Review paper

Chess and the human brain- Demystifying the therapeutic value of a board game

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Abstract
For most board-gamers, chess is construed as an engaging encounter of wits. The brain-racking game, however, offers much more than that which meets the eye. Although Rhazes recognized the extra-recreational value of the game in 852 A.D. only recently has this value been recognized. The objectives of the current paper were to review the structural and functional changes in the brain caused by playing chess, and to explore its utility in treating neuro-cognitive and behavioral disorders. A literature review revealed a growing body of evidence on the neuroplasticity induced by chess, with definite changes being documented in brain areas related to association, object perception and pattern recognition. Though the game is being introduced as an educational tool to enhance cognition and problem-solving skills in school, the evidence for its cognitive benefits is not yet compelling, and is limited mainly to the domain of mathematics. Chess has strong links to personality and behavior, and psychologists are successfully using it as a psychoanalytical tool to detect personality traits and channelize emotions and attitudes. As a clinical tool, the game has garnered interest as a therapeutic aid in managing dementia and behavioral disorders such as attention deficit hyperactivity disorder, panic attacks and schizophrenia. From being an exciting strategy game, chess is carving a niche for itself in the clinician's arsenal due to its emerging therapeutic value. Pending well-designed future trials, it remains to be seen if the 'King of all Games' has the potential to be a game-changer in the field of therapeutic neuropsychology.

Keywords
Chess therapy, Cognition, Neuro-cognitive disorders, Therapeutic neuropsychology, Clinical tool, Neuroplasticity, Default mode network, Chess personality, Chess for freedom, Cognitive reserve

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Introduction

The benefits of board games extend beyond fun and relaxation to the realms of stress management (1), art therapy (2), and behavioral modification for promoting habits such as healthy eating and cessation of smoking (3). Board games like Go, chess and Ska enhance learning and interpersonal interactions. They positively affect motivation and emotion, leading to decrease in depression, stress and anxiety levels (4). They improve memory, attention, and executive function, and prevent cognitive decline in older subjects by stimulating brain areas responsible for logical thinking, decision-making and problem-solving skills (3). Some of the cognitive benefits of board-games also accrue from other 'brain training' games such as Sudoku, crossword puzzles, Rubik's cube and computer-based cognitive training (5), giving a new perspective to the utility of gaming.

Chess is the most popular and highly researched among all the above games. In 1973, Simon and Chase identified its potential as the 'drosophila' or fruit fly of cognitive psychology research. Much like the utility of the fruit fly in the domain of genetic research, chess has proven to be a unique 'model organism' to study variations in cognition and a wide spectrum of neuropsychological disorders. In addition to having well-defined rules, it has the advantage of having well-maintained historical databases that provide an ideal model for investigating cognitive processes (6). Recognizing the chess-brain connection, major cognitive research projects such as Harvard's 'Chess Cognition Project' are including the game in their study protocols.

The current study aimed to objectively evaluate the structural and functional effects of chess on the brain, analyze its association with cognition and personality, and explore its utility in managing neurobehavioral disorders. Original articles and meta-analyses for the review were selected by performing an internet search in PubMed, ScienceDirect and Google Scholar. The search criteria included the terms '(chess) AND (brain)', '(chess) AND (cognition)', '(chess) AND (cognitive psychology)', '(chess) AND (behavioral disorders)', '(chess) AND (neuro-cognitive disorders)' and 'chess therapy'. Only manuscripts written in English were included in the review.

