, if they made a mistake and want a new sheet, they will get one. Marking is done punctually from 3 perspectives:

- Angles;
- Orientation of elements;
- Relative position of the figure or elements within it (Vlad, 1999).

The drawings are scored differently, as follows: 1 - 10 points; 2 - 8 points; 3 - 11 points; 4 - 11 points and 5 - 10 points. Thus, the maximum score the child can get is 50 points. To understand how the results are analyzed and interpreted, we recommend this book written by Vlad (1999).

Both tests do not impose a time limit in which students must solve the tasks, but the Raven test was solved in 25-30 minutes and each model in

the Bender-Santucci test took about 2 minutes, resulting in an average solving time of 10 minutes. Once they had received the necessary instructions and the coordinator ensured that the students understood, there was no further external intervention. Every question asked by the students was answered with: "Do as you want!" (Stegariu & Abălașei, 2022).

Statistical operations were carried out using IBM SPSS Statistics 20 software and Microsoft Excel.

Results

Following the application of the two tests, we recorded the following values which are presented in tables 1 and 2.

Table 1. Descriptive Statistics (Stegariu & Abălașei, 2022)

		N	Min	Max	Mean	Std. Dev.
Raven	Initial	67	13	55	39.57	8.22
	Final		9	58	42.58	7.16
Bender-Santucci	Initial		20	42	29.37	4.88
	Final		17	44	35.06	4.74

Table 2. Paired samples t-test (Stegariu & Abălașei, 2022)

Tests	N	Correlation	t	p	Cohen's d
Raven	67	0.769	-4.587	0.000	0.3867
Bender-Santucci		0.648	-11.515	0.000	1.1654

We can see that at the Raven test, the final results are superior to the initial ones and this outcome can be considered surprising because the initial average of 39.57 units falls into the category of *intelligence above the average level*. The final result represents the transition to a higher category, *superior intelligence*. It should also be noted that the minimum value from the final test was an accidental one if we consider the results recorded by the student B.R., but he answered affirmatively when asked if he understood the task. Accepting the initial value as the closest to its actual level implies an improvement in the collective average (over 43 units).

The Bender-Santucci test has a similar distribution of results, where the initial mean value is in the first category, but the progress of the group is so spectacular that the final results fit in the first category related to the age of 12 years (2 years more than the average age!). We notice that the final minimum value is lower than the initial one, but even under these

conditions, the group managed to progress. The standard deviation keeps approximately the same value thus, we can assume that the group is homogeneous.

In order to check whether the numerical differences are statistically significant, we applied the Paired Samples t-test, where the p-value is <0.000 in both cases. We also verified the level of correlation between the initial and final values in both tests and this was done to eliminate the possibility of having a couple of spectacular results that generated the collective progress. We note that in the Raven test we recorded a strong positive correlation (0.769) and in the Bender-Santucci test, a moderate-strong correlation (0.648). These values validate collective progress.

In order to provide a clearer perspective of the evolution, in addition to the Paired Samples t-test, we also calculated Cohen's d. A statistically significant result does not imply a practical superiority; therefore, it is recommended to calculate it. We can see that in the case of the Raven sample there is a 60.9% probability that a randomly chosen child will have a better final result, and 65.2% of the final results are higher than the collective average from the initial testing. In the case of the Bender-Santucci test, the value (**1.1654**) shows that the difference between the two means is greater than the standard deviation. Therefore, we can say that an accidental final result will have a higher value than the one obtained in the initial testing.

In figure 2, we have shown the distribution of the results recorded in the Raven test. We can see that the percentage of students with a higher intelligence has more than doubled (12% \rightarrow 26%). In the case of those with average intelligence, the percentage dropped significantly (39% \rightarrow 30%). In the other three categories the values remained approximately unchanged.

