RSGC
Royal St. George's College

The Young Researcher

2023 Volume 7 | Issue 1

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Hutton Mann Shaw

Recommended Citation
Mann Shaw, H. (2023). Checkmate: A correlational analysis of chess and executive functioning ability in adolescents. *The Young Researcher,* 7(1), 126-139. http://www.theyoungresearcher.com/papers/mannshaw.pdf

ISSN: 2560-9815 (Print) 2560-9823 (Online) Journal homepage: http://www.theyoungresearcher.com

Checkmate: A Correlational Analysis of Chess and Executive Functioning Ability in Adolescents

Hutton Mann Shaw

Abstract: The link between chess and executive functioning [EF] skills has been hypothesized since the 1990s and studied extensively in children and adults. This relationship is yet to be examined in adolescents. This study–through correlational analysis of Tower of London EF performance (measured by overall time taken, time taken on difficult problems, and time taken on easy problems) vs online Chess.com performance (measured by Blitz and Rapid ratings)–looks to examine this relationship and contextualize it with previous studies on differently aged participants. The findings of the study indicate that as a chess player's time score improved on all metrics, their chess rating increased. Given that previous research has found EF skills to be highly correlated with chess ability in children, but very minimally correlated in adults, the results of this study introduce the possibility that adolescence is a transition period where EF skills and chess ability become less connected.

Keywords: chess, executive functioning, chess rating

Introduction

Chess is a strategic game, hypothesized to be linked to skills such as memory, calculation, visuospatial thinking, and intelligence (Sala et al., 2015). Since the late 1900s, the relationship between chess and most of these skills has been studied extensively. In adults, higher IQ has been correlated with increased chess ability, while there has been no correlation between chess and visual or traditional memory (Sala et al., 2015; Waters et al., 2002). In children, chess has been correlated with an increased ability to learn spatial concepts, increased performance IQ, and increased math test scores (Sala et al., 2015; Frydman & Lynn, 1992; Sigirtmac, 2011). Despite substantial research on other age groups, some skills not yet examined in adolescents are: calculation, planning, working memory, and time management umbrellaed under the term executive functioning [EF] skills.

Chess players are required to foresee moves far in advance. Among masters, players with an Elo (a worldwide scale used to measure the strength of a player) rating of 2000 or over, the best move is typically one that will give them an advantageous position or piece count later in the game–sometimes up to 20 moves later. Therefore, it has long been assumed that EF skills must be of the highest calibre. In practice, however, the link is not so obvious. To date, most studies on children have found links to increased EF ability after playing chess. Alternatively, studies on adults have generally found no significant correlation between rating and EF (Nejati & Nejati, 2012; Atherton et al., 2003; Unterrainer et al., 2011). This leaves a grey area for adolescents, where it remains unclear the relationship between chess and EF ability. Thus, the question must be asked: **In persons 14-18** years of age, is there a correlation between chess rating and EF scores?

This study aims to answer this question through quantitative correlational analysis between EF test scores and online chess ratings. It was conducted using the Tower of London EF test, the same test used by many previous studies on chess and EF skills (Unterrainer et al., 2011). Six correlation coefficients were calculated using the Spearman coefficient, to test for a monotonic relationship. The sample for this study comprised 20 boys and 4 girls, who ranged from 100-2400 in chess Elo rating.

The results of this study will be beneficial to chess players/coaches and educators. Determining if there is a correlation will improve understanding of the cognitive skills linked to increased chess performance. This will give way to optimized on and off-board training methods, as well as more informed selection of students and classes to benefit from the use of chess as an educational development tool.

Literature Review

Previous Studies on Adults

Most commonly, chess has been studied as it relates to general intelligence. One of the first examinations was in 1927 when Djakow et al. (1927) studied 8 grandmasters (Elo of 2500 or over) and compared their intelligence scores on a general intelligence test to that of a similarly aged control group. They found no significant difference between the grandmasters and the control group. More recently, Doll and Mayr (1987) compared a control group's scores on the Berlin Structural Model of Intelligence test to that of chess masters. Conversely, they found a positive correlation between adults' general intelligence and chess ability.

Regarding more specific strata of intelligence such as spatial intelligence and memory, the results have leaned toward no correlation. Djakow et al. (1927) found no significant increase in visuospatial memory for grandmasters compared with their control group, except on a memory test where material closely resembled chess positions. In Doll and Mayr's (1987) study, there was also no link between increased performance and chess ability. Perhaps the greatest evidence for a lack of correlation between spatial/ memory intelligence and adult chess ability is a 2002 study by Waters et al. This study examined a 36-participant pool of chess masters, and their results on a visual memory test as they correlate to chess rating. Using the Spearman-Brown coefficient, no correlation was found, and scores were very similar to that of 550 random US naval recruits. As Waters et al. (2002) point out, "[a lack of correlation between chess ability and visuospatial memory among adults] seems to be a standard finding in the literature" (p.11) (Gobet and Campitelli, 2002; Sala & Gobet, 2016).