Brain activity and structural changes in chess players

Neuroplasticity, the ability of the brain to modulate its structure and function, is one of the most fascinating abilities of the human brain. Research has demonstrated that long-term acquisition of certain skills, such as those acquired by playing board games, potentiates the phenomenon. Of all the board games that have been researched in this regard, chess is considered a paradigm (7). Chess-playing activates various neural networks involved in problem-solving and other cognitive pathways. Using [^{15} O] water positron emission tomography (PET) imaging, Nichelli et al (8) established that distinct areas in the brain are

recruited to perform chess-related tasks. In this study, specific areas in the brain lit up on performing tasks like 'black/white discrimination' (ability to identify chessmen of a particular color on the board), 'spatial discrimination' (ability to identify the color of chessmen closest to a marked square), 'rule retrieval' (ability to analyze a simple chess move) and 'checkmate judgment' (ability to determine whether a player could checkmate in one move).

Apart from analyzing brain activity during chess-related tasks, researchers have also examined changes in the brains of chess players. Results from such studies have found chess experts to exhibit increased activity in brain areas responsible for association (frontal, parietal, lateral temporal and occipital cortices) (9), object perception (posterior temporal areas, left inferior parietal lobe, and the occipito-temporal junction) and pattern recognition ('retrosplenial cortex' and the 'collateral sulcus') (Figure 1) (10, 11). In another study, dynamic network analysis showed enhanced whole-brain dynamism / fluidity ('chronnectome') in expert chess players (7). Changes in brain fluidity were not found to correlate with the amount of time spent in training or to education status. Chess-playing has thus been recommended as a measure of cognitive 'reserve' along with factors such as education, occupation and leisure activities.

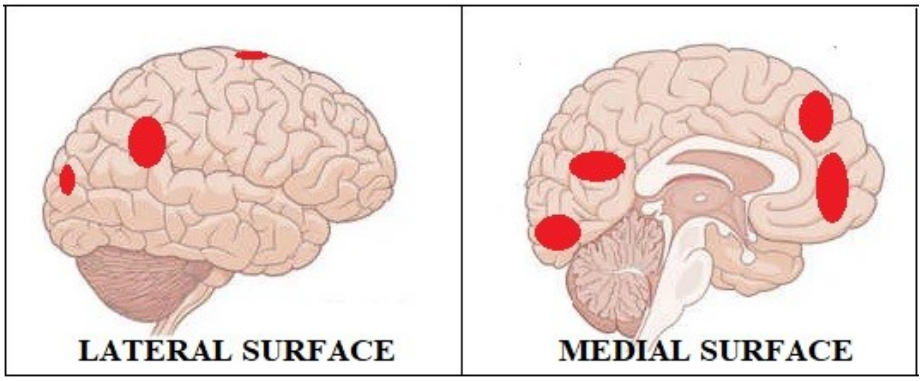

Figure 1. Representative figure showing some of the brain areas that demonstrate increased activity in chess players

Changes in some cognitive brain centers correlate with the degree of skill acquired in the game. Chess masters and grandmasters recruit brain areas that are distinct from those recruited by novices playing the game. For example, while chess-experts engage brain centers responsible for memory and knowledge storage and retrieval (frontal and parietal lobes) during the game, novices preferentially employ the medial temporal cortex, a region that is

involved in processing and retrieving new information (12). In a study that compared chess-experts and beginners (13), experts demonstrated increased activation in their cognitive areas- centers that deal with attention, executive functions, and problem-solving.

An interesting observation is that even in the 'resting state' (i.e. when the subjects are not playing chess), experts demonstrate differences in neural networks such as the 'default mode network' (DMN) (13). DMN is a network of brain areas that is active when a person is oblivious of his or her surroundings, or is in an introspective mode. Chess experts tend to suppress their DMN while solving problems. Modulation of the DMN-related network is not chess-specific; it has also been noted to occur with computerized cognitive games training (14), moderate-intensity aerobic exercise (15), and even psychedelic drugs (16). Chess-playing specifically alters the 'DMN-caudate nucleus loop' network; expert players have stronger functional networks between the DMN and the caudate nucleus, a structure deep inside the brain responsible for high-level functioning. This finding suggests that 'DMN-caudate nucleus loop' might play a role in acquiring chess-expertise.

