REVISTA Mundi
Engenharia, Tecnologia e Gestão
INSTITUTO FEDERAL Paraná

CHESS RESEARCH: RECENT TRENDS
PESQUISA DE XADREZ: TENDÊNCIAS RECENTES

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Abstract: Considerable research has been carried out on chess in the last seventy years. While classic research has centred on perception, memory, and decision making, contemporary research has focused on deliberate practice, individual differences, and education. Contrasting with classical research, which has mainly used experiments and computer modelling, more recent research has tended to use questionnaires, interviews, and analysis of computer databases as source of information. This article reviews these recent research trends, focusing on what has been learnt from chess research with respect to deliberate practice, intelligence, and transfer of skill. It also discusses ageing and risk taking between civilizations as examples of computer database analyses. Results clearly indicate that deliberate practice is a necessary, but not sufficient condition for achieving high levels of expertise. Other factors are important, some of which are innate. One of them is intelligence. Data show that chess players on average are more intelligent than individuals who do not play chess, and that chess skill positively correlates with intelligence. These results are unlikely to be explained by the hypothesis that chess leads to an increase of intelligence, as the results of experiments using chess instruction to bring about far-transfer effects are inconsistent. In addition, experiment designs used in chess instruction research are typically insufficient to allow strong conclusions about causality. Research using chess databases have led to interesting results, but its generalisability is likely to be limited. The article ends with recommendations for future research.

Keywords: Chess**.** Database. Intelligence. Practice. Talent.

Resumo: Uma pesquisa considerável foi realizada sobre o xadrez nos últimos setenta anos. Enquanto a pesquisa clássica se concentra na percepção, memória e tomada de decisão, a pesquisa contemporânea se concentra na prática deliberada, nas diferenças individuais e na educação. Ao contrário da pesquisa clássica, que utilizou principalmente experimentos e modelagem computacional, as pesquisas mais recentes tendem a usar questionários, entrevistas e análises de bancos de dados de computador como fonte de informação. Este artigo analisa essas tendências de pesquisa recentes, enfocando o que foi aprendido com a pesquisa de xadrez com respeito à prática deliberada, inteligência e transferência de habilidade. Ele também discute envelhecimento e riscos assumidos entre civilizações como exemplos de análises de banco de dados de computador. Os resultados indicam claramente que a prática deliberada é uma condição necessária, mas não suficiente para atingir altos níveis de especialização. Outros fatores são importantes, alguns dos quais são inatos. Um deles é a inteligência. Os dados mostram que os jogadores de xadrez, em média, são mais inteligentes do que os indivíduos que não jogam xadrez, e que a habilidade no xadrez se correlaciona positivamente com a inteligência. É improvável que esses resultados sejam explicados pela hipótese de que o xadrez leva a um aumento da inteligência, já que os resultados dos experimentos usando instruções de xadrez para produzir efeitos de transferência distante são inconsistentes. Além disso, os designs de experimentos usados na

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pesquisa de instrução de xadrez são tipicamente insuficientes para permitir conclusões fortes sobre a causalidade. Pesquisas usando bancos de dados de xadrez levaram a resultados interessantes, mas sua generalização provavelmente será limitada. O artigo termina com recomendações para pesquisas futuras.

Palabras-clave: Xadrez. Base de dados. Inteligência. Prática. Talento.

1 INTRODUCTION

A significant number of scientific studies have been carried out on chess, foremost in psychology and computer science (including artificial intelligence), but also in education, neuroscience, mathematics, and other fields. Although some important precursors should be noted, such as Binet (1981) and Djakow, Petrowski and Rudik (1927), chess research really started to blossom after De Groot's (1965) and Simon and Chase's (1973) seminal studies on chess perception, memory, and decision making.

It is possible to divide chess research into two main periods: the classical period (from about 1950 to about 2000) and the contemporary period (from about 2000 to now). After briefly describing the classical period – more extensive reviews can be found in Gobet (2018) and De Voogt and Retschitzki and Gobet (2004) – this article will present some important contemporary developments, focusing on psychology and education.