Such insights are not exclusive to studies conducted by Gobet (Waters et al., 2002; Gobet & Campitelli, 2002; Sala & Gobet, 2016). A meta-analysis on cognitive ability transfer between chess and other domains finds that most of the skills related to chess seem to be "specific to the game" (Bühren & Frank, 2010, p.158). Additionally, Sala et al. (2015), in their review of recent chess research on adults, and Woodworth and Thorndike's (1901) theory of identical elements suggest that the "transfer of skills [from chess to other domains among adults] is quite rare"
(p.1).

Previous Studies on Children

In children, positive correlations between chess ability and cognitive skill are more apparent. One of the best-known studies on children and chess was conducted by Lynn and Frydman (1992) on 33 young players aged between 8 and 13. This study found a link between increased full-scale IQ and performance IQ (essentially visuospatial ability) among the proficient chess players who participated in the Wechsler Intelligence Scale for Children [WISC] (included subtest for performance IQ). Despite the correlation, it is unclear whether the results suggest that the acquisition of chess skill requires previous visuospatial ability and intelligence, or whether these cognitive abilities are enhanced by playing and learning chess (Lynn & Frydman, 1992). While correlation does not mean causation, it is more than can be said for most studies which examine adults (Sala et al., 2015; Burgoyne et al., 2016).

Another study by Bilalić et al. (2007) aimed to answer the question of whether chess in children requires intelligence. This study used the same WISC to examine a sample of 57 young players. Rather than just looking at one variable hypothesized to be linked to chess performance, Bilalić et al. (2007) examined practice, years of experience, and intelligence. Contrary to the results of Lynn and Frydman (1992), they found that chess skill was impacted most by practice, and that there was no significant correlation between chess skill and intelligence. Today, the question of whether intelligence is required to acquire chess skill still remains largely unanswered. It has, however, been discovered that chess training alone is not enough to "explain expert performance," and some other variable, such as intelligence, must be at play (Sala et al., 2017, p.130).

It seems (both from individual case studies and meta-analyses), that chess is more beneficial for children than adults. Contrary to the findings with adults, there is typically a moderate correlation in children, especially in terms of visuospatial intelligence (Gobet & Campitelli, 2002). Moreover, chess can improve concept learning and scholastic achievement, as noted by Sala and Gobet (2016), even if it does not always. Not only does correlation seem more common, but the transfer of chess skills to cognitive skills in other domains seems much more likely among children. A meta-analysis by Burgoyne et al. (2016) finds that specifically in children in the early stages of learning chess, this transfer is common.

This is supported by the findings of Gliga and Flesner (2013) as well as Sigirtmac (2011), both of which came to conclusions starkly different from the conclusions made about adult samples.

Studies on EF

The first study on adults which discussed the possibility of EF playing a role in chess was in 2003 by Atherton et al. This study found, using MRIs, that there was limited activation of the frontal lobes when analyzing a chess position, suggesting limited use of EF in adults. Accordingly, more recently, a 2011 study by Unterrainer et al. (on 30-year-olds), which examined the Tower of London test scores between a control group of 30 non-chess players, and an experimental group of 30 advanced chess players, found no significant increase in overall EF abilities (with time restrictions in place). Again, a 2012 study by Nejati and Nejati, found that 30 expert chess players did not outperform a control group on the Wisconsin Card Sorting EF test.

In adults, the research is clear: EF skills are not better in superior chess players.

Paralleling the pattern for IQ, in children, the results have differed. A 2017 study by Grau-Pérez and Moreira examined 14 chess players and 14 non-chess players aged 7-12 on the Tower of London and Wisconsin Card Sorting EF tests. This study found that the experimental group performed better overall on both tests after having systematically studied chess for 1 year. Another study, which looked at the task monitoring and behavioural regulation aspect of EF, also found that a 44-student experimental group showed more improvement in EF (reported by parents) than a 39-student control group (Addarii et al., 2022). The last more relevant study (Oberoi, 2021) on children looked at 39 chess beginners (aged 8-17) from chess academies across the US, to see how their working memory, impulsivity, and decision-making improved after a chess intervention. This intervention included 14 sessions where the beginners were taught basic chess principles and had the effect of significant improvement in both decision-making and working memory. In short, the results of these three studies on children indicate that EF skills, in general, are improved by playing chess. Despite this, they do not answer the question of whether calculation and planning have a relationship with chess ability in those between **14 and 18** years of age. There have been a few other studies which examine EF skill improvement from playing chess in children, but they do not examine calculation and planning and were conducted on hyperspecific sample groups, such as college athletes or students with mathematical learning disabilities (Khosrorad et al., 2014; Dania et al., 2021).

The Gap

To summarize, this study aims to fill a current gap in the chess literature: in students aged 14-18, how does chess rating correlate with calculation and planning ability? As has been discussed, both this age group and this type of EF have never been studied together. In fact, all previous studies that examine planning and calculation ability have looked at those over 25 or those between 7-12. Particularly in chess research, where there is such a divide between the relationship in cognitive skills among adults compared with children, this study is crucial to a fuller understanding of EF, cognitive skills in general, and how they are related to the chess abilities of those on the brink of adulthood.