Effects of chess on cognition

Schools worldwide are focusing on developing competency in subjects like mathematics and science because of the growing demand in the job-market for qualifications in Science, Technology, Engineering, and Mathematics (STEM) subjects. Chess has garnered a lot of interest in this context since it has the potential to enhance mathematical and cognitive skills, either directly or indirectly. The latter is postulated to occur by a mechanism called 'transfer of skills' wherein a set of skills acquired in one domain translates to improved skills in other domains (17). Based on this knowledge, academicians have started introducing chess as part of school curricula. Proponents of this approach hypothesize that chess enhances cognitive skills by 'near-transfer' (transfer of skills to related domains) and 'far-transfer' (improvement in unrelated or distant domains). However, the optimism about the 'far-transfer' of skills by chess training is scientifically unfounded (17, 18).

Results from individual studies on the effects of chess on cognition vary widely. While some studies did not find chess to have any positive influence on domains such as focused attention (19), memory (20) and visual-spatial abilities (21), other studies demonstrated chess to have a beneficial effect on meta-cognitive abilities (22), mnemonic skills (23), reasoning, comprehension, short-term memory and processing speed (24). Some of the cognitive benefits of chess reportedly accrue soon after the onset of training. Trinchero et al (25) reported that a mere 25 to 30 hours of chess instruction is required to facilitate 'transfer of learning' from chess to other domains.

Sala et. al. (17) performed a meta-analysis in order to evaluate the above diverging results.

Their analysis included a total of 24 studies that compared mathematical, reading, or cognitive skill in school-going chess players versus controls. It compiled the 'effect size' (degree of the meaningfulness between variables) of chess on cognition from all studies into a single analysis represented by the funnel plot in Figure 2. The results of the analysis yielded a weighted effect size of 0.338 with a 95% CI [0.242; 0.435] and a p value of < .001, indicating that chess instruction had a 'moderate' effect (defined as an effect size between 0.3 to 0.5) on improving mathematical, reading, and cognitive skills in children. The improvement in mathematics was found to be much more than that in reading skills. This underlined the fact that the benefit of chess was seen best in a domain with skill-sets overlapping those required for chess, requiring only a 'near transfer' of skills. Improvement in an unrelated domain like reading would have necessitated a 'far transfer' of skills, a phenomenon which did not occur to a significantly demonstrable extent.

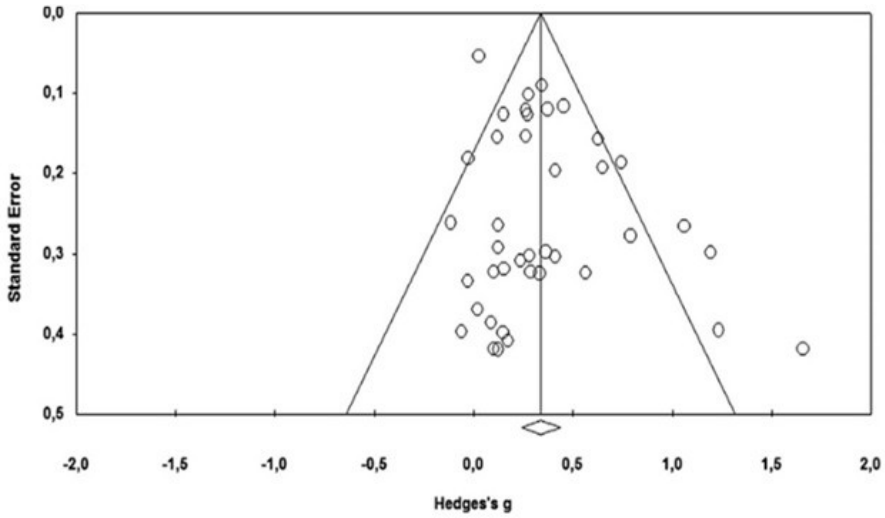

Figure 2. A funnel plot from a meta-analysis showing different effect sizes (Hedge's g). The diamond at the bottom represents the meta-analytically weighted mean effect size of 0.338- a moderate effect of chess on cognition (10).