1.1 The Classical Period

By and large, the classical period refined the ideas and methods proposed by De Groot, Chase and Simon. Theoretically, the key ideas about problem solving concerned search behaviour, in particular selective search, pattern recognition and progressive deepening – chess players' tendency to revisit the same moves and variations several times when thinking about a move. The key ideas in perception and memory research related to chess players' remarkable ability to recall briefly-presented chess positions, which was largely explained by chunking – the ability to learn and use groups of pieces as units.

The main methods used during this period were experiments, where some variables are manipulated and their effect on players of different skill levels is measured. Several studies (e.g., DE GROOT, 1965) used verbal protocols, where participants are asked to think aloud when they try to solve a problem (concurrent protocols) or to remember their thoughts when they faced a task (retrospective protocols). As several studies were interested in perception, it is not surprising that eye-movement methodology was sometimes used (e.g., DE GROOT; GOBET; JONGMAN, 1996).

This period is also characterised by close links with artificial intelligence, particularly with respect to the development of computer models that simulate aspects of human behaviour. For example, Baylor and Simon (1966) simulated the highly selective search displayed by players solving checkmate combinations, and Gobet and Simon (2000) simulated how perception and memory change as a function of players' skill level.

1.2 The Contemporary Period

The contemporary period roughly starts in 2000. Although old research themes are still present – in particular the research on memory – there is a clear shift of interest and new research themes appear. Much work has been done on deliberate practice with the aim of uncovering the practice activities that are central in acquiring chess expertise. The field of psychology often called "individual differences" has also attracted considerable attention. This field is concerned with intelligence and personality. When we wrote the book "Moves in Mind" (GOBET; DE VOOGT; RETSCHITZKI, 2004), we struggled to find material on this topic. Very recently, Blanch (2021) devoted an entire book on it! Considerable research has also been carried out in education on the potential benefits of learning chess, which relate to the broader question of transfer of skill. Finally, how ageing affects expertise and other aspects of cognition has also been studied in some detail. Later sections of this article will provide more information about these topics.

Interestingly, methods have also changed, at least to some extent. While experiments are still popular, relatively few recent studies have used verbal protocols, which were popular in the classical period. Questionnaires and structured interviews, which were rare previously, are now commonplace. Finally, many articles have used as a main tool the analysis of databases (e.g., ratings or games), as will be illustrated later in this article. Before 2000, very little had been done with databases in chess psychology, with the notable exception of Arpad Elo's (1978) book, which discussed how the rating he had developed could address questions related to ageing and the presence of a critical period in acquiring skill in chess.

2 DELIBERATE PRACTICE AND TALENT IN CHESS

Building on previous research (e.g. SIMON; CHASE, 1973), Ericsson, Krampe and Tesch-Römer (1993) proposed that deliberate practice is the key ingredient in becoming an expert. Deliberate practice consists of goal-directed and repetitive activities that support immediate feedback. These activities, which should be performed individually, tend to be effortful and not enjoyable. As they require high concentration, and to avoid risks of burnout and injuries in some sports, these activities should not be performed for more than four or five hours a day. Becoming an expert is a long process and takes about ten years of deliberate practice. Finally, talent plays no role in acquiring expertise, except for the motivation to engage in deliberate practice and height in some sports.

This framework has been very influential and has inspired substantial research in many domains of expertise, including games, sports, science and the professions (for extensive reviews, see the chapters in ERICSSON; CHARNESS; FELTOVICH; HOFFMAN, 2006). Chess has been the focus of several studies, which have had considerable theoretical impact on the deliberate practice framework. In the following, I will focus on the study I carried out with my then PhD student Guillermo Campitelli, as it was unique in collecting information both about practice and talent (CAMPITELLI; GOBET, 2008; GOBET; CAMPITELLI, 2007).

2.1 Data on Deliberate Practice

We used the standard methodology in this kind of research – retrospective structured questionnaires – asking chess players to report their practice activities and the amount of time they had spent performing them. Our sample consisted of 104 Argentinean players, ranging from weak amateurs to grandmasters. Chess is nearly unique in expertise research in that serious players have a rating, which is regularly updated as a function of their results in official games. This rating, called the Elo rating, uses an interval scale and is based on sound foundations in probability theory (ELO, 1965). The scale has a mean of 1500 and a standard deviation of 200. The following names are often used to denote 200 points intervals in the scale: Class C (1400–1600), Class B (1600–1800), Class A (1800–2000), Candidate Masters (2000–2200), Masters (2200–2400), International Masters (2400–2500) and Grandmasters (above 2500). Players above 2000 are considered as "experts".

