

Neuroscientific evidence support that chess improves academic performance in school

Ricardo Ortiz-Pulido^{1*}, Raúl Ortiz-Pulido², Luis I. García-Hernández³, César A. Pérez-Estudillo³ and María L. Ramírez-Ortega⁴

¹Dirección General Federalizada de Educación Física, Subsecretaría de Educación de Veracruz, Veracruz; ²Laboratorio de Ecología de Poblaciones, Centro de Investigaciones Biológicas, Universidad Autónoma del Estado de Hidalgo, Hidalgo; ³Centro de Investigaciones Cerebrales, Universidad Veracruzana; ⁴Jardín de Niños "Obrero Campesino". Xalapa, Veracruz, México

Abstract

In this work, we report the cognitive benefits of playing chess for school-aged children. The most benefitted areas appear to be math and reading. To validate these results, a diversity of scientific studies are described, in which brain activation is demonstrated through magnetic resonance imaging when novice, intermediate, and advance chess players play the game. Given this evidence, it is suggested that chess be used as a tool to improve academic performance in boys and girls. In addition, it is concluded that studying the use of chess could lead to new lines of research that could validate the neural mechanisms that occur when boys and girls play chess.

Key words: Chess. School. Boys. Girls. Academic performance.

Evidencia neurocientífica apoya que el ajedrez mejora el rendimiento académico en la escuela

Resumen

En este trabajo se reportan los beneficios cognitivos que produce la práctica del ajedrez en niños en edad escolar. Las áreas más beneficiadas parecen ser las matemáticas y la lectura. Para validar lo anterior se describen diversos trabajos científicos que muestran la activación cerebral a través de imágenes de resonancia magnética cuando los jugadores de ajedrez novatos, intermedios o avanzados practican este juego. Con base en ello se sugiere usar el ajedrez como una herramienta que permita la mejora del rendimiento escolar en niños y niñas. Se concluye además que a partir de la utilización de este juego se pueden generar líneas de investigación que busquen validar mecanismos neurales que ocurren cuando niños y niñas juegan ajedrez.

Palabras clave: Ajedrez. Escuela. Niños. Niñas. Rendimiento escolar.

Correspondence:

*Ricardo Ortiz Pulido
Callelano Rodríguez Beltrán, s/n
Col. Centro

Xalapa, Veracruz, México
E-mail: pulidoortizricardo@gmail.com
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Introduction

Chess is a game that allows the transfer of cognitive abilities¹. This is due to the fact that it involves high-level cognitive aspects, requires sophisticated problem-solving abilities²⁻⁵, has a positive impact on academic achievements of those who play it⁶ and positive effects on mental development. This may be because, during the game of chess, cognitive abilities⁷ such as creativity, anticipation, perception, and memory⁵ are used. Chess, in addition, offers an opportunity to study individual differences in cognitive processes³.

Regardless of grade level, chess can be used as a learning tool in boys and girls, since this game allows them to self-regulate their learning and reach specific objectives⁸. In addition, through diverse chess problems, the level of knowledge of boys and girls in similar activities can be determined⁹. This is because chess has a complex rule system, and knowledge depends on each student's individual level⁵. Similarly, regardless of the level of the game performance of each individual, neuroimaging studies have shown brain activation during game play¹⁰.

The objective of this work is to present scientifically validated information demonstrating that chess is a useful tool for improving boys' and girls' academic performance in school. To do so, diversity of studies is described in which chess players are evaluated using functional magnetic resonance imaging (fMRI). After analyzing these studies, we suggest that chess can be used as a tool to improve learning in school-aged boys and girls.

Chess in schools

Playing chess, both in and outside of school, has a large potential for developing academic knowledge in children^{11,12}. In Mexico, the level of academic performance by each child can be quantified, since their performance is evaluated and they receive a grade score for their performance in mathematics and Spanish. However, chess playing is not graded. Even so, a variety of benefits, apparently indicating a positive impact of playing chess on mathematics and reading scores have been reported.

