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The Effects of Chess on Cognitive Abilities and Critical Thinking of High School Students in Riyadh

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Abstract

This study investigates the relationship between chess proficiency and diverse cognitive functions in high school students in Riyadh, Saudi Arabia. While previous research has documented the benefits of chess on problem-solving, critical thinking, and memory in Western contexts, little is known about its impact within rapidly modernizing educational environments such as Riyadh. Utilizing a purposive sample of 120 tenth-grade students familiar with basic chess rules, participants completed three standardized cognitive assessments: the Trail Making Test (pattern recognition and cognitive flexibility), the Stroop Test (inhibitory control), and the Backward Digit Span (short-term working memory). Chess skill was quantified via Elo ratings ranging from 100 to 1750. Correlational analyses revealed a modest positive association between Elo and Trail Making accuracy ($r = 0.215$, $p < .01$), suggesting that higher chess expertise corresponds to superior visual-spatial processing and cognitive flexibility. The relationship between Elo and Stroop performance was weakly positive for correct responses ($r = 0.055$, $p = .40$) and negative for errors ($r = –0.177$, $p < .05$), indicating a slight enhancement of inhibitory control among stronger players. No significant correlation emerged between Elo and Backward Digit Span scores ($r = –0.070$, $p = .28$), implying that chess proficiency may not generalize to non-domain-specific working memory tasks. These results align with domain-specific transfer theories and underscore the multifactorial nature of cognitive skill development. Findings highlight chess as a valuable, yet targeted, tool for fostering certain executive functions in adolescents. Future research should employ longitudinal and experimental designs to establish causality and explore additional cognitive domains.

Keywords; Chess, Cognitive Abilities, Critical Thinking, Executive Functions, Inhibitory Control, Working Memory, Visual-Spatial Processing, Elo Rating, High School Students, Riyadh, Saudi Arabia

Introduction

Chess is known for its boundless potential and influence on the mind (Sala et al., 2017). These include problem-solving, critical thinking, focus, strategic planning, and many more

skills (Kazemi et al., 2012). Historically, chess has been used by teachers around the world as a helpful tool to enhance students' cognitive and critical thinking abilities, as proven by the abundance of research done on chess and school students earlier. Countries like Armenia have integrated chess into school curricula since the early 2000s (Gevorgyan et al., 2023). Educational programs in Denmark have proven that students who often play chess improve their math and overall academic performance (Rosholm et al., 2017).

Because chess is a game that primarily relies on the player's decision-making, many studies have derived from this idea that chess is a game that develops and enhances certain cognitive functions such as memory, attention span, and logical reasoning (Fattahi et al., 2015). By engaging players in complex strategies and requiring them to anticipate their opponent's moves, chess enhances these cognitive functions and cultivates essential skills for academic and real-world problem-solving (Sala et al., 2017). Such intensive mental exercise helps students develop strong memorization skills and a much more precise thinking process, which are vital components of critical thinking (Burgoyne et al., 2016).

In particular, the game promotes cognitive processes, including attention control, working memory, and cognitive flexibility (the ability to switch between thinking about two different concepts simultaneously), which are vital for academic success (Diamond, 2013). Globally, chess has been shown to improve cognitive skills, but its effects in Riyadh specifically have yet to be well studied. As Riyadh offers a modern educational environment, it provides a solid testing field to see how it affects the cognitive abilities of high school students.

In Riyadh, the massive increase in the popularity of chess among school students has led those who are interested to explore and study how it improves students' cognitive abilities. Schools (not only in Saudi Arabia) that added chess programs reported improved academic results and student-social interactions (Aciego, García, & Betancort, 2012). Such results align with other international studies that mention how chess plays a significant role in improving both personal and intellectual growth (Burgoyne et al., 2016).

This study sheds light on understanding how chess impacts cognitive and critical thinking in high school students in Riyadh. Given Saudi Arabia's educational goals towards modernizing school programs, chess will be a valuable tool in developing the upcoming generation's cognitive abilities.

a) What is the correlation between chess playing and the enhancement of short-term and long-term memory in high school students in Riyadh?
b) To what extent does chess influence inhibitory control (the ability to suppress impulsive responses) in high school students in Riyadh?

Literature Review

Although there are a number of studies on the relationship between chess and cognitive abilities, most research in the area has been conducted in the developed Western part of the world. Saudi Arabia represents a perfect place for such studies to be conducted. Throughout the literature review, most of the studies emphasize comparing the cognitive abilities of the older portion of chess players, and completely ignore the importance of studying the cognitive effects of chess on high school students (Burgoyne et al., 2016). The

present study concerns exclusively high school students, excluding any other age range from its sample.