In addition to exploring a new age category for an unstudied type of EF, this study will examine chess players of all levels, not just novice chess players. Moreover, it will focus on how a wide range of chess ratings are correlated with calculation and planning skills as opposed to solely looking at all chess players vs non-chess players. Ideally, this will provide a better understanding of the entire relationship between the two variables being studied. Furthermore, most of the existing research on EF looks at EF skills and chess from the lens of improving EF skills rather than through the lens of acquiring chess expertise. This study, alternatively, follows a framework similar to the studies which investigated if intelligence is required to master chess. In taking this alternative approach to an EF study, this correlational analysis will help to bridge the gap between chess expertise-focused studies, and more education-focused studies while also contributing to the ongoing discussion of cognitive skill transfer between chess and other domains in adolescents. Last, similar to Unterrainer et al. (2006), this study looks at overall Tower of London performance, performance on difficult problems, and performance on easier problems, rather than solely looking at overall performance.

Method

Finding Participants

This study gathered a sample of 20 boys and 4 girls between the ages of 14 and 18 who are rated in chess. This number was selected based on previous studies which examined chess and cognitive abilities, and the sample sizes that those studies chose (all around 30) (Unterrainer et al., 2011; Grau-Pérez & Moreira, 2017; Waters et al., 2002). For this study, slightly lower seemed reasonable, hence the choice of 24. A larger sample was deemed unfeasible without paying participants or extending the data-gathering period.

The students for this study, similar to all three anchor papers referenced in the previous paragraph, were selected for a desirable characteristic, making this a form of purposeful sampling. The desirable characteristic was chess rating, where efforts were made to analyze a wide range of levels to satisfy the requirements of a correlational analysis. These students were gathered through word of mouth, emails, and social media. Messages were sent to all high school students in three independent boys' schools and three independent girls' schools in Toronto. Possible participants were asked to fill out a form to be contacted with a meeting link.

Collecting the Data

Background Info

Simple background questions (Appendix 1) were asked through a Google Form about each participant's chess experience before completing the test. Although, apart from the chess rating, this information is not required for the crunching of numbers, it is important for the analysis in the discussion section. Participants were informed they could decline to answer questions.

The Tower of London Test

The most important part of this study is executing the test to measure the planning abilities of my participants. To do this, the Tower of London test was used. This test was selected as it has been used in every study to date that has examined planning skills and chess. For example, two of the anchor papers referenced above used it (Grau-Pérez & Moreira, 2017; Unterrainer et al., 2011). In the Tower of London test, the participant is given a starting position of objects and is required to convert that starting position to the given ending position. The objects were different coloured disks in three different stacks, where only the top disk could be moved between stacks.

This test was accessed through *Brainturk*, a website that provides the test for free (https://www.brainturk.com/tol). The version of the test used was an extension of the original test by Shallice (1982). This version consists of 27 increasingly difficult problems with an increasing number of disks. Unterrainer et al. (2011) employed a version where participants had to complete 48 increasingly difficult problems, but, given the resources available, a slightly less in-depth version was better suited.

On the google meet call, participants were asked to open the test online and to present their screen. The google meet was recorded so that I could keep track of how long it took participants to complete the test. This raw time data was then used to score the test, where the amount of time in seconds to complete the test was the score. This is a twist on part of the Krikorian et al. (1994) model. Essentially, the test was explained to participants who were allowed a few practice problems and then told to complete it as fast as possible. All results were recorded in an Excel spreadsheet.

The Correlational Analysis

After all data was collected, the analysis consisted of a correlational evaluation of the relationship between overall time score and blitz rating; overall time score and rapid rating; mean time score on difficult problems and rapid rating; mean time score on difficult problems and blitz rating; mean time score on easy problems and rapid rating; and mean time score on easy problems and blitz rating. For each, the Spearman rank coefficient (r) was used, the same coefficient used by Waters et al. (2002). This coefficient was selected as it can be used to analyze more than just linear relationships, and is relatively insensitive to outliers, unlike the Pearson coefficient. The expectation was non-linear results, so there was no harm in using a coefficient that better accounted for unpredictable relationships.

The last step before completing the analysis was converting all chess ratings to the same scale. FIDE ratings, Chess.com, and Lichess ratings were all accepted when collecting data, so a conversion table was used to convert all of them to Chess.com ratings (conversion table used: https://www.chess.com/article/view/chesscom-rating-comparisons). This was done as Chess.com was the most commonly reported rating scale.

To execute the analysis, the RANK.AVG and the CORREL functions were used in Microsoft Excel. Excel was then used to graphically represent the results. Finally, two-tailed P-values were determined for all six correlations to measure significance on the 0.05 scale using the T.DIST.2T Excel function. The same following null and alternative hypotheses were formed for all six correlations:

Null hypothesis: There is no correlation between chess rating and Tower of London time score. **Alternative hypothesis:** There is a negative moderate or stronger correlation between chess rating and Tower of London time score.

If the P-value indicated a statistically significant correlation (<0.05), the null hypothesis was rejected and the alternative hypothesis was accepted, and if the P-value indicated a statistically insignificant correlation (>0.05), the null hypothesis could not be rejected.