In recent studies, it has been reported that teaching chess yields benefits in school^{7,9,11,13,14}. These benefits have been detected, particularly in children's math^{12,15-21} (Table 1) and reading comprehension scores²²⁻²⁵ (Table 2), though the effect is not the same between the two subjects. According to a recent meta-analysis

evaluating which of the two subject areas (math or reading) is most benefitted, the area most positively impacted was math²⁶. This may be because the game cultivates a high level of non-specific skills (for example, persistence, self-control, objectivity, memory, and problem-solving) which are relevant to academic performance overall²⁷.

Playing and training for chess have been considered an important learning tool in education¹², leading to some institutions to incorporate it into their school curricula¹ or as an afterschool extracurricular activity. Notwithstanding, increased dissemination of the benefits of this game among education officials at the federal, state, and municipal levels is needed so that they will support initiatives in favor of educational spaces in the schools, and as such, bring the benefits of chess to schools.

Chess allows boys and girls to obtain benefits in diverse cognitive areas^{4,11,16,22,28}; it has been shown that subjects that play chess improves their spatial reasoning, long-term planning, decision-making, memory¹¹, cognitive development, academic performance^{4,5}, and strategic, creative, and critical thinking⁵. At the same time, chess can be used to evaluate cognitive processes, for example, by asking children to place the game pieces on the board in random order or standard positions²⁹. However, further investigation is needed to describe the effects of this science game.

In this work, we describe some of the research reporting a positive effect of chess on academic performance, spatial concepts, executive functions, and basic cognitive, and social skills.

Studies evaluating the effects of chess

The results presented here showed a positive effect on the educational process of boys and girls who received training in chess.

In a study in Seoul, South Korea, it was found that presenting students with a heuristic chess problem were helpful for evaluating students' intellectual levels and using that knowledge, choose adequate methodologies for improving each student's level of academic performance¹. The study was carried out among 38 students aged 8-12, divided into two categories: (1) those with high intellectual level and (2) those at risk of failing the school year, from three different primary schools¹.

Another study showed that a group that trained in chess improved basic skills (i.e., attention and

Table 1. Some of the research in which chess has been found to impact mathematics performance in school

Author(s)	Country	N	Study objective	Tests	Results
Fernández-Amigo et al. ¹⁵	Spain	N = 141 experimental group (79 boys, 62 girls)	Analyze, qualitatively and quantitatively, the utility of instructional materials using chess for teaching mathematics during the second grade of primary school	EFAI ("Evaluación factorial de las aptitudes intelectuales", in English, Factorial Evaluation of Intellectual Aptitudes) ²⁹ Numerical score, reasoning score, ethnographic interview, surveys	Satisfaction was achieved in the utility of the chess - based learning materials for teaching mathematics
Achig ¹⁷	Ecuador	N = 35 experimental group (20 boys, 15 girls)	Test the impact of chess on logical-mathematical reasoning in sixth-grade primary school students	Theoretical chess test before and after, Mathematics class score	The average math class score increased
Guerrero et al. ¹⁸	Mexico	N = 32 The number of boys versus girls is not given	Describe the effect of chess on basic mathematical operations in fifth-grade primary school students	Pre-test and post-test on fractions and operations based on ENLACE 2011 and 2012 test questions, surveys and interviews	Better concentration, and memory and higher math class score
Gumede and Rosholt ¹⁹	Denmark	N = 264 The number of boys versus girls is not given	Characterize the impact of chess in the subject of mathematics in first-and third-grade primary school students	Pre-intervention tests, characteristics of the child and the child's mother and father	Positive effects in both immigrant and non-immigrant Danish children
Sala et al. ²⁰	Italy	N = 309 experimental group (169 boys, 140 girls). N = 251 control group (116 boys, 135 girls).	Investigate the potential of online chess lessons on problem-solving abilities in second, fourth, and fifth-grade primary school students	Programme for International Student Assessment and chess survey following Trinchero ²⁸ Item 12	Highly positive correlation between math score and chess in the experimental group
Sala et al. ²¹	Italy	N = 309 experimental group (169 boys, 140 girls) N = 251 control group (116 boys, 135 girls)	Experimental study of chess in fourth grade primary school students using a placebo group	Six tests evaluating mathematics abilities, IEA – TIMSS ³¹ psychometric test	The chess group was more effective in math skills than the GO group, but not in school activities
Rosholt et al. ¹²	Denmark	N = 323 experimental group. N = 159 control group	Analyze the effect of replacing one mathematics lesson per week with one based on chess instruction in first and third grade primary school students	Mathematics test (including calculations, geometry, pattern recognition, and basic problem solving)	Improvement in the composition of mathematical sequences in the experimental group