Chess-personality connection

There has been growing interest in the field of 'personality neuroscience' that explores correlations between changes in behavior and personality with alterations in brain structure and function. Using the Human Connectomics database of over 500 people, Ricelli et. al. (26) demonstrated that variations in brain cortical anatomy correlated well with basic personality traits. Given that chess is known to induce anatomical and functional changes in the brain,

it is no surprise that the game has also been linked to personality in multiple ways.

The term ‘chess personality’ is reflective of the players’ behavior and defines the personality-defining elements at which the player excels. Grandmaster Yuri Averbakh categorized chess players into different personality types (‘killers’, ‘fighters’, ‘athletes’, ‘gamblers’, ‘artists’ and ‘researchers’) based on how they approach the game. Historically, there is strong evidence to prove that chess expertise is linked with strong personality traits. Many world-famous personalities had a penchant for becoming avid chess players. Scientists such as Albert Einstein and Sir Isaac Newton; actors like John Wayne and Marilyn Monroe; authors such as Charles Dickens, William Shakespeare and George Orwell; and illustrious US presidents like Abraham Lincoln and Winston Churchill were avid chess players. On the flipside, there are also anecdotal reports of brilliant grandmasters like Robert James Fischer and Paul Charles Morphy prematurely ending their careers after being afflicted by serious neuropsychiatric disorders (27). In the light of such facts, it is surprising that only a few studies have scientifically analyzed the chess-personality connection.

One of the few available objective studies on the chess-personality connection was performed by Bilalic et. al. (28) on 219 chess-playing primary school children and 50 of their non chess-playing peers. The authors used the ‘Big Five Questionnaire for Children' (BFQ-C) (29) that included domains of ‘energy/extraversion’, ‘agreeableness’, ‘conscientiousness’, ‘emotional instability’ and ‘intellect/openness’. The study evaluated personality characteristics of children who took up chess as a hobby, and determined if certain personality factors predicted expertise in the game. It was found that children with higher scores in the ‘intellect/openness and ‘energy/extraversion’ domains were more likely to play chess. There were obvious gender differences; girls scored higher in the ‘agreeableness’ scores, and boys with higher scores in this domain were less likely to take up chess. Differences in personality profiles were evaluated across subgroups based on expertise levels: elite players, weaker players and non-players. Although none of the BFQ-C factors were associated with self-reported skill levels, the subgroup of 25 ‘elite players’ had significantly higher ‘intellect/openness’ scores than their weaker and ‘non-playing’ peers. The typical elite chess player is construed as an intelligent but introverted male who prefers chess over outdoor or social activities. With the hypothesis that elite players would demonstrate a poorer extraversion trait and would be socially inhibited, Vollstädt-Klein et al (30) objectively evaluated elite players using the Freiburg Personality Inventory Revised (FPI-R). Their results indicated that while elite male players preferred self-absorbing over social or outdoor activities, their personalities were not as deviant as they are often considered. The personality profiles of the female players were quite distinct from those of the male players.

Stronger male players, for example, were more introverted, while stronger female players were more extraverted. The personality profiles of the elite male players did not significantly differ from the normative scores of the male population. Female players, on the other hand, demonstrated better profiles than their non-player counterparts; they demonstrated less physical complaints and higher achievement and life satisfaction. All these findings indicated that gender is an important variable that affects the chess-personality connection.