The results showed that our sample took on average 11,000 hours of deliberate practice to reach master level. Deliberate practice explained about 18% of the variance in skill, which is slightly less but still comparable to the 25% that were found in the study carried out by Charness et al. (2005). However, these numbers hide a very important fact: there was a huge variability in the amount of deliberate practice. Some players needed eight times longer (3,000 hours vs. 24,000 hours) than others to become masters. Moreover, some players practiced for more than 25,000 hours, but never reached the master level. Hambrick et al. (2014) provide some more data about the large variability in deliberate practice in this Argentinean sample, and also show, through reanalyses of Ericsson et al.'s (1993) data, that there was also considerable variability in the pianists and violinists they studied.

The deliberate practice framework stipulates that skill is a monotonic function of deliberate practice. That is, each increment in practice should lead to an increment in performance. This prediction was not borne out by our data. Although the candidate masters and the masters practiced the same amount of time in the first three years of serious practice, the masters reached higher ratings. In addition, the candidate masters did not improve much after three years despite considerable amounts of deliberate practice.

2.2 Data on Starting Age and Handedness

Elo (1965) proposed the hypothesis that there is a critical period for acquiring chess skill. This prediction was supported by our data: the age at which players start playing chess seriously is a good predictor of the skill level they will reach (GOBET; CAMPITELLI, 2007). Starting age correlated negatively with current rating (r = –.37), meaning that it is advantageous to start early; crucially, this correlation remained essentially unaffected after the amount of practice is partialled out (r = –.40). The effect size is substantial, as can be seen when the results are expressed using probabilities. The probability of becoming an international-level player was .24 for players who started to play seriously at the age of 12 or before, but it was only .02 for players who started to play after the age of 12.

As a proxy for talent, we measured handedness with the Edinburgh questionnaire (OLDFIELD, 1971). We found that chess players tended to be more often non-right-handed (i.e., left-handed or ambidextrous) than the population. The respective percentages were 18% and 10.2%. In addition, the players' degree of handedness – whether they tended to be extreme right-handers or extreme left-handers – was lower than in the general population. That is, players tended to be more mixed-handed. However, we did not find any correlation between handedness and skill within the sample of chess players. Thus, it seems that handedness is a weak marker for chess skill, differentiating players from individuals who do not play chess, but failing to discriminate between chess players of different ability.

In conclusion, the results indicate that deliberate practice is necessary, but not sufficient for reaching high levels of skill (CAMPITELLI; GOBET, 2011). Other factors are important, such as starting age, intelligence (the topic of the following section) and, to a lesser extent, handedness. Some of these factors may be innate in nature. These conclusions have been supported by research in other domains of expertise (GOBET, 2016).

3 INTELLIGENCE AND CHESS

Intelligence can be defined as “a general reasoning capacity useful in problem-solving tasks of all kinds” (KLINE, 1991, p. 6). It is an important but sometimes controversial topic, in particular when attention is directed to differences between genders or ethnic groups (e.g., MACKINTOSH, 1998). However, it is a valid concept as measures of intelligence have been shown to correlate with numerous variables, including education level, job performance, and even health (HUNT, 2011; MACKINTOSH, 1998). Chess has often been considered as a paragon of intelligence. Is this view correct?

A fair amount of research has been carried out to address this question. Rather than discussing all the studies in detail – there are simply too many – I will report the result of meta-analyses carried out together with my former PhD student Giovanni Sala. A meta-analysis is a statistical procedure that combines quantitative measures between studies to calculate an overall effect size. Typical examples of effect sizes are correlations and standardized mean differences between two groups (e.g., one group receiving a treatment and a control group).

A first question is whether chess players are more intelligent than non-players. Sala et al. (2017) found seven independent samples on this question, with a total of 485 participants. The meta-analysis yielded a medium-size effect: d = 0.49. Thus, on average, chess players are more intelligent than the population at large.

