

# Neurology, psychiatry and the chess game: a narrative review

## Neurologia, psiquiatria e o jogo de xadrez: uma revisão narrativa

Gustavo Leite FRANKLIN<sup>1</sup>, Brunna N. G. V. PEREIRA<sup>2</sup>, Nayra S.C. LIMA<sup>3</sup>, Francisco Manoel Branco GERMINIANI<sup>1</sup>, Carlos Henrique Ferreira CAMARGO<sup>4</sup>, Paulo CARAMELLI<sup>5</sup>, Hélio Afonso Ghizoni TEIVE<sup>1,4</sup>

### ABSTRACT

The chess game comprises different domains of cognitive function, demands great concentration and attention and is present in many cultures as an instrument of literacy, learning and entertainment. Over the years, many effects of the game on the brain have been studied. Seen that, we reviewed the current literature to analyze the influence of chess on cognitive performance, decision-making process, linking to historical neurological and psychiatric disorders as we describe different diseases related to renowned chess players throughout history, discussing the influences of chess on the brain and behavior.

**Keywords:** cognition; recreational games; neurology; psychiatry; decision making; behavior; history.

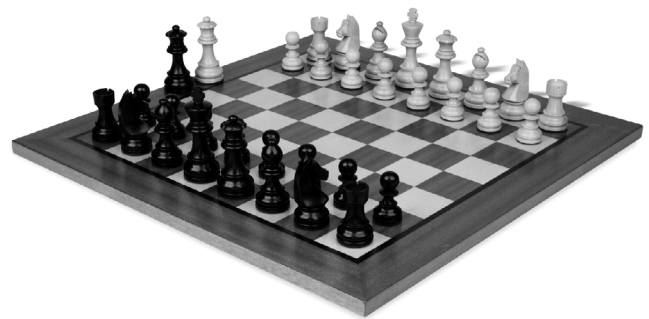
### RESUMO

O jogo de xadrez compreende diferentes domínios da função cognitiva, exige grande concentração e atenção e está presente em muitas culturas como instrumento de alfabetização, aprendizado e entretenimento. Ao longo dos anos, muitos efeitos do jogo no cérebro foram estudados. Dessa forma, revisamos a literatura atual para analisar a influência do xadrez no desempenho cognitivo, no processo de tomada de decisão, vinculando-a a distúrbios neurológicos e psiquiátricos históricos ao descrevermos diferentes doenças relacionadas a renomados jogadores de xadrez ao longo da história, discutindo as influências do xadrez no cérebro e no comportamento.

**Palavras-chave:** cognição; jogos recreativos; neurologia; psiquiatria; tomada de decisões; comportamento; história.

The chess game first description dates back to the 6<sup>th</sup> century AD in India, and in the 10<sup>th</sup> century it spread from Asia to Europe<sup>1</sup>. Once a leisure game, chess reached the level of championships and competitions by the late 19<sup>th</sup> century, leading to its popularity over the following decades. This game is played on a chessboard, a square board divided into 64 squares (eight-by-eight) of two alternating colors, which is similar to that used in draughts (checkers) (Figure 1)<sup>2</sup>.

Chess is considered a complex game, which requires cognitive training and expertise<sup>3-6</sup>. In the last 30 years, numerous studies evaluating brain activity in chess players have been



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Figure 1. Chessboard.



<sup>1</sup>Universidade Federal do Paraná, Hospital de Clínicas, Departamento de Medicina Interna, Serviço de Neurologia, Curitiba PR, Brazil.



<sup>2</sup>Hospital da Cruz Vermelha, Departamento de Neurologia, Curitiba PR, Brazil.



<sup>3</sup>Universidade de Vila Velha, Vila Velha ES, Brazil.

<sup>4</sup>Universidade Federal do Paraná, Hospital de Clínicas, Programa de Pós-Graduação em Medicina Interna, Grupo de Doenças Neurológicas, Curitiba PR, Brazil.