Therapeutic utility of chess

In 2021, World Champion Anatoly Karpov introduced the 'Chess for Freedom' program, an initiative that uses chess to rehabilitate prison inmates. Although it sounds far-fetched, the project has an underlying scientific basis. Chess has multiple therapeutic dimensions that extend beyond attention, memory and abstract thinking to psychological domains such as self-motivation, impulsivity and mood. 'Chess for Freedom' utilizes some of these benefits to improve behavior and mitigate depression, stress and anxiety. Utilizing chess for such therapeutic benefits ('chess therapy') has come a long way since 852 A.D. when Dr. Rhaze, a physician in Baghdad, first used the game to help patients 'think clearer'. This novel psychotherapy is now being utilized in the management of various neurobehavioral and psychiatric disorders such as attention deficit hyperactivity disorder (ADHD), panic attacks, schizophrenia and dementia.

Attention deficit hyperactivity disorder (ADHD) presents in childhood with a combination of problems such as hyperactivity, difficulty maintaining attention, and impulsive behavior. It is the commonest psychiatric disorder in childhood and currently a major public health issue. In order to explore chess-therapy as a treatment modality for ADHD, Fontecilla et al (31) prospectively analyzed the effectiveness of an 11-week trial of chess-training on 42 children diagnosed with the condition. The severity of the disorder was evaluated using the Swanson, Nolan and Pelham Scale for parents (SNAP-IV), and the Abbreviated Conners Rating Scales for parents (CPRS-HI). Statistically significant improvement in both the scales, indicating a substantial reduction in the severity of ADHD, was noted after 11 weeks of chess-training. If widely utilized, the findings of this study may have significant implications in decreasing the social and financial burden of ADHD.

Chess has also been studied as a tool for treating panic attacks, defined as episodes of sudden overwhelming fear in response to ordinary situations. These episodes affect 1 out of 10 people every year and can severely impair quality of life if they occur frequently. Chess therapy with the right level of difficulty has been reported to decrease the incidence of panic attacks (32), and pending more trials, may be included as one of the behavior-modifying techniques for managing the condition.

Schizophrenia, a dreaded psychotic disorder that affects the way one thinks, feels and behaves, leads to significant personal, social and occupational impairment. Chess therapy has proven to be an inexpensive but promising modality to improve cognition in patients with this disorder. This was demonstrated in an open, unblinded study by Mathieu et al (33) wherein 26 schizophrenic patients on medications were randomly assigned to one of two treatment groups: Game of Chess (GC) or Treatment As Usual (TAU). Patients in the GC group received 10 hours of chess-training, while those in the TAU groups received their usual medications. Patients were evaluated before and after treatment by a neuropsychological test battery. Significant changes in the results of one of the tests ('Tower of London' task) were observed after treatment (chess training) in the GC group. The post-intervention latency times in the 'Tower of London Task' were found to be shorter in the GC group than in the TAU group, indicating that playing chess for just 10 hours improved the 'initial planning time' and overall executive function in patients with schizophrenia.

Dementia is another neuro-behavioral disorder for which chess therapy has promising therapeutic potential. A progressive degenerative disorder affecting memory, thinking and the performance of daily activities, dementia is the seventh important cause of death and a major cause of disability worldwide. Knobel et al (34) postulated a significant role of environmental factors in altering the molecular pathways that lead to biological aging and dementia (Figure 3). While environment-modifying interventions such as cessation of smoking and control of sugars delay the progression of dementia (34), chess therapy is being looked at as an intervention that *protects* against dementia (35, 36).

A study by the Einstein Aging Study (EAS) published in the New England Journal of Medicine in 2003 (36) attributed the benefits of cognitive activities including chess in delaying the onset of dementia to the building up of a 'cognitive reserve' that contributes to the brain's ability to withstand damage. Analysis of the data provided by this study shows that a larger proportion of elderly persons who played chess or other board games frequently were dementia-free compared to those who rarely did so. Further studies have suggested that leisure activities including chess are protective against dementia and the development of Alzheimer's disease. However, a recent scoping review analyzed the results of 21 relevant studies (35), and concluded that the accumulated evidence on the topic is weak.