A second question asks whether skill level in chess correlates with measures of intelligence, such as IQ. Burgoyne et al. (2016) found 26 independent samples on this question, with 1,779 participants in total. With all measures of intelligence combined, the average meta-analytic correlation was r = .24 (a medium effect size). Similar results were obtained when only measures of fluid reasoning (Gf) and comprehension-knowledge (Gc) were used: r = .24 and r = .22.

As is well known, correlation does not mean causation. Thus, what do these correlations mean? Can we establish the direction of causality? Of course, an indefinite number of causal models are consistent with the results, including (a) intelligence causes skill in chess; (b) chess causes intelligence; (c) the causal link between chess and intelligence is bidirectional; and (d) a third variable (e.g., motivation) mediates the causal link between intelligence and chess. We will see in the following section that it is unlikely that chess plays a causal role with respect to intelligence. Thus, hypothesis (a) seems a plausible candidate, of course along many other causal models involving more variables.

4 THE QUESTION OF TRANSFER

The question of transfer, already present during the classical period, has received enormous attention in the last twenty years or so. It may be helpful to start with a few definitions, to avoid any ambiguity. *Transfer* concerns abilities developed in one domain that can be used in another domain. The term can be further refined into near transfer and far transfer. *Near transfer* concerns transfer to a similar domain, for example from algebra to calculus. *Far transfer* concerns transfer to a non-similar domain, for example from Latin to mathematics. While some cases can be ambiguous, these definitions will suffice for the vast majority of research that will be discussed in this section. Note that it is possible to further subdivide near transfer. For example, when studying working-memory training, one can distinguish between “nearest transfer” (tasks that are the same as or very close to those used during training) and “less near transfer” (tasks that are different but still aim at improving memory) (see SALA; GOBET, 2020).

4.1 Early Research on Chess Instruction

For many years, strong claims have been made by the chess community about the possibility that chess improves school achievement and develops abilities such as intelligence and memory. However, an early review of the literature on transfer and chess teaching (GOBET; CAMPITELLI, 2006) reached disappointing conclusions. There were few scientifically valid studies, and only a couple of those studies had been peer-reviewed, a must in science. Thus, in general, the data available at this point did not provide any clear evidence for far transfer. The review also noted that, in most studies, poor experimental designs were used, and pointed out the correct design to establish causality in such intervention studies. In what the review called the "ideal experiment", there should be three groups: (a) a treatment group (chess, in our case), (b) a passive control group, which keeps doing normal activities, and (c) an active control group, which carries out a novel activity, such as playing a video game. The active control group is important for controlling non-specific effects, such as placebo effects (e.g., improvements in performance due to the knowledge that one participates in an experiment). Pre-tests should be given before the intervention to make sure that the groups do not differ at the beginning of the experiment, and post-tests should be administered after the intervention, to measure the extent to which the groups' performance changes over time. Participants should be randomly allocated to the three groups, to ensure that a number of characteristics that could affect the results (e.g., intelligence, motivation, or personality) are more or less evenly distributed among the groups. Ideally, the experiment should be double-blind: neither the participants nor the experimenters know to which group the participants belong. Whilst this is possible in medicine, where such designs are standard for evaluating the efficacity of new drugs, in practice it is very difficult to blind participants in studies involving chess, as obviously participants would know to which group they belong.

4.2 Experiments with an Active Control Group

It turns out that this design has been rarely used with to study the cognitive and academic effects of chess instruction, despite the fact that a considerable number of studies have been conducted on this question in this century. To my knowledge, only two experiments used such a design with chess, both reported in Sala and Gobet (2017a). The two experiments had a treatment group (chess), an active control group (either Go or checkers), and a passive control group. Class assignment to the groups was random. Measures of mathematical problem-solving ability and metacognitive skills were taken at pre-test and post-test. Fifty-two fourth graders took part in the first experiment (Go) and 233 third and fourth graders took part in the second experiment (checkers). Participants either received chess lessons in the chess group or Go/checkers lessons in the active control group, or attended regular school activities. In none of the two experiments did the results about mathematical problem-solving ability and metacognitive skills indicate any evidence of far transfer.

