# THE NEUROSCIENTIFIC BASIS OF CHESS PLAYING: APPLICATIONS TO THE DEVELOPMENT OF TALENT AND EDUCATION

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Abstract

From a review of research studies reporting neuroscientific investigations of chess playing, chess playing seems to involve the activation of the occipital lobe suggesting visual processing and the activation of the parietal lobe suggesting attentional control and spatial orientation. Among amateur players, chess playing seems to involve the activation of the medial temporal lobe and the hippocampus suggesting the novel encoding and analysis of chessboard information. Whereas, among expert chess players, chess playing seems to involve the activation of the frontal lobe suggesting higher-order reasoning and the utilization of expert memory chunks from well-organized chess knowledge memory stores. However, the paucity of neuroscience research on chess cognition warrants caution regarding these conclusions. Much more psychological research on chess cognition and chess playing -- both behavioral and neurocognitive -- is needed so that we can better understand how chess players think.

Neuroscientific research on chess playing will enlighten educators as to the neuroscientific changes that accompany the development of talent in this talent area and as to the extent to which those neuroscientific changes associated with the development of chess with neuroscientific changes associated with the increases in forms of scholastic achievement as youth move from novice to intermediate and perhaps even to expert chess ratings. One implication is that individuals may make greater use of their frontal lobes when engaged in chess and other cognitive activities as they develop talent in chess and those other cognitive areas.

The neuroscientific basis of chess playing:

Applications to the development of talent and education

It is generally held among cognitive psychologists that two psychological processes underlie skillful performance in chess playing (Gobet, F., & Simon, H. A., 1996). One process is the recognition of features in chess positions. This process leads to the recall of information from the long-term memory of the skilled chess player. Such information relates to possible moves and other implications of the chess positions. This process of recognizing patterns of chess pieces on a chessboard is dependent on the knowledge of chess possessed by the chess player. If a chess player has more knowledge about chess, then the chess player will likely recognize more features in chess positions. If a chess player has less knowledge about chess, then the chess player will likely recognize fewer features in chess positions.

The second process is termed "planning by looking ahead" (Gobet & Simon, 1996). This process relates to deciding on what move to make. In this process, the chess player considers possible moves, possible responses by the opponent to those moves, possible responses by the chess player to those responses by the opponent, and so forth. The second process has been termed "calculation" in the chess community (e.g., Soltis, 1994). It is commonplace among skilled chess players that the evaluation of possible moves serves as a component of this second process. A skilled chess player will tend to consider each possible move and then evaluate the move in terms of whether the chess position resulting after the move is more advantageous than the chess position prior to the move. This second process requires mental discipline and concentration and tends to improve as a result of practice and habit.

Some cognitive researchers have examined the neurological basis of chess playing. Cranberg and Albert (1988) reviewed prior research on chess playing and concluded with the hypothesis that chess ability is located in the right hemisphere. The authors reported disproportionately high numbers of left-handed chess players which suggests greater usage of the right hemisphere, because the left hemisphere is involved in the usage of the right hand, the right eye, and the right ear and the right hemisphere is involved in the usage of the left hand, the left eye, and left ear.

Nichelli, Grafman, Pietrini, Alway, Carton, and Miletich (1994) used positron emission tomography (PET) to identify neural areas activated during chess playing. In their study, the subjects were right-handed males who were regular chess tournament players and who had played chess for at least 4 years. They were each injected with a radiolabeled isotope tracer, $H_2{}^{15}O$, as they performed cognitive tasks. The parts of the brain that are more active tend to absorb more oxygen and retain greater amounts of the tracer. The retained oxygen isotope would then release positrons that are detected by the gamma ray detector in the PET scanner, which permits the location of the brain activity.

During the PET scan, black and white chess diagrams were presented on a computer screen to the subject. In the black/white discrimination task, each subject was asked to indicate whether or not there were chessmen of a given color on the board. In the spatial discrimination task, an X was displayed in one of the board's squares and each subject was asked to identify the color of the chess piece closest to the X. In the rule retrieval task, each subject was asked to analyze a single move and to answer questions such as "can the white knight capture a black rook?". In the checkmate judgment task, each subject was asked to indicate whether the player with a given color could checkmate in the next move.