Findings

The sample size of this study was 24 students, composed of 4 female and 20 male participants. Participants were asked for their Rapid, Blitz, and Bullet chess ratings, however, only Rapid and Blitz ratings were used on account of about 40% of participants not playing Blitz, and, therefore, having a skewed score in that category. The overall mean rapid rating was 940, and the overall mean Blitz rating, matching online rating conversion charts, was slightly lower at 784. There was no significant difference in ratings between ages, so comparison has been omitted. In general, there was no apparent link between chess rating and length of time playing chess, apart from those participants who had been playing for less than 1 month, who generally had lower ratings in both blitz and rapid categories.

There does, however, appear to be a link between increased chess score and recent consistency in playing. The eight highest Rapid-rated participants, all rated over 1000, reported playing at least a few times a week. Alternatively, playing consistently did not necessarily mean a higher chess score, suggesting that it is important to chess rating, but not the sole contributing factor.

After completing the tests, the mean score between participants was determined to be approximately 279 seconds, with the best score being 166 seconds, and the worst score being 502 seconds. The lowest score was achieved by the participant with the 2nd lowest Rapid rating of 558 and the 3rd lowest Blitz rating of 365 among the participants. The highest score was achieved by the participant with the 10th highest Rapid rating of 1000 and the 6th highest Blitz rating of 1050. Furthermore, participants' time scores appeared unaffected by their cumulative time playing chess.

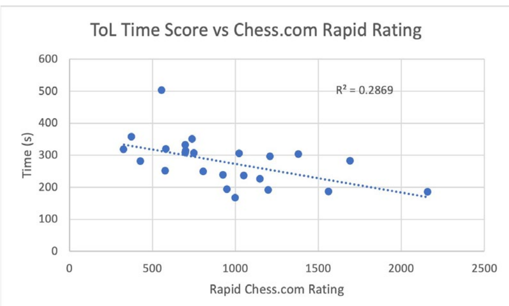

Fig.1

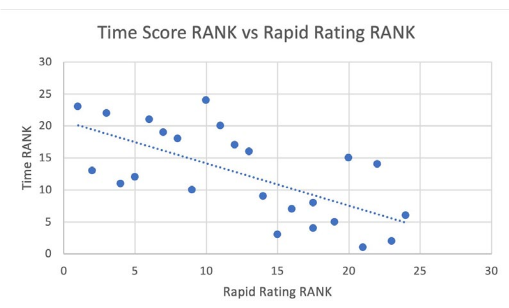

Fig.2

Following the bulk of analysis, the Spearman coefficient was determined to be -0.641 between rapid ratings and overall time scores on the Tower of London Test. This indicated a moderately strong negative correlation between the rapid ratings and overall time scores. This correlation was also deemed significant as the P-value <0.05 at 0.003125, so the null hypothesis was rejected. Since the R^2 value of the relationship between raw rapid ratings and overall time score was 0.23 (as seen in Fig.1), indicating a low correlation, it can be concluded that the relationship between these two variables is only roughly linear (possibly due to measurement noise), but is moderately monotonic. Essentially, Spearman's coefficient–which is the same as calculating Pearson's coefficient on the ranked data–measures how well the two variables can be related by a monotonic function. Monotonic functions are defined to be either entirely non-increasing or entirely non-decreasing but do not have to be linear. As is seen in Fig.2, the relationship between the ranked data is more linear, and that is why the Spearman correlation is moderately strong, but the Pearson correlation is fairly weak. The negative coefficient indicates that as rating increases, for the most part, time taken decreases. Therefore, those with a higher Rapid rating are more likely to perform better overall on the test and are more likely to have better EF.

As is seen in Fig.3, results for overall time scores vs Blitz ratings were very similar with a Spearman correlation coefficient of -0.604, a slightly less strong correlation, and, therefore, a slightly less monotonic relationship. The P-value of 0.006193 also suggested that this correlation was statistically significant, so the null hypothesis was, again, rejected. The R^2 value of the raw relationship (Fig.3), and visual interpretation of the scatter, also suggest that it is roughly linear, but the ranked data indicates a moderately strong negative correlation. This means that as the Blitz rating increases, a moderate amount of the time, the Tower of London time score will decrease.