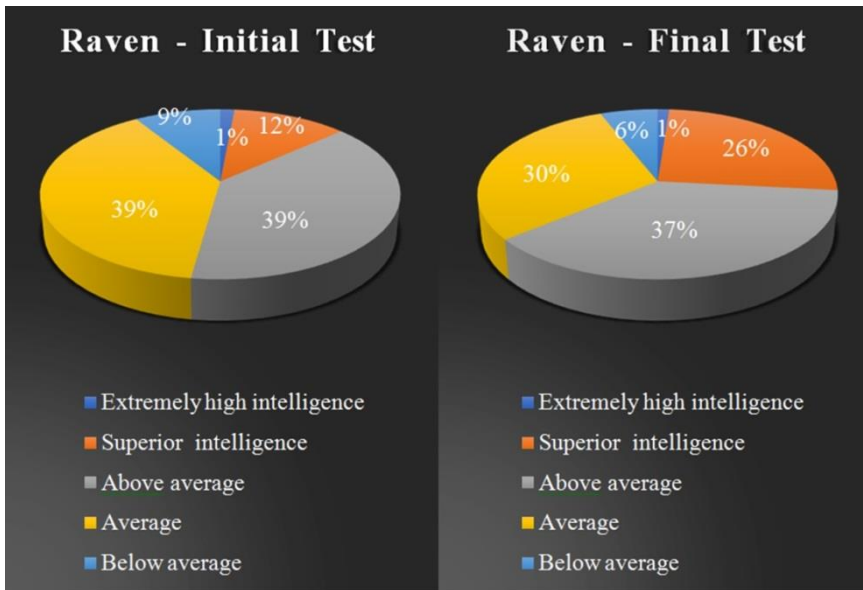


Figure 2. Raven results distribution – initial and final (Stegariu & Abălășei, 2022)

Figure 3 shows the distribution of the results from the Bender-Santucci test. We can see that the initial result is a very good one, because 84% of the students are in the first category. Even under these conditions, the percentage was improved to 97%, but the progress was so spectacular that it falls into the first category in the upper age group.

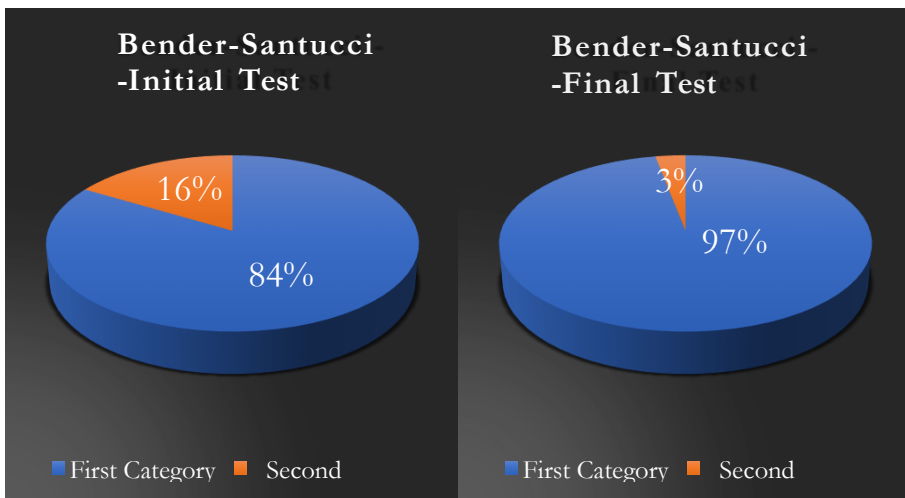


Figure 3. Bender-Santucci results distribution – initial and final (authors own conception)

According to table 3, we can see that there is a moderate positive correlation (0.50) between the results of the two tests. Also, R^2 shows in what proportion the independent variable is a predictor for the dependent one. Thus, the intelligence quotient influences the development of the ability of spatial orientation in a proportion of 25%.

Table 3. Regression statistics – Raven - Bender-Santucci (Stegariu & Abălașei, 2022)

Multiple R	R ²	Adjusted R ²	Standard Error	Observations
0.50	0.25	0.24	4.13	67

To validate the regression equation, the value of p must be less than 0.05 and the intersection with the Oy axis must differ from 0. According to table 4, we notice that the value of p (0.000) is less than 0.05 so we must reject the null hypothesis which stated that there is no linear relationship between intelligence and spatial orientation. Also, the point where the regression line intersects the Oy axis has the value 20.85, different from 0.

Table 4. Simple linear Regression – Raven - Bender-Santucci (Stegariu & Abălașei, 2022)

	Coefficients	Standard Error	t Stat	p-Value
Intercept	20.85	3.07	6.79	0.000
X Variable	0.33	0.640.078	4.69	0.000

With the help of the intercept value (20.85) we can present the simplest regression equation: Predicted variable = $0.33 \times \text{I.Q.} + 20.85$. If we enter the value of 38 obtained in the Raven test that places the student in the category *intelligence above the average level*, we obtain a predicted value of 33.39 in the Bender-Santucci test. This falls into the first category related to the age of 12.