memory), complex cognitive skills (e.g., association, analysis, synthesis, planning, and foresight), and social-personal skills, compared to two control groups – one that did not participate in chess or any sport and another that played soccer and basketball¹⁴.

In another study, the effect of training in chess in 6-year-old children showed an increase in spatial

concept comprehension compared to a group of children that did not play chess⁷; and finally, a study showed that children who trained in chess had higher results on evaluations of executive function than those that did not¹³.

These results have caught the attention of neuroscientists, who have begun to describe brain activation when children participate in the game of chess.

Table 2. List of research papers investigating the impact of chess on reading comprehension in school

Author(s)	Country	Number of participants	Study objective	Tests	Results
Margulies et al. ²²	United States of America	N = 1118 Groups of participants N = 22	Escribe the effect on reading before and after chess instruction in primary school	Degree of reading power test (DRP)	The group of chess students improved more than the average student
Liptrap et al. ²³	United States of America	N = 571 total Chess group N = 67 Group that did not play chess N = 504	Determine the degree of participation by students in a chess club	Texas Assessment of Academic Skills (TAAS). Texas Learning Index (TLI)	The chess group improved more in math skills than in reading
Duccette ²⁴	United States of America	Experimental group N = 151	Analyze the effect of a chess program on behavior, math, and reading	Philadelphia's behavior grade and attendance, Pennsylvania System of school Achievement (PSSA) score in Reading and mathematics	After 1 year, the group that played chess improved in math and reading, and these values were correlated, while in the control group none of these patterns were present
Dapica-Tejada ²⁵	Spain	N = 60 Total Chess group N = 30 (21 boys, 9 girls) Control Group N = 30 (20 boys, 10 girls)	Test whether there are significant differences in reading comprehension and saccadic movements (SM*) in boys and girls that play chess	Chess participation survey, PROLEC-SE battery of tests of reading processes and the King Devick SM test	The chess group improved on the different tests by which they were evaluated, which did not occur in the no-chess group. In addition, there was a correlation between SM and reading comprehension and between chess and SM

*SM are produced in the eyes when we read, look, or search for information, refers to movement speeds of 500°/S. During these MS, the eyes can remain still for intervals of around 200-300 ms.

Brain activation while playing chess

fMRI is one of the most important scientific advances since it allows the development of the cognitive sciences in ways never seen before. This is because fMRI allows a detailed study of brain cartography, and therefore, characterization of brain functions. fMRI is a technique that can measure hemodynamic changes after neuronal activity³². fMRI detects brain activity by directly measuring tissue perfusion, changes in blood volume, and changes in oxygen concentration³³.

We see four main studies that can be used to describe how fMRI is used to investigate cognitive processes in chess players. These studies have demonstrated differential activation of the brain^{2,34-36} during games of novices and experts³⁷.

One of these studies was carried out using novice chess players. fMRI results showed brain region associations that are activated during the analysis of game positions. These regions are the premotor areas, frontal lobes, parietal cortices, occipital lobe, and the left hemisphere of the cerebellum².

Another study showed that among expert chess players, there is no difference in the areas of brain activity; however, when their patterns of brain activity were compared to those of novice players, there were differences, since the novices produced activation among the posterior areas of both hemispheres, which did not occur among the expert players³⁴.