<sup>5</sup>Universidade de Minas Gerais, Hospital das Clínicas, Departamento de Medicina Interna, Grupo de Pesquisa de Neurologia Cognitiva e Comportamental, Belo Horizonte MG, Brazil.

Gustavo Leite FRANKLIN  <https://orcid.org/0000-0002-0207-3671>; Brunna N. G. V. PEREIRA  <https://orcid.org/0000-0003-0588-5226>;

Nayra S.C. LIMA  <https://orcid.org/0000-0001-8243-2859>; Francisco Manoel Branco GERMINIANI  <https://orcid.org/0000-0001-9494-9759>;

Carlos Henrique Ferreira CAMARGO  <https://orcid.org/0000-0002-3533-0347>; Paulo CARAMELLI  <https://orcid.org/0000-0002-4786-6990>;

Hélio Afonso Ghizoni TEIVE  <https://orcid.org/0000-0003-2305-1073>

**Correspondence:** Gustavo Leite Franklin; Rua General Carneiro, 181 - Centro; 80060-900 Curitiba PR, Brazil; E-mail: gustavolf\_88@hotmail.com

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published<sup>7</sup>. Different studies using neuroimaging and neuropsychological tests evaluated individuals with chess expertise in an attempt to define which major areas of the brain are associated to game performance, reasoning about the brain activity associated to chess-relevant cognition and the neural substrate underlying problem-solving mechanisms<sup>1-14</sup>.

Chess players are usually stereotyped as intelligent or with unusual skills. Indeed, there are some studies that try to realign the degree of intelligence to the psychometric aspects of chess players<sup>15</sup>. Otherwise, players tend to be more introverted, intimate and intuitive than the non-player population, as showed by Kelly et al., who analyzed a sample of 270 average players and 209 masters and concluded that chess players had significantly higher scores on introversion, intuition and thinking when compared to the general population norms. Also, Avni et al. employed selected scales of the Minnesota Multiphasic Personality Inventory (MMPI) and found that chess players differ from non-players in terms of unconventional thinking and orderliness<sup>16,17</sup>.

Like other competitive games, players are often submitted to a lot of pressure and may be associated to worsening anxious and compulsive personalities. Perhaps for these reasons, teaching chess aiming cognitive improvement in primary school is still questioned<sup>4,13</sup>.

Although there are many studies related to the chess game, they tend to focus on limited aspects of the game or its practice. In this way, the aim of this review was to group different scientific perspectives related to memory, cognition and decision-making, and to analyze possible influences of the chess practice for brain and behavior, also providing a historical perspective of some neuropsychiatric disorders related to renowned chess players of all time.

## METHODS

A literature review was performed on the results of the database searches from June to September 2018. The articles were selected from PubMed database and published chess books and biographies, to compose the historical note present in the paper. The paper was designed following three lines of research related to the chess game. First, the cognitive aspects related to the game, in which we include studies on decision-making, memory and neural circuits associated to the practice of playing chess. Second, the possible influences of playing chess on brain performance, behavior, and even on the body. In the third topic, we searched for historical aspects related to neurological and psychiatric diseases of iconic chess players.

To find representative articles, the following keywords were input, respectively, to elucidate each line of research: 1. [cognition AND chess]; [decision making AND chess]; [memory AND chess]; [memory AND cognition AND chess]; [cognition AND recreational games]; [memory AND

recreational games]; [intelligence AND chess]; [brain AND chess]; [neurology AND chess]; 2. [behavior AND chess]; [educational AND chess]; [stress, psychological AND chess]; [psychology AND chess] [psychology AND behavior]; 3. [history AND chess]; [stroke AND chess]; [schizophrenia AND chess] [psychiatry AND chess]. The articles in this review were selected only when the full text or chapter was available in the database and were excluded from the sample if the text mentioned the exclusive study of a recreational game other than chess. Although the keywords searched were determined for each research section, some articles cited may be present in other parts of the paper to maintain the fluidity of the article.