Two analyses were especially relevant to chess playing. The results of the spatial discrimination condition were subtracted from the results of the rule condition and that led to the finding that retrieval of move sequences associated with a chess piece involved activation of the hippocampus and the left temporal lobe. The left temporal lobe is located in the lower portion of the left side of the human cortex just above and behind the ear and is usually activated when people are involved in the identification of objects or semantic analysis. The results of the rule retrieval condition were then subtracted from the results of the checkmate condition. This subtraction led to the findings that the region bordering the occipital and parietal lobes is differentially activated and is likely involved in the generation of sequential board images. Additionally, the two prefrontal regions are differentially activated and are likely involved in the planning and sequential execution of endgame and other chess game strategies. The occipital lobe is located in the back of the brain and is activated in the processing of visual stimuli. The parietal lobe is located in the upper posterior portion of the brain and is activated when a subject shifts attention from location to location. The frontal lobe is located in the front of the brain and is involved in higher-order reasoning. In conclusion, this study indicated that chess playing which involves solving complex problems requires the activation of distinct interrelated cerebral areas.

Onofrj, Curatola, Valentini, Antonelli, Thomas, and Fulgente (1995) used single photon emission computerized tomography (SPECT) to examine brain activation among five expert chess players attempting to solve a complex chess problem. They found that there tended to be prefrontal and temporal lobe activations in the non-dominant hemispheres among the expert chess players during their chess deliberations – i.e., the right hemispheres of the dominant right-handed participants and the left hemisphere of the dominant left-handed participants. Their research supported the view that the non-dominant hemisphere is specialized for chess skill.

Atherton, Zhuang, Bart, Hu, and He (2000, 2003) also examined the neurological basis of chess playing but with a different methodology. Instead of using PET, they used functional Magnetic Resonance Imaging (fMRI) to identify the cerebral regions involved in chess cognition. With fMRI, the subject is placed into a large donut-shaped device sometimes referred to as a magnetron. When a magnetron is used for fMRI, a subject is given a task and fMRI measures the ratio of oxygenated to deoxygenated hemoglobin in the brain of the subject. This ratio is higher in active brain regions than in less active brain regions. fMRI is sensitive to changes in this ratio and creates a map of changes in blood flow associated with local brain activity. fMRI studies are preferable, because PET exposes participants to low levels of radioactive agents and cannot be used repeatedly on the same participants for an extended period of time. On the other hand, fMRI has no known risks.

In this study, there were six novice chess players. The subjects were presented with three stimuli. One stimulus was a blank chessboard (Blank Board). A second stimulus was a chessboard with pieces that were randomly placed on the board (Random Board). In the Random Board condition, each subject was asked to locate a specific symbol marked on various pieces on the board. A third stimulus was a middle game position (Game Board). In the Game Board condition, each subject was asked to determine the best possible move for white with the chess position being the 13th move in a game randomly drawn from the 13th edition of Modern Chess Openings (DeFirmian & Korn, 1990). Figure 1 provides an example of a middle game position used in the study.

With the use of a mirror and a computer screen, each subject looked out of the magnetron and viewed each stimulus board for 30 seconds in a random sequence that was repeated three times for a total scan time of 6 minutes. The brain activations resulting from looking at the blank board provided a baseline of brain activations for the subject. The brain activations resulting from looking at the random board provided information regarding activated brain regions associated with shared visually oriented cognitive tasks. The brain activations resulting from looking at the Game Board provided information regarding activated brain regions associated with chess playing. Figure 2 provides a pictorial depiction of the recorded brain activations.

In general, the results of this study are not surprising. First of all, all players displayed activation in the occipital lobe representing the processing of visual stimuli.

Second, the chess players displayed involvement of their parietal lobes for possible control of attention and spatial orientation. Third, the expert chess players tended to have higher levels of activation in their frontal lobe regions than the novice chess players suggesting higher-order reasoning among the expert chess players.