Most research papers tackling chess and its effects on cognition examine the basic cognitive tasks. For instance, Adriaan de Groot (1946/1965) studied the chess experts of his time and analyzed their problem-solving and decision-making processes. Philip Rifner (1992) expanded this research by analyzing how chess impacted middle school students' problem-solving skills, but this was restricted to specific cognitive domains. This study, on the other hand, explores a variety of tests and cognitive domains to help get a more general idea. Frydman and Lynn (1992) investigated the relationship between IQ and chess skill, although they only looked at pattern identification and reasoning. Similar to the research conducted by Frydman and Lynn (1992), this study examines how chess affects players' ability to recognise patterns.

More recent meta-analyses by Sala and Gobet (2017) critically reviewed previous studies and highlighted the need for larger and better-controlled studies. In contrast, the present study examines a wider array of cognitive abilities, including critical thinking, memory, and spatial awareness, using a comprehensive range of tasks. By doing so, it aims to provide a more nuanced understanding of how chess influences cognitive development in high school students in Riyadh.

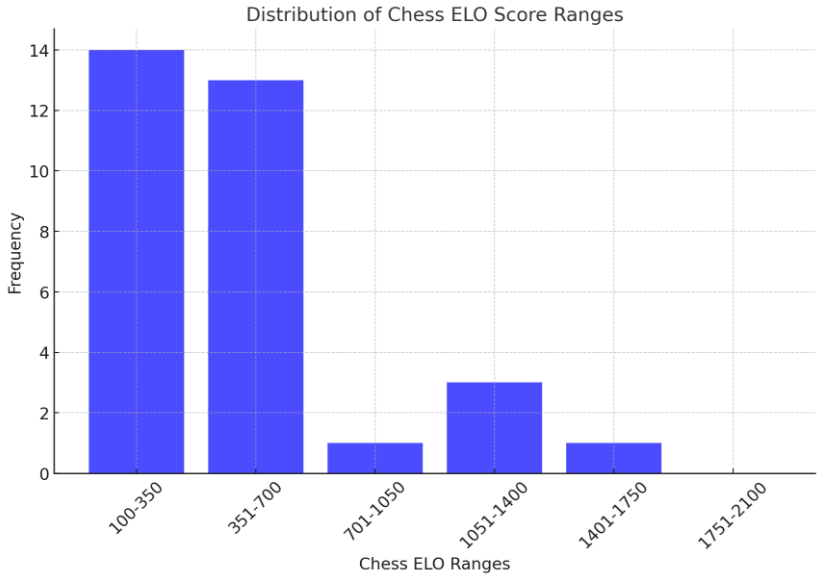
While several studies have explored the relationship between chess and cognitive development, there remain significant gaps in the literature, particularly when it comes to specific populations and cognitive domains. Much of the existing research, such as that by Rifner (1992) and Frydman and Lynn (1992), focuses on general cognitive abilities like problem-solving and pattern recognition. However, there is little attention given to the effects of chess on more specialized cognitive functions such as inhibitory control and attentional focus in younger populations. Moreover, the geographic and cultural contexts of these studies are predominantly Western, leaving a gap in understanding how chess might influence cognitive abilities in non-Western, rapidly modernizing contexts such as Riyadh. The present study aims to address these gaps by examining how chess affects critical thinking, memory, and inhibitory control in high school students in Riyadh, Saudi Arabia—a region that has seen little focus in the chess and cognition research field.

Methods of Research

The methodology adopted in this study is designed to examine the effects of chess on cognitive abilities of high school students. Further, the adopted methodology helped point out whether chess level is interrelated with cognitive abilities of a person. The sample was not random. The students must meet these criterias: (1) Know the basic rules of chess such as the fundamentals of castling and the rule of en passant. (2) Must be a 10th grader.

The study was based on three tasks: Inhibitory control, pattern recognition, and short-term memory. We used the Backward Digit Span test to assess short-term memory. We asked the participants to repeat a sequence of numbers backwards, which tests their ability to hold and operate on information. To measure inhibitory control, the stroop test was utilized. Subjects are required to inhibit their natural responses and instead concentrate on stating the color of ink and not on the words written. Finally, the Trail Making Test was used to

estimate the pattern recognition ability by measuring the ability to identify and connect sequences which involves cognitive flexibility and visual attention.