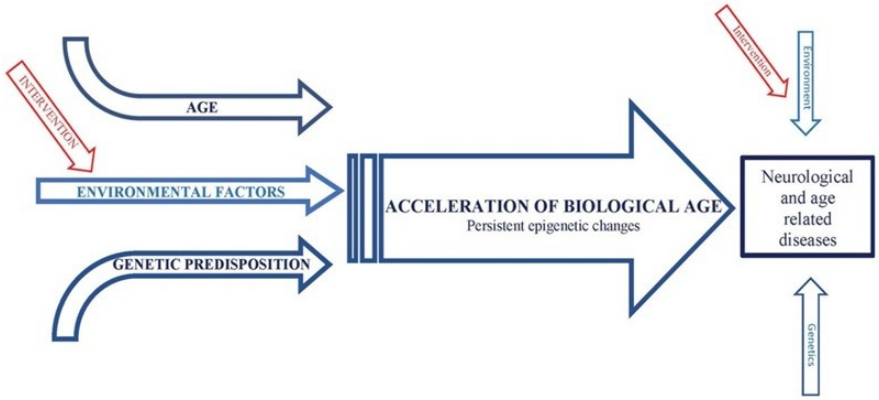

Figure 3. A postulated framework demonstrating the role of environmental factors along with age and genetic predisposition in the cascade of biological aging and age-related neurological diseases (25).

Future directions

The current review sheds light on the multi-dimensional nature of the chess-brain connection (Figure 4). There are many gaps in the current understanding of this phenomenon, its implications and perceived utility. While there is definite evidence for the ability of chess to induce structural neuroplasticity, the verdict on its functional relationship with cognition is not out as yet. Available evidence on the subject shows, at best, only a moderate effect of chess on cognition. This too needs cautious interpretation since most of the studies included in the meta-analysis on the topic had only one control group, and hence did not have an 'ideal' design (17). A placebo effect of chess in these studies cannot be ruled out since the effect of chess was not compared to other activities such as checkers or sports. Further, in view of the short follow-up in most of these studies, it is unclear whether the cognitive benefits of chess, if any, become more pronounced over time, and if they are sustained till adulthood. These issues can be potentially addressed with well-designed prospective trials running over longer periods. Such studies should also compare the cognitive benefits of chess with less-popular but equally stimulating games like Sudoku, crossword puzzles, checkers and other board games.

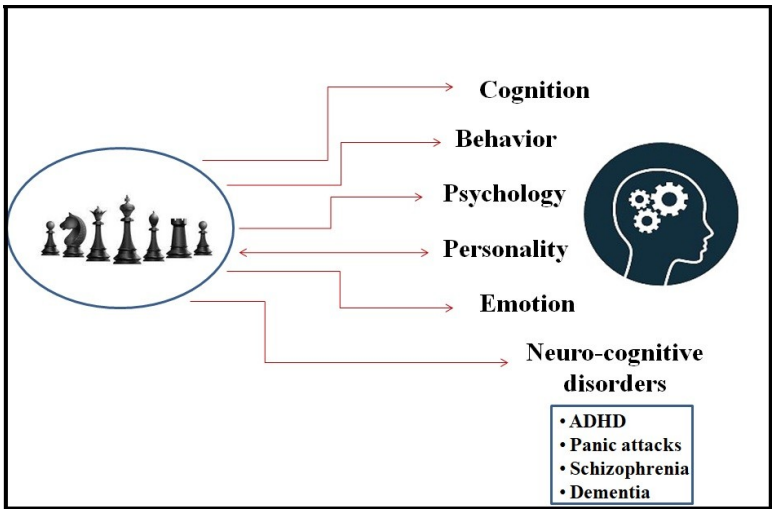

Figure 4. The multi-dimensional facets of the chess-brain connection including the utility of chess therapy in treating neuro-cognitive disorders.