4.3 Meta-analytic Evidence and The Institute of Education Study

The meta-analysis performed by Sala and Gobet (2016) found 24 studies with a total of 5,221 participants. Compared to Gobet and Campitelli's (2006) review, the quality of research was much improved. The results showed a modest effect on academic skills (e.g., mathematics) and cognitive ability (e.g., intelligence), g = 0.34, which is equivalent to about one third of a standard deviation. However, as just noted, active control groups were very rarely used, which means that placebos and self-selection cannot be ruled out.

The meta-analysis did not include a more recent and large study carried out by the Institute of Education, London (JERRIM; MACMILLAN; MICKLEWRIGHT; SAWTELL *et al.*, 2017), which comprised 3,865 9–10 years old pupils. Classes were randomly assigned to the two groups (chess or passive control). The pre-test consisted of Key Stage 1 public examinations for literacy, science, and mathematics, and the post-test, performed one year after the end of the treatment, evaluated the same disciplines in Key Stage 2 public examinations. Chess instruction was provided for one year (25–30 hours). The results were clear, albeit disappointing: there were no differences between the two groups at post-test with respect to literacy, science, and mathematics.

In spite of strengths (e.g., large sample size and random assignment of the classes to the two groups), the study suffers from several weaknesses (SALA; FOLEY; GOBET, 2017). First, as the post-test was administered one year after the end of the instruction, there was no immediate post-intervention measure. This would have allowed a direct comparison with previous studies, which had focused on the short-term impact. Second, the results suffered from a ceiling effect, as roughly half of the sample obtained scores above 75% in the mathematics tests. Third, there was no active control group.

4.4 Far Transfer beyond Chess

The results reported in this section will disappoint researchers and practitioners interested in using chess for educational purposes. However, it should be noted that the difficulty of obtaining far transfer is not specific to chess. Together with Giovanni Sala and other colleagues, I have carried out several meta-analyses on the cognitive and academic effects of other cognitive interventions: working memory training, video-game playing, music, and exergames (video games with a physical component). The results consistently indicated a lack of far transfer (for reviews, see SALA; GOBET, 2017b; SALA; GOBET, 2019). We also carried out a second-order meta-analysis, analysing chess and all these interventions together (SALA; AKSAYLI; TATLIDIL; TATSUMI *et al.*, 2019). The overall effect size was small, and it was null when interventions were compared to active control groups. Thus, the observed far-transfer effect is due to factors that are unspecific, such as placebos and publication bias. Importantly, there was little variability between the types of training, which suggests that the difficulty of obtaining far transfer is an invariant of human cognition.

Thus, the results from chess research and other domains of cognitive training are not encouraging with respect to improving children's intelligence and academic achievements. As noted in several talks at the London Chess Conferences 2018 and 2019, and as discussed in Gobet (2018), it is likely that researchers should focus on less ambitious aims. These include facilitating social interaction, enabling friendships to develop, and fostering simple – but important – skills such as anticipating the consequences of one's actions and learning how to lose gracefully.

5 USING CHESS DATABASES

As noted earlier, an interesting characteristic of current research on chess is that it has made considerable use of computerised databases. Researchers have used a number of dependant variables, such as Elo ratings, the first move played in a game, the quality of moves played (estimated by top computer programs), the presence of blunders, date of birth, number of games, just to mention a few (e.g., BILALIC; SMALLBONE; MCLEOD; GOBET, 2009; GOBET; CHASSY, 2008; LEONE; FERNANDEZ SLEZAK; GOLOMBEK; SIGMAN, 2017; SMERDON; HU; MCLENNAN; VON HIPPEL *et al.*, 2020; STAFFORD, 2018; STRITTMATTER; SUNDE; ZEGNERS, 2020). In this section, I consider two examples. The first uses the first move played in a game as a way to estimate risk, and the second uses Elo ratings as a means to measure how skill evolve as a function of age.