## RESULTS

In the initial screening, using the above-mentioned keywords, 58 articles and 21 published books were found. Out of these, 24 articles and 6 books were excluded because they were redundant, had repeated information, or were unrelated to the game or chess players, so we included 34 articles and 15 published books.

## DISCUSSION

### Chess and cognitive function

In general, the results of studies that evaluated the cognitive abilities of chess players vary widely. This is true for both neuropsychological and neuroimaging studies<sup>5-18</sup>. A pioneering study of chess players published by Binet, in 1966, identified a mnemonic virtuosity in these players<sup>9</sup>. However, other studies evaluating working memory<sup>12</sup>, visuospatial abilities<sup>14</sup> and planning performance<sup>5</sup> in chess players showed different or inconclusive results<sup>18</sup>. In 1998, Gobet et al. compared four theories of expertise in relation to chess players' memory and concluded that the "Template theory", a unified theory which associates the "Chunking theory" to schematic knowledge and planning process, helps to explain chess players' performance<sup>7</sup>. The Chunking theory described by Chase and Simon states that the ability of chess players to copy and recall positions are due to the expert's storage in long-term memory of many different patterned clusters of pieces (or chunks)<sup>19,20</sup>.

Lane and Chang studied a sample of 79 chess players and used different cognitive tests, including a memory test for chess positions, a test of declarative chess knowledge, a test of fluid intelligence and a questionnaire evaluating the amount of time spent playing and studying chess. They concluded that high-level conceptual processing in chess players plays an important role in memory<sup>21</sup>. Despite emphasizing memory, these results do not contradict the previous template theory by Gobet and Simon. This theory was once again sedimented in 2016, when in a comprehensive meta-analysis; Burgoyne et al. studied the relation between cognitive

abilities and chess skills. They concluded that chess skills correlate positively with fluid reasoning, comprehension-knowledge, short-term memory, and processing speed, particularly in young chess players<sup>22</sup>. In 2017, Sala et al. conducted another meta-analysis, in which they compared the performance of chess players and non-chess players in intelligence-related skills. Their study also confirmed that chess players outperformed non-chess players in these skills, thus supporting the idea that intelligence plays an important role in the acquisition of expertise and contradicting the academic-selection-processes argument<sup>23</sup>.

Several studies, in which neuroimaging were used, including magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI), single photon emission computed tomography (SPECT) and positron emission tomography (PET) (Table 1), tried to define which areas of the brain are related to chess playing<sup>3-18</sup>.

Onofrij et al., in 1995, using SPECT to detect cerebral activation, studied five expert male chess players during the mental solution of a complex chess problem. They concluded that non-dominant dorsal-prefrontal activation during chess problem solution could be detected by SPECT<sup>10</sup>. Rennig et al. published a paper in 2013, in which they analyzed the results of four fMRI studies that compared chess experts and chess novices when complex visual stimuli were presented during a chess game. They found that the temporoparietal junction plays an important role in the processing of complex visual stimuli in chess experts<sup>24</sup>. Hänggi et al. published a study in 2014, investigating morphological differences in chess players' brains. They showed that mean diffusivity was increased in chess players compared to controls in the upper left longitudinal fasciculus and the expertise (evaluated by the Elo score - a chess tournament ranking) was inversely related to mean diffusivity within the right superior longitudinal fasciculus, highlighting that there are specific differences in grey and white matter morphology between chess players and non-players in brain regions associated to cognitive functions for playing

chess. Their findings are not enough to conclude whether they are the cause or consequence of the intensive and long-term chess training and practice, but complement the investigation on brain activity associated to chess-relevant cognition and may help elucidate the neural substrate underlying problem-solving and decision-making mechanisms<sup>3</sup>.

Decision-making is regarded as the cognitive process resulting from the selection of a belief or a course of action among several alternative possibilities. Every decision-making process produces a final choice, which may or may not prompt action. Such tasks engage decision-making processes, that determine which movement to make next and when to make it, how those movements that are selected are planned and controlled, and how movements and task goals are dynamically updated in response to changes in the world. In decision making, the decision variable is the accumulated evidence in favor of one decision over another<sup>11</sup>.