As it can be seen in figure 4, we obtained an upward regression line between I.Q. and spatial orientation. We can observe an accidental result recorded in the Raven test that influenced to some extent the trajectory of the regression line. In this figure it can be seen that most of the results are in the range of 40-50 units for the Raven test, respectively 30-40 for the Bender-Santucci test.

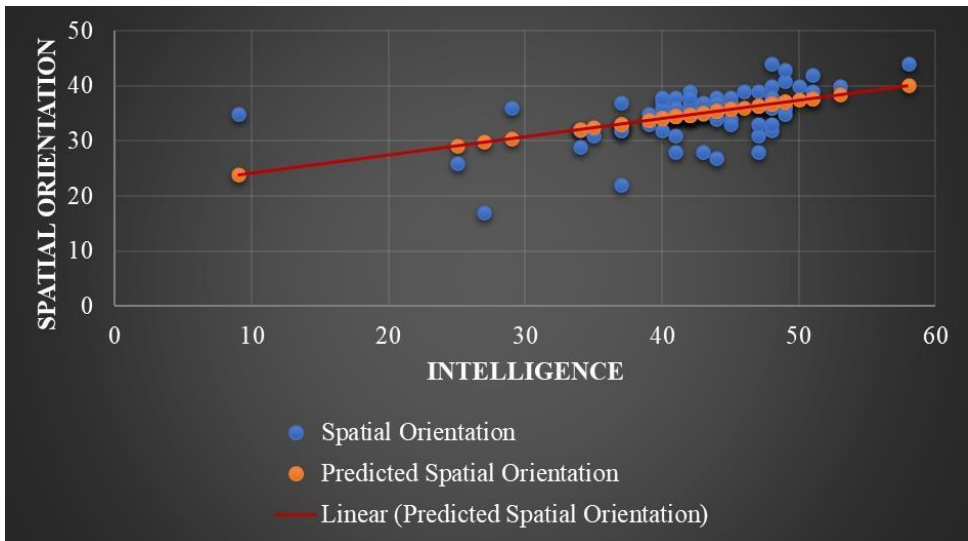


Figure 4. Simple linear Regression – Raven - Bender-Santucci (Stegariu & Abălașei, 2022)

Discussion

Thinking plays an essential role in everyday life and how we think shapes our actions and defines our daily existence. It helps us to establish the goals on the basis of which we make decisions (Baron, 2000). The mind can be compared to a neural computer, which has as its operating system a large number of algorithms based on causal and probabilistic reasoning about the elements of the environment.

The game of chess stimulates the intensity of the thinking process through the constant flow of information processed by the brain, which leads to the regulation of the processes of accumulation, analysis and processing of the material with which the individual comes into contact. This process is very beneficial because it increases the general level of intelligence by accumulating relevant information that people use in various daily activities (Alifirov et al., 2019). The percentage of situations during a game where the number of ideas behind the candidate moves is bigger than 1 exceeds 90%, rare being the cases where only one move maintains balance. The chess player is bound to check, at least on a superficial level, at least 2 wins almost every move (Stegariu & Abălașei, 2022).

Scientific notions are obtained following a process of synthesis and include only the essential features of the environment highlighting the laws that guide it. This way of ordering the thought process is always present on the chessboard. In addition to the general rules that make the game possible,

there are numerous laws that direct the events on the chessboard. An example would be: The knight moved to the edge of the board is a mistake. Starting from the way the knight moves we notice that there are 8 squares available, 4 to the right and 4 to the left. Placed at the edge of the board, the option to move sideways can only be done in one direction, thus, out of the 8 squares, 4 remain (Stegariu & Abălașei, 2022).

When analyzing a position at one point in the game one tries to observe several key elements of the chess game and the results are accumulated to provide a verdict on the status of the position. Checked elements include: king safety, material balance, immediate threats, pawn structure, etc. Regardless of the complexity of the position it can be classified as equal, better for white or better for black. We note that the game of chess involves a transition from abstract to concise where the child perceives the evolution of events during the game. These clear perceptions form the basis of the judgments that the child operationalizes every time he is in front of the chessboard (Stegariu & Abălașei, 2022).

It has been shown that constant neural activity, specific to higher cognitive processes such as thinking, memorizing or distributing attention during a chess game, produces a deep engagement of the nervous system. This change generates adaptations that are felt throughout the body as the brain creates systems to regulate and self-regulate physiological functions. The more complex the process of logical thinking, the more neural formations of the axons - dendrites - synapses type are used (Stegariu & Abălașei, 2022). Since students of this generation love to play, we believe that practicing a sport like chess will improve their critical thinking and problem-solving skills.