5.1 Civilization Differences in Risk Taking

Chassy and Gobet (2015) were interested in what risk taking in chess could tell us about risk taking between civilizations. A "civilization" was defined by Huntington (1996) as a group of states sharing similar values. Note that these values do not have to be political, and can be cultural or religious, as is apparent in the list of 11 civilizations identified by Huntington: African, Buddhist, Ethiopian, Hindu, Japanese, Jewish, Latin, Muslim, Orthodox (which includes Russia, among other countries), Chinese, and Western (which includes the United States and countries of Western Europe, among other countries). The games were taken from Fritz Big database 2010. As is customary in the literature, risk was defined as the standard deviation (σ) around the expected value (μ).

Chassy and Gobet were interested in the first move of a game, and categorized the openings in three groups, in line with the chess literature: 1.e4 ("risky" opening), 1.d4 ("conservative" opening), and other first moves ("mixed" openings). The labels risky, conservative, and mixed were confirmed by the calculation of the standard deviations, which were $\sigma = 41.45\%$, $\sigma = 40.02\%$, and $\sigma = 40.64\%$, respectively. Although the differences between the three openings are small, they are highly significant statistically, given the large sample (N = 1,546,289 , $p < 10^{-280}$).

For the analysis of risk taking in civilizations, the analysis focused on all games from expert players (Elo ≥ 2000) over a 11-year period (1999–2009), with a total of 667,599 games. The country of a player was identified by cross-checking the corresponding FIDE rating list. To ensure enough statistical power, a minimum number of 1,000 games was required per civilization, which led to the exclusion of two civilizations: the Ethiopian one (19 games) and the Japanese one (295 games).

The three least risky civilizations were the Jewish (42.2% use of the risky opening), the Chinese (46.0%), and the Orthodox (47.8%). The three most risky civilizations were the Buddhist (56.9%), the Latin American (54.6%), and the Hindu (54.6%). The results on the conservative strategy were nearly a mirror image. The three most conservative civilizations were the Jewish (49.9%), the Chinese (44.7%), and the Orthodox (42.5%). The three least conservative civilizations were the Latin American (35.0%), the Hindu (36.8%), and the African (37.2%). The mixed strategy was less than 11% in all civilizations.

Chassy and Gobet also looked at the percentage of games that ended in a draw before move 15, which can be taken as a measure of the extent to which players refused to fight. The three least pacific civilizations were the Buddhist (0%), the African (3%), and the Hindu (3.4%). The three most pacific civilizations were the Orthodox (8.8%), the Latin American (7.7%), and the Western (7.6%).

Given the current tensions between the Western civilization, the Orthodox civilization, and the Chinese civilization, it is reassuring that those civilizations were amongst the least risky, the most conservative, and, as measured by the tendency to accept rapid draws, the most pacific.

5.2 Ageing and Chess Expertise

The second example is Vaci, Gula and Bilalić's (2015) paper on how skill develops and declines as a function of age. In particular, these authors were interested in testing the hypothesis that "age is kinder to the initially more able", originally proposed by Blum and Jarvik (1974, p. 372). Vaci and colleagues focused on the German chess rating database rather than the database of the International Chess Federation, arguing that the former is more reliable as it is not selective in the way data are collected – the database collects records for all tournaments in Germany – and it does not suffer from restriction of range, as even beginners are included. Altogether, Vaci and colleagues had access to the ratings of 131,147 unique players.

Analysing the data with a linear mixed-effect model with a cubic function, they found that the results both supported and rejected Blum and Jarvik's hypothesis. Specifically, they found that age is more cruel to the experts (defined as players with a career peak rating $\geq$ 2000) with respect to initial decline. The maximum of the function (first derivative) occurred at about 37 years with experts, which is earlier than non-experts, whose maximum was at about 42 years. However, age was kinder to experts with respect to stabilization of post-peak decline, defined as the second derivative of the function. This inflection point occurred at 52 years with experts and 57 years with non-experts.

6 FINAL CONSIDERATIONS

Chess has been a very active domain of research for many years, at least since De Groot's (1965) seminal research. The considerable amount of data that have been collected on chess, in particular in psychology, computer science, and education, has had a significant impact on the theoretical developments in these fields (CHARNESS, 1992; GOBET; DE VOOGT; RETSCHITZKI, 2004).