The role of the amygdala in the decision-making process was reviewed by Bechara et al. in 2003. They presented strong evidence in support of the hypothesis that the amygdala and the orbitofrontal cortex are part of a neural circuit involved in decision making. The authors defined primary inducers as "stimuli that unconditionally, or through learning, can produce states that are pleasurable or aversive", and secondary inducers as "entities generated by the recall of an emotional event, that generates thoughts and memories about the inducer, eliciting a somatic state". They concluded that the amygdala is a critical substrate in the neural system and is needed to link the orbitofrontal cortex, trigger somatic states from primary inducers and, additionally, stated that the ventromedial cortex plays a critical role in the neural system, necessary for the triggering of somatic states from secondary inducers<sup>25</sup>.

More recently, Gläscher et al., studying 344 individuals with focal brain lesions, 165 of whom had lesions in the prefrontal cortex (PFC), confirmed that there is a remarkable functional-anatomical correlation between the PFC and value-based decision making<sup>26</sup>. Liebherr et al. published an interesting study demonstrating the importance of considering decision making in older adults in 2017. They pointed out the relevance of learning and of cognitive and emotional contributors responsible for age-related differences in decision making<sup>27</sup>. Recently, several studies have confirmed that decision making is also linked to emotional intelligence, contradicting a previous hypothesis, that stated it was a purely rational and cognitive process<sup>28</sup>.

In chess, "Kotov's Syndrome" was first described by the Russian chess grandmaster and author Alexander Alexandrovich Kotov (Figure 2A), in his book "Think like a Grand Master"<sup>29</sup>. The syndrome refers to the situation in which a chess player, after studying a complicated position in great depth for a long time and failing to find a suitable variant, notices that he/she is running out of time and quickly makes a move that he/she has not yet analyzed and is often

**Table 1. Neuroimaging and the game of chess.**

Activated areas	Associated activity	Exam	References
Left superior longitudinal fasciculus	NA	MRI	1
Parietal areas and the left frontal lobe	Spatial task	fMRI	6
Non dominant prefrontal area Non-dominant middle temporal area	Solution of a complex chess problem	SPECT	10
Temporo-parietal junction	Processing of complex visual stimuli	fMRI	24

incorrect, thereafter losing the game<sup>29</sup>. This situation clearly involves decision making and emotional intelligence. In 2017, Alipour et al. published a case report on the use of quantitative electroencephalography in an eight-year-old boy with substantial chess training while he was playing chess against a computer. The authors observed a lower power spectral density in higher frequency bands in the right hemisphere in decision making during the game<sup>30</sup>.

### Influences of chess on brain and behavior

In a Spanish study conducted in eight schools, children who played chess as an extracurricular activity were compared to children who chose other activities, such as soccer and basketball<sup>31</sup>. Children were assessed at the beginning and end of the school year with the WISC-R intelligence test, a self-assessment test (TAMAI) and an evaluation by their teachers. The results showed chess to be a great educational tool. They concluded that after one year of practicing, children performed better on tests that measured attention, organization, speed, planning, and problem-solving<sup>31</sup>. In a previous study, Atherton et al. investigated whether the predominant cognitive domain involved in the board game was logic or spatial ability. They conducted an MRI study and found a pattern of cerebral activation involving parietal areas and the left frontal lobe, suggesting that spatial ability is predominant. Much of this activation is probably due to thinking about possible moves and anticipating the opponent's next move<sup>6</sup>.

Chess has also been studied as a tool for treating schizophrenic patients. In one study, 26 clinically stable patients who were on antipsychotics and had normal IQs were divided into two groups: a chess group, whose members were given training and played chess, and a control group<sup>32</sup>. All the subjects were assessed with a battery of cognitive tests. After 10 hours of training in chess skills, the chess group had a better planning score, indicating that playing chess may be a valuable tool in the treatment of these patients<sup>33</sup>.