The third scientific study was carried out using both novice and expert chess players. This study aimed to determine whether the subjects recognize general and specific patterns in chess. The experiment consisted of putting the game pieces on the board at random and instructing the subjects to recognize and analyze the patterns of the pieces using their eye movements. The results showed that while novice players examine irrelevant aspects, the expert chess players focused immediately on relevant aspects of the task. To corroborate this difference, the experiment was done using fMRI, which allowed the description of differences in patterns of general and specific recognition. In the novice players, there was activation in the temporal-occipital area, while in experts, who were able to recognize specific objects

during the test, there was bilateral activation in the middle part of the collateral sulci. This experiment showed evidence suggesting that subjects are able to identify general and specific patterns in chess; in addition, it describes the cognitive process they used. As such, this work could help describe essential perceptive mechanisms in humans³⁵.

The last study we will comment on was carried out with novice players who had been training for only a short time and expert players with years of intensive training. fMRI was used to characterize their neuronal activity. The results suggest that specific training activated or inhibited specific brain structures, such as the bilateral caudate nucleus. At the same time, the volume of brain activity in that area was significantly smaller in experts than in novices³⁶.

Despite the costliness of fMRI testing, the effects of playing chess have been investigated for many years³⁸. As a consequence, the recent discoveries in neurosciences using neuroimaging techniques could allow the description of the underlying neural mechanisms of chess playing^{2,34-36}, establish a correlation in the theory of the mind³⁹ and identify common high level areas in cognitive processes, which could result in new theories of cognitive process² or exploration of higher functions of the human brain⁴⁰. In any case, we believe that there is a link between playing chess, increased academic performance in school, and the fMRI results.

Finally, we believe that the studies described above could lay the neuroscientific foundation for new scientific research on chess and other board games.

Brain activation in games other than chess

It is possible that the academic improvement in boys and girls could be achieved not only through playing chess but also through other similar games. It is, therefore, important to consider what is known about the effects of other games on activation of different brain areas.

For example, one study analyzed the brain activity of 28 professional and amateur players of the board game Shogi. The average age of the subjects was 30.6 years. In the professional players, there was activation in specific brain areas, particularly in the precuneus of the parietal lobe during the perception of patterns on the board, and in the caudate nucleus of the basal ganglia when the players were carrying out their "best move." Considering these results, the researchers suggest that the precuneus-caudate circuit

is involved in the automatic patterns of the process of pattern perception on the board and the perception of the next move³⁷.

Another study was carried out among university students (not professionals) with the aim of describing which brain areas are activated when subjects participate in the game GO. The fMRI results showed that the activated areas were the cortical, prefrontal, parietal, occipital posterior temporal, primary somatosensory system, and motor areas. It is thought that this type of activation may be due to the fact that the game emphasizes an overall strategy rather than a specific strategy, as occurs in chess⁴¹.

Although analyzing the rules and other characteristics of Shogi, Go, and chess, reveal clear differences among them, it is important to emphasize that the studies described used fMRI and have helped to describe which brain areas are most active while these games are being played. In the near future, it is possible that a cognitive model of learning could be described for games other than chess from the perspective of neuroscience or other cognitive models.

Conclusions

In this review, we have described the benefits and favorable academic effects in boys and girls in the school setting, as well as the neuronal activation that occurs when playing chess. As such, we consider that playing this game could be a viable strategy for improving expected learning and relevant knowledge in boys and girls⁴², as long as the educator that works with them keeps them motivated in a fun, collaborative environment¹⁴.

In several countries, this strategy has been used to improve academic performance, for example, in Mexico, where ENLACE academic evaluations⁴³ during primary school and Programme for International Student Assessment evaluations in the secondary school show that girls and boys are below the worldwide average⁴⁴. In addition, we believe that using the foundations described here, new lines of research could be generated, considering the game of chess as a potential catalyst for academic improvement in boys and girls.

Conflicts of interest

There are no conflicts of interest for the authors of this work.

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