Findings and Discussion

Discussion

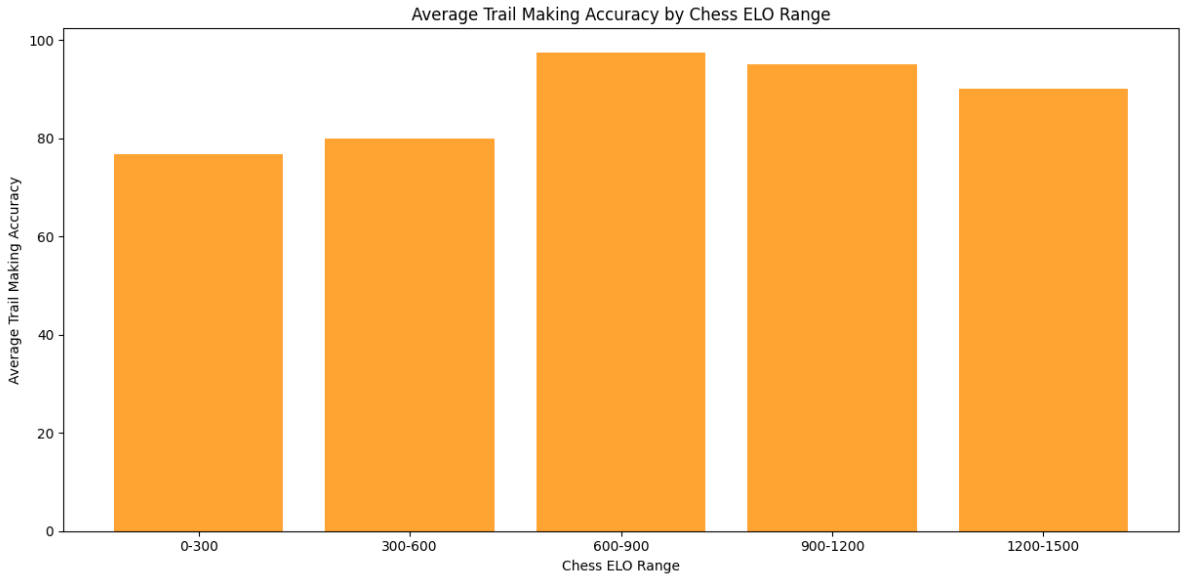
This study explores the correlation between chess proficiency, which is measured by chess ELO ratings (ranging from 100 to 1750), and a variety of cognitive abilities amongst Riyadh's high school students. The analysis in the graph representations shows that chess has an influence on specific cognitive domains in a domain-specific-manner. The following discussion gives further details on each cognitive task, integrating our findings with relevant scholarly work.

Trail Making Test

The Trail Making Test is commonly used to evaluate cognitive flexibility, visual scanning, and processing speed. In this study, there was positive correlation (r = 0.215) between Chess ELO ratings and Trail Making Accuracy, which infers that higher proficiency in chess correlates with higher performance on this test. Researchers like Bilalić et al. (2007) have demonstrated that visual-spatial skills are displayed by skillful chess players, and Sala et al. (2017) have linked chess practice to enhanced executive functions. These cognitive processes are critical for navigating the rapid shifts and complex patterns required in the Trail Making Test, providing a theoretical basis for the observed relationship.

Looking closely at the dataset,notable frequency patterns can be observed in the Trail Making Accuracy scores. The majority of the participants scored 100 or near 100, which indicates a high level of accuracy in completing sequential tasks, while a small number had very low scores (as low as 0 or 10). High chess ELO players from the collected data with ratings over 1000 exhibited near-perfect scores, supporting a correlation between chess expertise and consistent attentional focus and rapid information processing. However, participants with low Trail Making Accuracy scores, sometimes observed among low Chess ELO performers, might reflect occasional lapses in concentration or variations in test engagement. This variability suggests that while performance on tasks requiring swift visual-spatial processing is boosted

by chess proficiency, the overall performance of a participant can also be affected significantly by individual differences and other situational factors.



In the modest correlation of 0.215 observed between Chess ELO and Trail Making Accuracy, it can be inferred that chess training is likely a factor that can influence performance on the Trail Making Test. This relationship highlights that cognitive flexibility is correlated with chess performance, given the strategic and visual-spatial demands inherent in the game. However, it is essential to note that other elements, such as innate attentional control, test anxiety, and varying levels of motivation, may also have crucial roles in cognitive tasks performance such as the Trail Making Test. This is displayed in the data from the uploaded spreadsheet, where variability in the Trail Making Test is revealed among participants with similar Chess ELO ratings. The variability suggests the influence of additional factors other than chess expertise.