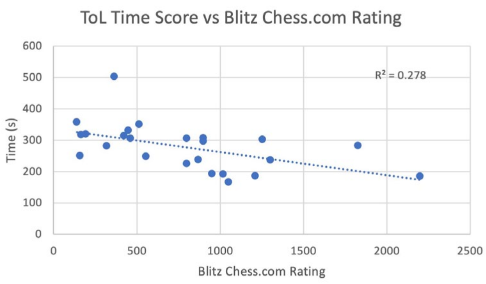

Fig.3

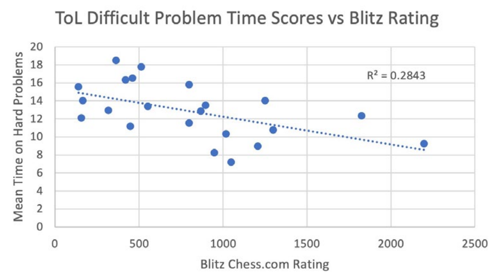

Fig.5

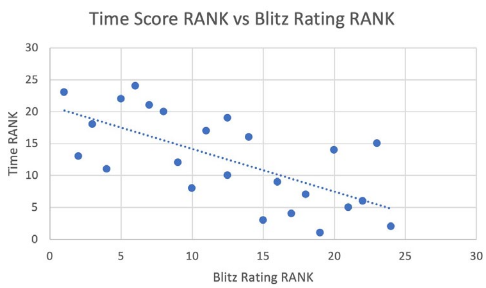

Fig.4

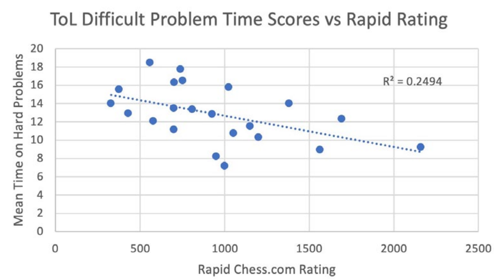

Fig.6

The link between performance on difficult problems and rapid and blitz ratings was less strong, with a coefficient of -0.513 for rapid ratings (Fig.5) and a correlation of -0.561 for blitz ratings (Fig.6). Both of these correlations are moderate negative correlations, meaning that as blitz or rapid rating increases, the time taken to complete the test decreases. Additionally, both of these coefficients were deemed statistically significant with P-values of 0.0146 and 0.0066, respectively. The null hypothesis for both coefficients was rejected and the alternative hypothesis was accepted.

The correlation between performance on easier problems and rapid and blitz rating was stronger than on more challenging problems. For rapid and blitz rating, the coefficients were -0.653 (Fig.7) and -0.556 (Fig.8), respectively. Once again, both of these coefficients were deemed statistically significant with P-values of 0.000987 and 0.00717, respectively. The correlation between rapid rating and Tower of London time score is, therefore, negative and moderately strong, and the correlation between blitz rating is negative but only moderate. The null hypotheses for both correlations were rejected, and the alternative hypotheses were accepted.

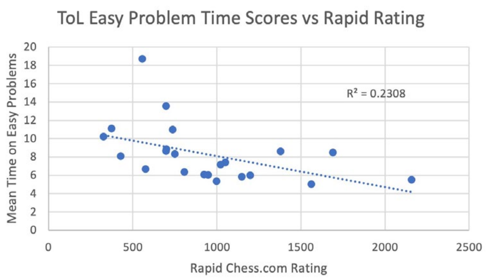

Fig.7

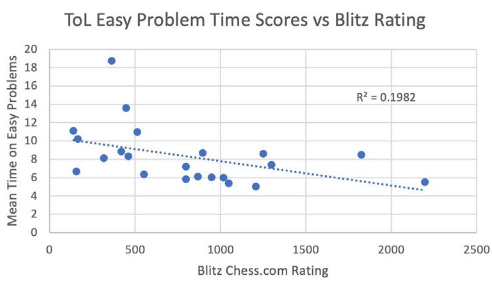

Fig.8

Discussion

The results of this study indicate a moderate--moderately strong correlation between chess rating and all Tower of London time scores in chess players aged 14 to 18. For all six analyses, this correlation was statistically significant, with two-tailed P-values well below the 0.05 benchmark that was used in this study. These P-values are an indication of the high likelihood that the results of my small sample group are a reflection of the overall population. Overall, this suggests a correlation between increased chess ability and increased EF skills. As most studies in the field have noted, however, this does not indicate causation, and so no conclusion can be drawn as to whether EF skills are required to be good at chess, or if chess skills are required to have superior EF skills. Additionally, there were a couple of outliers in all 6 calculations, and the correlations were only moderate, so even if causation could be concluded, it would not fit all cases.

Given the results of other studies on other groups, the results of this study are expected. All three previously mentioned studies on children found improvements in EF skills in young persons who had played more chess. This includes working memory, decision-making, and planning and calculation skills as measured by the Tower of London test (Addarii et al., 2022; Oberoi, 2021; Grau-Pérez & Moreira, 2017). In adults, however, EF skills have almost no correlation of significance with chess ability, with two almost identical studies on adults finding no correlation between chess rating and planning skills as well as chess rating and visuospatial memory (Unterrainer et al., 2011; Waters et al., 2002). The results of this study, therefore, fill the gap, and demonstrate the possibility that adolescence is a transition period where EF skills and chess ability become less connected; we see that in children it can have a significant effect; in adolescents, it can have a moderate effect; and in adults, it has next to no effect. The implications of this may be that, with age, chess also becomes a less effective tool for improving math skills or spatial concept development, which has largely been shown to help younger children (Sigirtmac, 2011; Sala et al., 2015).