More recently, it has been suggested that being taught chess improves elementary school students' mathematical skills<sup>34</sup>, but this remains a controversial issue<sup>35</sup>. Sala et al.

studied the effects of chess instruction on the students' cognitive and academic skills in 2017, and concluded that exposure to chess instruction is associated to better mathematics performance in the general population of elementary school students in the short-term. However, this finding was not confirmed after additional experimental studies with an active control group<sup>22-24</sup>.

The discussion about stress in chess players was studied by Troubat et al., in 2009, who evaluated the effects of psychological stimuli on physiological responses. They studied the effects of playing chess in chess competitors with a series of cardio-respiratory and metabolic variables. It was observed that since the beginning of the contest, heart rate was rather elevated and both heart rate and respiratory exchange ratio slightly increased during the game. Such elevated levels could indicate that substrate oxidation mainly involved carbohydrates. The authors concluded that high cognitive demands during a chess game resulted in sympathetic activation, with great heart rate variability and increased arterial blood pressure<sup>36</sup>.

### Historical neurological and psychiatric aspects related to chess players

Many chess players have become renowned for their brilliance and feats on the board, only losing to themselves in their own brilliance. Many grandmasters have been afflicted by neuropsychiatric disorders (Table 2), which blighted their careers and prematurely ended their lives<sup>37-41</sup>.

The very first world champion, Wilhelm Steinitz, was no exception. Short, bald and with a congenital "lameness" disease, Steinitz was not physically impressive<sup>37</sup>. At the chessboard, however, he used to become a majestic figure. In 1862, he won the London championship and in 1866 he played against Adolf Anderssen, considered the world's best player at the time. Although he declared himself the world champion after beating Anderssen, it was only after winning the first official World Championship, held in the USA in 1886, that Steinitz was formally named the first Chess Champion of the World, a title he was to retain until 1894. In June 1899, however, his mental health began to deteriorate rapidly. He claimed



Figure 2. (A) Alexander Alexandrovitch Kotov (1913-1981); (B) Robert James "Bobby" Fischer (1943-2008); (C) José Raúl Capablanca (1888-1942).

that he could talk to any person anywhere by telepathy and move chess pieces with a mere thought. He would spend each morning walking barefoot in the small yard behind his New York home, regardless of the weather, and try to call people with his “wireless phone”. As the years went by, he veered into a much more serious state of psychosis. For some time, he was confined to a Moscow Asylum. He insisted that he had played chess with God and “God lost”<sup>37</sup>. He was hospitalized in the East River Sanatorium on Wards Island in Manhattan, where he died of a heart attack on August 12<sup>th</sup>, 1900<sup>37-42</sup>.

One of the most remarkable psychiatric cases in chess history was that of Robert James Fischer (Figure 2B). In 1957, his daring and innovative gaming made “Bobby Fischer”, at 14 years old, the youngest winner ever of the U.S. Chess Championship. According to Frank Brady, author of one of the most famous biographies of Fischer, Bobby Fischer seemed to be very eccentric and lack conventional social skills since his childhood. During his early adolescence, Fischer consulted with, at least, three different mental health professionals. After beating Boris Spassky and winning the World Chess Championship in 1972, Bobby lapsed into a period of growing paranoia and isolation, manifested primarily as an aggressive anti-Semitism and pathological fearfulness<sup>43</sup>. Although one diagnosis suggested that he suffered from Asperger’s syndrome, which is supported by his significantly impaired ability to relate to others, stereotyped and repetitive behaviors and by an exaggerated focus on one area of interest since early childhood. Fischer did not meet all the necessary criteria for a differential diagnosis between Asperger’s syndrome and schizoid personality disorder<sup>44</sup>. There is also evidence of paranoid personality disorder because of his long-standing pattern of pervasive distrust and suspiciousness of others and his interpretation of other people’s behavior as malevolent.