Some of the neural pathways activated by chess-playing need further elucidation. For example, though chess-induced activation of various cognitive pathways has been established, the exact role of the 'DMN-caudate nucleus loop' in developing chess expertise is unclear. DMN-modulation is not chess-specific, and alternatives like exercise also achieve this functional neural change. Since intelligence quotient (IQ) plays a major role in determining chess skill (37), it might make sense for children with lower IQs to engage in exercise-centric games rather than being pushed to excel in 'brain-training' activities like chess.

'You get better only what you train in'. This dictum seems to be the norm across all domains of cognition and 'brain training', and chess is no exception. Current evidence clearly demonstrates a lack of far-transfer of skills from chess and other activities like music and working memory training (18). Policymakers should pay heed to this and consider halting the use of resources for further research in this area. Focus should move away from exploring far-transfer of skills to the clarification of domain-specific cognitive correlates. Future trials on the subject, if any, should include pretests and a minimum of two control groups - an active control group and another group not doing any alternative activity (18).

Despite the existing controversy on the subject, it may still be prudent to include chess-training as an extra-curricular activity in schools.

Chess-playing involves using arithmetical skills, and designing chess-based exercises can prove to be a fun way to help children grasp mathematics better. Besides, chess- playing has definite benefits in enhancing emotional and social skills of children and controlling impulsivity. These benefits will also help in preventing issues like drug- and alcohol-abuse in vulnerable school-goers. On similar lines, programs aimed at psycho-social rehabilitation like 'Chess for Freedom' should be introduced not only in prisons, but also in mental hospitals and behavioral health facilities to improve behavioral, emotional and communication skills.

The biological basis of chess ability being linked to personality traits and its potential to bring about behavioral changes warrant further research. Though personality traits and psychiatric disorders are heritable, they are recognized to have underlying changes at the neuro-transmitter level, especially those related to serotonin and dopamine (38). This could imply that people with specific neurotransmitter ratios, and hence certain personality traits (like those seen in some of the great personalities alluded to earlier), would have an inherent propensity to enjoy chess and succeed at the game. On similar lines, people with neurotransmitter imbalances or those on neurotransmitter-agents should, in theory, play the game differently from others. This could translate to the possibility of people with 'chess-unfriendly' personality traits being at higher-than-normal risk for developing neuro-cognitive disease. As of now, there is no evidence to prove or disprove any of the these hypotheses; the only available study related to the neural biochemistry of the game just shows that central nervous system stimulants can modulate chess performance (39).

On the clinical front, the medical fraternity is increasingly using chess for its therapeutic efficacy in neuro-cognitive disorders. Since most of these disorders have significant social and financial implications, all their major treatment trials should probably include chess therapy as a simple and affordable management option. Since the current evidence for the protective effect of chess against conditions like dementia is weak, larger prospective studies are required to clarify the subject further. For the time being, given the definite evidence of the cognitive-stimulating functions of chess, it is safe to consider chess to be protective against the development of dementia. Chess-playing should probably be introduced as a routine activity for people considered at-risk for developing dementia.

Conclusion

Chess is much more than a strategy board game. It activates various brain circuits that lead to improvement in domains such as attention, executive function and problem-solving. There is moderate evidence that these benefits translate to enhanced cognitive skills in children, mainly in the domain of mathematics. The game is closely linked to behavior and personality, with gender being an

important variable in this association. Thus, while stronger male players are more introverted than non-players, female players have better personality profiles than their non-playing counterparts. As a clinical tool, the game seems to have diverse therapeutic potential in treating various neuro-cognitive and behavioral disorders. It is suggested to be protective against dementia, though the available evidence on the matter is weak. Patients with attention deficit hyperactivity disorder reportedly demonstrate significant improvement in their symptoms with chess-training. There are reports of the game decreasing the incidence of panic attacks and improving the overall executive functioning of patients with schizophrenia. Pending well-designed prospective trials, it remains to be seen if the 'King of all Games' proves to be a game-changer in the field of therapeutic neuropsychology.

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