Ultimately, as the background info responses indicate, and Sala et al. (2017) suggested, no one cognitive strength is enough to explain expert chess ability, whether that be intelligence or EF-related skills. This study supports this narrative as EF skills are generally better in higher-rated players, but are not always. Additionally, higher ratings being linked to recent consistency in playing points to practice as a good secondary tell-tale of how advanced a chess player might be. This result partly aligns with the conclusion made by Bilalić et al. (2007) in their study on child chess players, which found that chess skill was most impacted by practice as opposed to years of experience or intelligence. Unfortunately, this study lacks the comparative component between different contributing factors. Nevertheless, it aligns with the idea that multiple factors are impactful. Additionally, the shallow impact of years of experience playing chess on chess rating, likely due to inconsistent playing, supports the findings of Bilalić et al. (2007) that this factor is not a significant determinant. Last, in contrast to the findings of Unterrainer et al. (2011), adolescent chess players proved more dominant on easy problems rather than hard problems. Unterrainer et al. (2011) found that adult chess players, while not significantly better overall, proved more dominant on harder problems.

In the context of other chess studies with cognitive ability, this study fully supports the idea that the effect of different factors on chess performance changes with age. Apart from practice, it seems that all factors–including intelligence, EF skills, memory skills and so on–are more significant in young players trying to improve at chess. Whether it is preexisting EF skills that entice young players into playing chess, encouraging them to practice more or to improve other cognitive skills, or it is playing chess that actually improves cognitive skills through practice, this study suggests that one or the other, or a balance of the two, is true.

Limitations

The majority of the limitations of this study stem from a lack of time and resources. First, the sample size of this study is only a limited representation of the entire population of 14 to18-year-olds. Only 24 participants were included in the final analysis, obviously only a fraction of the number of students who play chess and could contribute to the results. Therefore, despite both P-values indicating a very low probability that the null hypothesis is correct (that there is no correlation between chess rating and EF ability), the low sample size decreases the strength of the data. In addition to the smaller sample size, the lack of female representation in this study and in the literature at large is a serious limitation to the generalizability of all results. This study aimed to have equal numbers of females and males, but, unfortunately, one girls' school entirely declined to participate, and, for a variety of reasons, the two others were difficult to communicate with. Second, and probably the most specific to this study, is the inaccuracies in results due to the difference in access to technology between participants. Since the entire study was conducted online, as meeting in person with every participant was not possible, some participants used trackpads and some used mice. It seems unlikely that this would have skewed the data towards a correlation, as it would be no more likely for a higher-rated chess player to have a mouse than a lower-rated player, but it still limits the accuracy of results. In addition to discontinuities in equipment, the tests were all completed at different times of the day, and on different days of the week, which could have impacted fatigue, and, by extension, performance. The effects of this limitation should be minimal, however, as every person has different times when they are most awake, and participants got to choose the time of their test. It should also be mentioned that, in the broader sense of chess score vs EF skills, it is possible that the correlations would not be significant, especially if the Tower of London measure does not correlate with other EF measures. Finally, Chess.com's rating accuracy may contribute to the limited accuracy of the results of this study. In comparison with official chess ratings, it is much easier to cheat on Chess.com to unfairly advance your rating or to have a rating that doesn't reflect your ability if you do not play enough.

Future Directions

A future continuation of this study should aim for a larger sample group (probably around 50), with a better range of chess ratings and a more diverse spread of gender and demographics. Additionally, it should aim to include more EF questions by possibly running the EF test twice, and should better mitigate the speed differences in technology from participant to participant. This would probably be best achieved by completing the study in person, where all participants use the exact same technology. To investigate the possibility that the broader significance of correlations found in this study was a nonspecific effect, future research could also examine how chess scores correlate with other measures such as the Wisconsin Card Sorting Test. Last, in addition to a continuation of this study, another comparative study on factors that contribute to chess mastery in this age group would be very interesting and a great complement to the existing literature. A study like this would give insight unavailable from this study by looking at multiple factors and ranking the magnitudes of their effects, also providing a better estimate of actual cause.

Conclusion

The results of this study indicate that there is a statistically significant, moderate negative correlation between Tower of London scores and Blitz and Rapid Chess.com ratings for those between 14 to 18. The basis that these two variables rise together introduces a variety of implications for education and the chess world. Up until this point, it was known that chess could be an effective scholastic tool in ages 5-12, but unknown how effective it might be in adolescents. This study confirms it to be at least a possible tool, one that should be attempted, in a school setting. Additionally, with the recent spike in interest in online chess in Toronto and beyond, this study provides numerical evidence in support of allowing adolescents to play chess during breaks at school (Keener, 2022). In terms of adolescent competitive chess players, this provides insight into possible tweaks in training methods for improvement in chess ability. Further comparative research is required to determine if EF skill training is superior to other forms, but this study establishes it in the literature.