Compared to the classical period, the contemporary period has seen changes in the methods used and the questions studied. With respect to the methods, experiments have remained a common tool, but questionnaires, structured interviews and the use of chess databases have increased in popularity in the last twenty years, with a concomitant decline in the use of computer modelling. This decline might reflect the kinds of questions that have been studied. While the classical period focused on perception, memory and decision making, which are fairly amenable to computer simulations, the contemporary period has concentrated on deliberate practice, individual differences, and education. These topics seem harder to study using computer modelling, given the number of variables that are involved. However, it is possible to do so (for example, see CAMPITELLI; GOBET; BILALIĆ, 2014) and my recommendation is that researchers pay more attention in the future to this important research method.

In spite of the complexity of the questions addressed, it is remarkable that the contemporary period has reached clear-cut conclusions with some of them. Deliberate practice has been shown to be necessary but not sufficient for reaching high levels of skill in chess. That is, only individuals that practice in a systematic way will reach the highest levels of skill. However, not everybody will succeed in spite of intensive practice, since factors independent of practice are important as well, such as starting age and to a lesser extend handedness. Another factor related to talent is intelligence, and research has clearly established that chess players are more intelligent, on average, than people who do not play chess and that intelligence correlates with chess skill.

Although this is more controversial with researchers and practitioners, I believe that a clear answer has been reached too with regard to the question of whether cognitive training leads to far transfer (e.g., increase in intelligence or improvement of academic performance). As reviewed above, several meta-analyses and a second-order meta-analysis have established that far transfer is highly unlikely with such activities as working memory training, video-game playing, music, and exergames. In fact, when the treatment groups are compared to active-control groups, the analyses show that the effect size is essentially zero, and that there is little to no variation between the different types of interventions, both within a domain (e.g., no difference between action video games and non-action video games) and between domains (e.g., no difference between music and working-memory training).

The case of chess is less clear. On the one hand, Sala et al.'s (2019) second-order meta-analysis shows that chess results are in line with the other types of intervention. On the other hand, Sala and Gobet's (2016) meta-analysis showed that chess instruction leads to a modest effect size. In general, few chess studies have used the three-group design with an active-control group, so there might still be some uncertainty about whether there is far transfer from chess instruction to other fields. The obvious recommendation is to collect data with an active control group. In addition, as noted above, dependent variables beyond intelligence and academic achievement should be investigated, including social skills and simple skills such as learning to lose. Another avenue for further research is to closely integrate aspects of school curricula into chess instruction. For example, if the aim is to teach Cartesian coordinates in mathematics, one could first teach the coordinate system used in chess to record games. Then, one could make an explicit link between the chess board and the mathematical concept. "Explicit" is a key word here: it is important to help children make the connections, as they are unlikely to make them automatically.

The main methodological change in chess research in the last twenty years has been the intensive use of chess databases to study questions in psychology and other sciences. Using this tool, researchers obtained interesting results about risk taking and the effects of aging on chess skill, among other topics.

This methodology has several strengths: (a) the samples are large; (b) the entire world is covered, which avoids the biases linked to specific cultures, a rampant problem in psychology; (c) verbal factors are controlled for, as chess is a non-verbal activity; in addition, databases include players who jointly speak a multitude of languages; (d) the data can be used chronologically, for example to study career trends; and (e) different types of information are available (ratings, move quality, age, etc.).

Using chess databases has weaknesses too, which limits the generalisability of the results and sometimes makes the interpretation of the results difficult: (a) the population is self-selected (e.g., chess players are on average more intelligent than the overall population); thus, at least for some questions, it is doubtful that chess players are representative of the general population; (b) databases might suffer from inherent biases (e.g., inflation of ratings over time and arbitrary selection of tournaments); and (c) databases might not contain the "right" information; for example, there is no information about practice, and using the number of games played in a given period as a proxy for practice, as done in some studies, is not satisfactory.

To conclude, for more than seventy years chess has been an active and fruitful domain of research. Exciting data have been collected and important theoretical contributions have been made; both had considerable impact well beyond the narrow field of chess research. The current trends clearly indicate that the future of chess research is bright.

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Edição especial – Xadrez, Ciência & Tecnologia
Enviado em: 24 dez. 2020
Aceito em: 09 mai. 2021

Editores responsáveis: Valério Brusamolin/ Mateus das Neves Gomes