Prior research supports this multifactorial view, emphasizing that rapid decision-making and pattern recognition are not only shaped by chess skill, but also by a wide spectrum of personal and environmental factors (Bilalić et al., 2007; Sala et al., 2017). For example, Bilalić et al. (2007) found that expert chess players exhibit superior memory for chess-related information but not on general memory tasks, suggesting domain-specific cognitive benefits.

Stroop Test

The Stroop Test is a research-backed authentic method of measuring cognitive control, assessing abilities such as selective attention and inhibitory control. During a chess game, these cognitive faculties are likely to be highly developed. This study showed a very weak positive correlation (r = 0.055) between Chess ELO (the rating system) and correct stroop test responses. On the other hand, a noticeable negative correlation (r = -0.177) was prominent between Chess ELO and wrong answers on the stroop test, showing that more skilled chess players end up making less mistakes on the stroop test. This finding aligns with research by Unsworth et al. (2012), who highlighted the role of inhibitory control in tasks requiring resistance to interference, a skill that chess players gain through repeated practice in suppressing irrelevant moves during gameplay.

Prior research provides context for these findings. Bilalić et al. (2007) demonstrated that chess experts exhibit domain-specific cognitive advantages, such as superior memory for chess positions, but noted that these benefits do not universally extend to non-chess tasks. Similarly, Sala et al. (2017) cautioned that transfer effects from chess training to broader cognitive domains are often limited. The Stroop Test's reliance on general inhibitory control may explain the partial overlap with chess skill, as both activities demand suppression of automatic responses. However, individual differences in baseline attention, test anxiety, or motivation emphasize that chess expertise is one of many contributors to Stroop performance.

In conclusion, the observed correlations suggest that chess proficiency may modestly enhance inhibitory control, as reflected in reduced Stroop Test errors. However, the minimal association with correct responses underscores the complexity of cognitive transfer, reinforcing the need to consider multifactorial influences when interpreting such relationships.

Backward Digit Span

The Backward Digit Span Test is commonly used to measure working memory capacity, that is, the ability to temporarily hold and manipulate information in one's mind. Working memory is a critical cognitive function that supports abilities that are central to chess expertise, including complex reasoning, problem-solving, and decision-making. In this study, the observed weak negative correlation ($r = -0.070$) between Chess ELO ratings and Backward Digit Span performance indicates a minimal relationship between chess skill and working memory span. This finding diverges from what prior research has suggested, indicating that enhancement in working memory, particularly for domain-specific tasks, may have been exhibited by chess players. (Bilalić et al., 2007; Burgoyne et al., 2016). That said, this lack of strong correlation is in agreement with studies demonstrating that the cognitive benefits of chess may not be a major factor in non-chess-related working memory tasks (Sala & Gobet, 2017).

A variability in Backward Digit Span scores across participants is revealed with a closer look at the data set. Some participants got high score, while others performed poorly, scoring as low as 3 or 4 digits recalled correctly. However, what was worth noting is that participants with high Chess ELO ratings did not consistently outperform participants with low Chess ELO ratings on the Backward Digit Span Test. In the data set, participants with a Chess ELO above 1000 barely outperformed participants whose Chess ELO were significantly lower. This finding suggests factors other than chess expertise, such as individual differences in working memory capacity or test-taking strategies, may have a more substantial impact on the performance of the Backward Digit Span Test.

The weak negative correlation of -0.070 between Chess ELO and Backward Digit Span underscores the limited influence of chess training on general working memory capacity. While chess requires players to mentally manipulate complex configurations of pieces and anticipate future moves, these skills appear to be domain-specific rather than broadly transferable to tasks like the Backward Digit Span. This interpretation is supported by research from Burgoyne et al. (2016), who found that chess players excel in tasks directly related to chess but show no significant advantage in general cognitive measures. Similarly,

Sala and Gobet (2017) conducted a meta-analysis revealing modest or negligible transfer effects of chess training on working memory and other cognitive abilities outside the chess domain.

In conclusion, the weak negative correlation between Chess ELO and Backward Digit Span performance indicates that chess proficiency does not strongly carry over to general working memory skills. While it is certain that domain-specific cognitive skills, such as pattern recognition and strategic planning, are enhanced by chess, its influence on broader cognitive functions like working memory appears to be minimal. This finding aligns with existing literature emphasizing the specificity of cognitive training effects and the multifactorial nature of working memory performance. Future research should explore how individual differences and contextual factors interact with chess expertise to shape cognitive outcomes, helping better understand the relationship between chess and cognition in more detail.

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