References

Addarii, F., Ciracò, E., Polo, K., & Neri, E. (2022). Chess at school, executive functions and pandemic: an exploratory study. *Quaderni ACP*, 153-156. https://pesquisa.bvsalud.org/global-literature-on-novel-coronavirus-2019-ncov/resource/fr/covidwho-1965215

Atherton M., Zhuang J., Bart WM., Hu X., He S. (2003). A functional MRI study of high-level cognition in the game of chess. *Brain Res Cogn Brain Res, 16*(1), 26-31. https://sci-hub.se/10.1016/s0926-6410(02)00207-0

Bilalić, M., McLeod, P., & Gobet, F. (2007). Does chess need intelligence?—A study with young chess players. *Intelligence, 35*(5), 457-470. https://bura.brunel.ac.uk/bitstream/2438/642/1/Does%20Chess%20Need%20Intelligence-revision-finalINT.pdf

Bühren, C., & Frank, B. (2010). Chess players› performance beyond 64 squares: A case study on the limitations of cognitive abilities transfer (No. 19-2010). MAGKS Joint Discussion Paper Series in Economics. https://www.econstor.eu/bitstream/10419/56575/1/628596561.pdf

Burgoyne, A. P., Sala, G., Gobet, F., Macnamara, B. N., Campitelli, G., & Hambrick, D.Z. (2016). The relationship between cognitive ability and chess skill: A comprehensive meta-analysis. *Intelligence, 59*, 72-83. https://eprints.lse.ac.uk/102241/1/INTELL_2016_117_The_Relationship_between_Cognitive_Ability_and_Chess_Skill_a_Comprehensive_Meta_Analysis.pdf

Dania, A., Kaltsonoudi, K., Ktistakis, I., Trampa, K., Boti, N., & Pesce, C. (2021). Chess training for improving executive functions and invasion game tactical behavior of college student athletes: a preliminary investigation. *Physical Education and Sport Pedagogy*, 1-17. https://www.tandfonline.com/doi/abs/10.1080/17408989.2021.1990245

Djakow, I. N., Petrowski, N. W., & Rudik, P. A. (1927). *Psychologie des schachspiels*. Berlin: de Gruyter.

Doll, J., & Mayr, U. (1987). Intelligence and success in chess playing: An examination of chess experts. *Psychologische Beitrage, 29*(2-3), 270–289. https://psycnet.apa.org/record/1989-72580-001

Frydman, M. & Lynn, R. (1992). The general intelligence and spatial abilities of gifted young Belgian chess players. *British Journal of Psychology, 83*(2), 233-235. https://sci-hub.se/10.1111/j.2044-8295.1992.tb02437.x

Gliga, F., & Flesner, P.I. (2014). Cognitive benefits of chess training in novice children. *Procedia-Social and Behavioral Sciences, 116*, 962-967. https://reader.elsevier.com/reader/sd/pii/S187704281400345 0?token=7750EC7260A44367AC54EA4EF332EDF447D152048C32A9BE32585C57C5077878C293059246B431A44B9B82406EF28666&originRegion=us-east-1&originCreation=20221102163844

Gobet, F., & Campitelli, G. (2002). Intelligence and chess. https://bura.brunel.ac.uk/bitstream/2438/2274/1/Gobet-Intelligence%20and%20chess.pdf

Grau-Pérez, G., & Moreira, K. (2017). A study of the influence of chess on the Executive Functions in school-aged children/Estudio del impacto del ajedrez sobre las Funciones Ejecutivas en niños de edad escolar. *Studies in Psychology, 38*(2), 473-494. https://sci-hub.se/https://doi.org/10.1080/02109395.2017.1295578

Keener, G. (2022). Chess is booming. *The New York Times.* https://www.nytimes.com/2022/06/17/crosswords/chess/chess-is-booming.html

Khosrorad, R., Kouhbanani, S.S., & Sanii, A.R. (2014). Chess training for improving executive functions and mathematics performance of students with mathematics disorders. *International Journal of Educational Investigations, 1*(1), 283-295. https://core.ac.uk/download/pdf/35290845.pdf

Krikorian, R., Bartok, J., & Gay, N. (1994). Tower of London procedure: A standard method and developmental data. *Journal of Clinical and Experimental Neuropsychology, 16*(6), 840–850. https://sci-hub.ru/10.1080/01688639408402697

Nejati, M. & Nejati, V. (2012). Frontal lobe function in chess players. *Acta Medica Iranica, 50*(5), 311-4. https://tinyurl.com/3x8mjfsy

Oberoi, A. (2021). Using Chess as an Intervention to Improve Executive Functioning Among Youth (Doctoral dissertation, Walden University). https://scholarworks.waldenu.edu/cgi/viewcontent.cgi?article=12482&context=dissertations

Sala, G., Burgoyne, A. P., Macnamara, B.N., Hambrick, D.Z., Campitelli, G., & Gobet, F. (2017). Checking the "Academic Selection" argument. Chess players outperform non-chess players in cognitive skills related to intelligence: A meta-analysis. *Intelligence, 61*, 130-139. https://www.sciencedirect.com/science/article/pii/S0160289616301635#bb0040

Sala, G., & Gobet, F. (2016). Do the benefits of chess instruction transfer to academic and cognitive skills? A meta-analysis. *Educational Research Review, 18*, 46-57. https://www.sciencedirect.com/science/article/pii/S1747938X16300112