For the measurement of the intelligence quotient, we opted for the Raven Progressive Matrix because the format of the test assumes many similarities with the game of chess. The main aspect is given by the fact that each item follows a logical pattern that propagates inside the series. Also, the child is not told what logical principle he must follow to solve the item, only that there is one. These two traits are found in every game of chess and failing to observe them often leads to unfounded decisions that are easily punished (Stegariu & Abălașei, 2022).

The Raven testing revealed the collective intelligence level, which at the beginning was *above the average level* and at the end, *superior intelligence*. It should be noted that the initial level is high and its improvement represents a spectacular progress. On the final test, one student had an accidental result that affected the collective mean, although he claimed to have understood the task. The ability to reason with abstract elements plays an essential role in the

child's maturation process. An interesting analogy between the fundamental laws of chess and their applicability in everyday life is presented in the book *How life imitates chess* (Kasparov, 2008).

The Bender-Santucci test measured the level of spatial orientation of the research subjects and at initial testing, the majority (84%) fits in the first category for their age. The recorded values are spectacular and the high level of correlation between the two skills (I.Q. and spatial orientation) indicates, on a superficial level, the existence of a codependency. The progress is satisfactory, especially since 97% of the final results fits into the first category in an older age group. The ability to perceive forms and subsequently to reproduce or use them in another given context represents a milestone in the teaching process. During a game of chess, the child discovers the value and importance of the pieces when he wants to realize a plan and notices that the pieces left on the board cannot serve that purpose. In addition to this aspect, the simple way of moving the pieces divides the board into different shapes, for example: in bishop endgames, the child realizes that on the opposite color cannot generate threats and a simple move of the pawn from white to black can mean his salvation. Also, the fact that the rook moves linearly, and the pawn is not allowed to change the file, will generate a reflex to attack that pawn frontally. The queen's movement turns the fight between it and any piece (except the opponent's queen) into a siege, where the outside intervention of another piece is vital. The area in which one's own or the opponent's king is located takes on special importance, since a precisely executed invasion can lead to victory. All these examples reinforce the idea that the game of chess educates the ability of spatial orientation.

Spatiality is essential in the game of chess from several perspectives and the most important connection with school life is given by the affective component. The sense of ownership of the objects he uses at school is identical to that of his own pieces and the loss of some of these generates strongly felt emotions. His half the board is a place where he feels safe and any opposing move that defies this aspect triggers the conservation instinct. The same thing happens when a colleague takes his seat (Stegariu & Abălașei, 2022). This ability is more present at boys than at girls and due to the fact that there is a correlation between intelligence and spatial orientation, it can represent a possible explanation why males are better represented than females among top chess players (Frydman & Lynn, 1992). The link between chess and intelligence represents the main interest of several studies and to have a clearer picture we recommend reading the following works (Alifirov et al., 2018; Burgoyne et al., 2016; Cibeira et al., 2021; Gao et al., 2021; Kakoma & Giannakopoulos, 2016; Sala et al., 2017)

We used linear regression to show whether the intelligence quotient can be considered a predictor of the level of spatial orientation. According to the data presented in table 3, the intelligence quotient can be considered a predictor of the level of spatial orientation to the extent of 25%. We consider this value to be significant, and if we take into account the age of the subjects, we see the importance of studying chess.

The choosing of the two tests was an important step in the conduct of this research and the age of the subjects was a decisive factor. There are limitations of the research that we tried to combat by using an applied experimental design and for this reason we recommend duplicating the research on a significantly larger number of subjects. It can also be extended over the course of an educational cycle where the role of intelligence in the processes of growth and development can be observed in depth.

Conclusions

The I.Q. is a predictor of the level of spatial orientation. Practicing chess is associated with superior cognitive abilities [57-62] thus, we can say that students who study chess in school will benefit from a multilateral development.

Related to the subjects of the research and the context in which they practiced chess, we can state that the intelligence quotient is a predictor of the level of spatial orientation at a percentage of 25%.

Due to the fact that spatial orientation is vital in the didactic process, we can say that chess represents a solution for enriching the school offer. Also, the competitive side of chess educates respect and develops fair play which have an important role in the development of children's socio-cultural skills. Highlighting the relationship between intelligence and spatial orientation can represent a starting point for research focused on the link between intelligence and psychomotor abilities in students who study chess.

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