Amidzic, Riehle, Fehr, Wienbruch, and Ebert (2001) used Magnetoencephalography (MEG) to compare patterns of electrical activity in the brain termed γ-band activity in professional and amateur chess players during matches. The participants in their study were 20 male players with an average age of 42 years. Ten of the players were amateur players with Elo ratings of 1700 and above on the Elo chess skill rating scale and ten of the players were professional grandmasters with Elo ratings between 2,400 and 2,600. Each participant played chess against a computer and the researchers scanned their brains for focal γ-bursts in the 5 seconds after each move with the use of the magnetic imaging equipment working in conjunction with a computer program. They examined representations of the single slices of the brain and found pronounced activity in the hippocampus and medial temporal lobe in the amateur players but pronounced activity in the frontal and parietal cortices in the grandmasters. To Amidzic, et al. (2001), the grandmasters made use of expert memory chunks that accounted for the focal γ-band activity in their neocortices; whereas, the amateur players were encoding and analyzing chessboard information in areas associated with the analysis of new information. The authors suggested that as large memory chunks for chess are formed in the brains of players, brain activation would tend to shift from the hippocampus and the medial temporal lobe to the neocortex.

In general, chess playing seems to involve the activation of the occipital lobe suggesting visual processing and the activation of the parietal lobe suggesting attentional control and spatial orientation. Among amateur players, chess playing seems to involve the activation of the hippocampus and the medial temporal lobe suggesting the encoding and analysis of chessboard information. Whereas, among expert chess players, chess playing seems to involve the activation of the frontal lobe suggesting higher-order reasoning and the utilization of expert memory chunks from well-organized chess knowledge memory stores. Although these conclusions support the finding from cognitive psychological research on chess playing that there are differences in how novices and experts at chess playing actually play chess (e.g., Saariluoma, 1995), the paucity of neuroscience research on chess cognition warrants caution regarding these conclusions. Much more psychological research on chess cognition and chess playing -- both research that is neuroscientific and research that is not neuroscientific -- is needed so that we can better understand how chess players think. With continued collaboration and cooperation between chess players, novice, intermediate, or expert, and psychological researchers, we will inexorably develop a much better understanding of how chess players think than is presently the case.

## Conclusions

Chess is a complex game with an indeterminately high cognitive ceiling. It involves spatial problem solving in which participants often need to control as much space on the chessboard as possible in order to win the game. Chess requires spatial cognition on the part of the participants as well as the character traits of reflectivity, carefulness, and patience, Chess makes use of spatial thinking, logical thinking, and critical thinking (Saariluoma, 1995).

To address the challenge of inadequate levels of scholastic achievement and critical thinking among American youth, noted chess commentators such as Gershunsky and Gufeld (2000) have recommended that chess instruction be made available to American youth in the schools. They contended that chess instruction would improve the reasoning skills and scholastic achievement among school-aged students. However, their arguments and those of other supporters of chess in the schools are often made without the presentation of any empirical research.

Unfortunately there are but a few journal articles that report the educational benefits of chess. Christiaen and Verholfstadt (1978) and Smith and Cage (2000) are the only two peer-reviewed journal articles that reported empirical studies on the effects of chess instruction on youth and both of these experimental studies found salutary cognitive effects of chess instruction – primarily, on nonverbal abilities and mathematics achievement. As youth move from novice to intermediate and perhaps even to expert chess ratings, neuroscientific research on chess playing will enlighten educators as to the neuroscientific changes that accompany the development of talent in this talent area and as to the extent to which those neuroscientific changes associated with the development of chess with neuroscientific changes associated with the increases in forms of scholastic achievement. One implication is that individuals may make greater use of their frontal lobes when engaged in chess and other cognitive activities as they develop talent in chess and those other cognitive areas.

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Figure Caption

*Figure 1.* A middle game position used as a Game Board position in the study.

*Figure 2.* Cortical activations from a novice chess player as revealed by an fMRI study (Atherton, et al., 2000, 2003). The brighter areas are cortical regions identified when activation recorded during the analysis of a middle game chess position is subtracted from activation recorded during the visual search for marked pieces randomly placed on a chessboard.