Sala, G., Gorini, A., & Pravettoni, G. (2015). Mathematical problem-solving abilities and chess: an experimental study on young pupils. *Sage Open, 5*(3), 2158244015596050. https://journals.sagepub.com/doi/pdf/10.1177/2158244015596050

Shallice, T. (1982). Specific impairments of planning. *Philosophical Transactions of the Royal Society B: Biological Sciences, 298*(1089), 199–209. https://sci-hub.ru/10.1098/rstb.1982.0082

Sigirtmac A. (2011). Does chess training affect conceptual development of six-year-old children in Turkey? *Early Child Development and Care, 182*(6), 797-806. https://sci-hub.se/https://doi.org/10.1080/03004430.2011.582951

Unterrainer, J.M., Kaller, C.P., Halsband, U., & Rahm, B. (2006). Planning abilities and chess: A comparison of chess and non-chess players on the Tower of London task. *British Journal of Psychology, 97*(3), 299–311. https://sci-hub.ru/10.1348/000712605X71407

Unterrainer, J.M., Kaller C.P., Leonhart R., & Rahm, B. (2011). Revising superior planning performance in chess players: The impact of time restriction and motivation aspects. *The American Journal of Psychology, 124*, 213-225. https://sci-hub.se/https://doi.org/10.5406/amerjpsyc.124.2.0213

Waters, A.J., Gobet, F., & Leyden, G. (2002). Visuospatial abilities of chess players. *British Journal of Psychology, 93*(4), 557-565. https://bura.brunel.ac.uk/bitstream/2438/805/1/Visuo-spatial_abilities.pdf

Woodworth, R.S., & Thorndike, E. L. (1901). The influence of improvement in one mental function upon the efficiency of other functions. (I). *Psychological Review, 8*(3), 247–261. https://sci-hub.ru/https://doi.org/10.1037/h0074898

Appendix A

Background Questions:

How long have you been playing chess?

How often do you play chess?

Did/do you attend a chess academy/receive chess lessons?

How old are you?

What is your gender?

Do you play chess competitively? If yes, for how long?

What are your rapid, blitz, and bullet chess ratings? On what scale? (Lichess, Chess.com, etc.)

Optional: Do you have any learning/cognitive conditions or disabilities?

Appendix B

Number	Rapid	Blitz	Bullet	Total Time	Mean Time Hard	Mean Time Easy
1	328	166		317	14	10.1875
2	1692	1828		282	12.29	8.461538462
3	558	365		502	18.45	18.6875
4	700	450	500	331	11.13	13.54545455
5	1382	1253	1211	302	14	8.571428571
6	808	555		248	13.36	6.3125
7	927	869	986	238	12.82	6.0625
8				5:02		
9				4:54		
10	1052	1301		236	10.73	7.375
11	702	422	272	313	16.3	8.823529412
12	1150	800	800	225	11.5	5.8
13	740	515	682	350	17.75	10.94736842
14	1563	1210	1122	186	8.92	5
15	950	950	950	193	8.21	6
16	1200	1019	961	191	10.29	5.95
17	700	899		307	13.47	8.636363636
18	1025	800		305	15.77	7.142857143
19	579	158	700	250	12.08	6.642857143
20	582	193	1200	319		
21	1210	900	745	296		
22	375	140		357	15.54	11.07142857
23	2160	2200	2400	185	9.2	5.470588235
24	752	463	403	306	16.5	8.294117647
25	430	320	280	281	12.92	8.071428571
26	1000	1050	1200	166	7.17	5.333333333

Appendix C

Consent Info Given to Participants

Description:

You are being asked to participate in a quantitative research study on chess and planning scores. If you agree to participate, you will complete the Tower of London planning test. This test will be conducted on my computer in person, or on your computer over Google Meet, and consists of 27 different questions of varying difficulty. For each question, you will see, on screen, three different stacks with different colours of disks stacked randomly on them. You will be given a starting position for these disks, and the goal/ending position. You will be tasked with converting the starting position to the ending position as fast as possible.

In addition to completing the test, you will be asked the following questions for some background information:

How long have you been playing chess?

How often do you play chess?

Did/do you attend a chess academy/receive chess lessons?

How old are you?

What is your gender?

Do you play chess competitively? If yes, for how long?

What are your rapid, blitz, and bullet chess ratings? On what scale? (Lichess, chess.com, etc.)

Do you have any learning/cognitive conditions or disabilities?

Risks and Benefits:

There are no apparent risks in participating in this study. This study will contribute to the adaption and development of more informed training methods for improving in chess. Additionally, it will benefit students by allowing educators to optimize their use of chess as a learning tool.

Confidentiality:

Your name, if given to me, will not be mentioned at any point in the study, nor will it be recorded with the data you provide. You will always be anonymous.

Right to Withdraw or Refuse to Answer:

You may withdraw from this study at any point and have your information and data completely removed from the study. Additionally, you have the right to refuse to answer any questions which you feel uncomfortable answering. It should be noted that, while you may refuse to participate in parts of the study, your data may be removed entirely if you choose not to participate in a significant portion of it.