**Table 2. Psychiatric and neurological diseases in chess players.**

Chess player	Disease	References
Wilhelm Steinitz	Psychosis/Schizophrenia	37, 38
Robert James Fisher	Asperger’s syndrome/ Schizoid personality disorder	38, 43
Paul Charles Morphy	Psychosis-Schizophrenia	33, 38
Lembit Oll	Depression/Bipolar disorder	38, 39
Karen Grigorian	Depression/Suicide	38, 40
George Mackenzie	Depression/Suicide	38
Alvis Vitolins	Depression/Suicide	38, 41
José Raul Capablanca	Hemorrhagic Stroke	45, 46, 48
Harry Pillsbury	Neurosyphilis/Stroke	48, 49

Furthermore, Fischer had an unstable family life, experienced the pressure of early fame and may have had a genetic predisposition toward psychological difficulties. He died of kidney failure on January 17<sup>th</sup>, 2008, in Reykjavík, Iceland, where he had played against Spassky three decades before to become the first American-born world chess champion<sup>43</sup>.

Paul Charles Morphy, the New Orleans chess prodigy, who was active in chess a century before Bobby, also lapsed into a state of delusion and paranoia, in his case, centered on a belief that he was being persecuted by his brother-in-law. In many letters, his best friend, Charles Maurian, noted that Morphy was “deranged” and “not right mentally”. In 1882, his mother, brother and a friend tried to admit him to a Catholic sanitarium called Louisiana Retreat, but he was so well able to argue for his rights and sanity that they sent him away. Two years later, Morphy was found dead in his bathtub at the age of 47. The autopsy showed that he had died of a stroke<sup>33-38</sup>.

Like Morphy, many grandmasters were afflicted by strokes and other neurological disorders. An iconic case was Capablanca. José Raúl Capablanca was born in Havana, Cuba, in 1888 (Figure 2C). According to his own accounts, he learned the rules of the game at the age of four by watching his father playing. He won the Cuban Chess Championship when he was 12 and the World Chess Championship against the German Emmanuel Lasker in Havana in 1921. He was a contemporary of the greatest chess players of all time, such as Akiba Rubinstein, Alexander Alekhine, Frank Marshall and Siegbert Tarrash<sup>37-46</sup>. Capablanca was described as very anxious, particularly during chess games and, in 1921, Capablanca began to complain of “sanguineous uneasiness”<sup>45,46</sup>. In fact, uncontrolled hypertension caused him frequent, severe headaches, and as a result, he had difficulty competing in championships. On the evening of March 7<sup>th</sup>, while watching a game at the Manhattan Chess Club, Capablanca suffered a severe headache and, suddenly, lost consciousness. He was quickly taken to the hospital but died six hours after being admitted<sup>45</sup>. A full autopsy showed complete destruction of the right thalamus and the adjacent portion of the corpus striatum, replaced by a large intraparenchymal hematoma. The ventricular system was completely filled with blood, dilated throughout and displaced somewhat to the left<sup>47</sup>.

Harry Pillsbury, another world-class chess player, known for his memory skills and blindfolded playing, also had a neurological disease, which culminated in his death. According to many reports, at the beginning of the 20<sup>th</sup> century, he used to have frequent headaches and had three different strokes, leaving him partly paralyzed<sup>48</sup>. The etiology of the strokes is uncertain, but in March 1905 Pillsbury was hospitalized for complications of neurosyphilis. Harry’s health condition was so severe that in a psychotic outbreak he tried to jump out of a four-store window at the hospital. He died at the age of 33 at Friends Asylum in Frankford, Pennsylvania. His obituary in the New York Times stated that he died from an “illness contracted through overexertion of his memory cells”<sup>49</sup>.

## CONCLUSION

Chess is an intellectually complex, strategically demanding and highly competitive game. Although further studies might be needed to provide greater evidence of the real effects of the game on the cognition process, there are

many benefits described in the literature. There are also several studies highlighting possible influences of the practice of chess on brain, body and behavior, which give us an insight on the broad spectrum of actions of the practice of playing chess and its possible use as a learning and therapeutic tool.

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