Intelligence and chess

Fernand Gobet, & Guillermo Campitelli

Psychological research into expert behaviour in board games is currently split into two, almost independent, strands. The first direction of research, initiated by De Groot’s (1946) and Simon and Chase’s (1973) seminal research on chess, is interested in the cognitive processes underlying experts’ remarkable feats and in the learning mechanisms that enable novices to move to high levels of performance. The second line of research, exemplified by the early work of Alfred Binet on chess (Binet, 1894), is more interested in the innate characteristics that are putatively necessary for high ability.

By and large, our own research has focused upon the first of these strands, and has led to the development of several computational models of chess expertise (De Groot & Gobet, 1996; Gobet, 1993, 1997, 1998; Gobet & Simon, 1996, 2000). These models, built in the tradition of Simon and Chase, suggest the following requirements for becoming an expert: acquiring a large number of perceptual patterns (more than 100,000 in the case of chess), linking them to information such as strategic themes, tactical motives, potential moves, and using them during look-ahead search. As a consequence, these models emphasise the role of practice and study. However, these models, which contain various parameters such as the capacity of short-term memory or the time to learn a Ôchunk’ of information, also suggest that there are innate individual differences between players.

The goal of this paper is to critically evaluate the evidence supporting the hypothesis that innate talent (for example a higher level of intelligence) may account for aspects of chess skill. We start by giving some standard definitions of intelligence, and then present empirical data on chessplayers’ intelligence, both with children and adults. In the second part of this paper, we discuss Geschwind and Galaburda’s (1985) influential theory of the neurobiology of talent in music, mathematics, and visual arts, and review evidence of its applicability for explaining chess expertise. For that purpose, we will present empirical data based on brain lesions, brain-imaging studies, and handedness. In the conclusion, we will attempt to reconcile the strand of research emphasising practice and the role of the environment with that emphasising the role of innate talent.

Expertise in chess

Mainstream cognitive research into chess expertise (there is not much research into other board games) was started by De Groot's (1946) work on the decision-making processes of chessplayers. De Groot identified the critical role of perception, which allows rapid access to information stored in long-term memory. Building on this research, Simon and Chase (1973) proposed a detailed theory of the cognitive mechanisms involved in chess playing, and, in particular, specified the learning mechanisms allowing acquisition of perceptual knowledge. Several aspects of this theory and of its revisions have been implemented as computational models, which closely replicate empirical data about eye movements, memory performance, and search behaviour (De Groot & Gobet, 1996; Gobet, 1993, 1997, 1998; Gobet & Simon, 1996, 2000; Simon & Barenfeld, 1969; Simon & Gilmartin, 1973). Pattern recognition plays an important role in this line of research: through years of practice and study, masters have learnt several hundred thousands of perceptual patterns, which, once recognised in a particular position, give rapid access to information such as potential moves or move sequences, tactics, strategies, and so on. Simon and his colleagues proposed that pattern recognition explains a number of important phenomena, such as highly selective search (even chess grandmasters rarely search through more than one hundred moves before selecting a move), automatic and "intuitive" discovery of good moves, and extraordinary memory for game-like chess positions. Simon and Chase (1973) suggested that at least ten years of practice and study were necessary to acquire the minimum knowledge required to become a grandmaster.

Individual differences

As already mentioned, the computer models developed in the Simon and Chase tradition leave ample room for individual differences: these models include various parameters, such as the capacity of short-term memory, the time to learn new information, or the time to store information into short-term memory. While these parameters have been set using empirical data aggregated across subjects, it is reasonable to assume that these values may vary between individuals (however, for a strong dissent with this assumption, see Ericsson, Krampe & Tesch-Römer, 1993). Indeed, anecdotal evidence would suggest the presence of such individual differences. For example, while many chess players train very hard to become the next Bobby Fischer or Garry Kasparov, only a handful of them reach grandmaster level. And among the minority of those who are successful, there are obvious differences in the time needed. Some players require more than 20 years (e.g., Pal Benko; Paul Van den Sterren), while others need only 10 years (e.g., Bobby Fischer, Judith Polgar) or even less (Ruslan Ponomariov, who became grandmaster in 1997, needed only about 7 years).

In addition, there are important individual differences in the style of play: some players are aggressive, others defensive; some prefer tactical complications, others transparent strategic planning. Finally, one can look at extra-chess activities for evidence of individual differences. In his 1946 book, De Groot found that there were important differences in training and background in the sample of 55 grandmasters he studied. In particular, he found that 13 of his grandmasters had a training in science or mathematics. Interestingly, such differences in background have tended to fade away in recent years: nowadays, with the stringent training requirements of competitive chess, most players are professional, with no university training.

Where do these differences come from? Several psychological explanations, paralleling the strands of research mentioned above, have been advanced. Information-processing research tends to emphasise the role of the environment (presence of coach or playing opportunities, coaching techniques, etc.). The extreme position in this strand has been taken by Ericsson (e.g., Ericsson et al., 1993) in his theory of deliberate practice, which denies the role of innate differences, except for motivation and the ability to sustain long-term practice.

On the other side of the divide, several theories have emphasised the role of innate talent, proposing that individual differences are due to variations either in general intelligence or in specific aspects of intelligence. Variations in general intelligence may in turn be due to differences in speed of information processing or in the quality of signal transmission in the nervous system. Specific differences (e.g., in visuo-spatial ability) may be due to differences in development of definite regions of the brain, such as right-hemisphere. Below, we will consider Geschwind and Galaburda's (1985) theory, which relates innate talent to differences in brain structures.

The intelligence of chess players

Definitions and measures of intelligence

While central in several subfields of psychology, the concept of intelligence has turned out to be rather elusive and difficult to define. Indeed, it has generated its share of controversies for over one century. Two main schools have dominated this field. The first proposes that several types of intelligence co-exist and the second considers intelligence as a unitary concept. A good example of the first approach is offered by Gardner's (1983) theory of multiple intelligences, which identifies seven types of intelligence, such as spatial, logico-mathematical, and musical intelligence. How the second approach construes intelligence may be illustrated by some definitions, taken from Mackintosh's text (1998).

Intelligence is seen as:

- “general mental efficiency” (Burt, 1949)
- “the aggregate or global capacity of the individual to act purposefully, to think rationally, and to deal effectively with his environment” (Wechsler, 1944)
- “a general reasoning capacity useful in problem-solving tasks of all kinds” (Kline, 1991)

Alfred Binet, who incidentally carried out the first study on the mental abilities of chess masters in 1894, was the first psychologist to develop an intelligence test (Binet, 1903).[1] His influence is still visible in some of the tasks used in intelligence tests, and even in their name: intelligence tests are often called Intelligence Quotient (IQ) tests, a remnant of Binet’s work where the intelligence score was the quotient of mental age to physical age.

A variety of tests have been designed to measure intelligence, typically adopting a compromise between unitary intelligence and multiple intelligences, and providing measures both for various components of intelligence and for general intelligence. For example, the popular Wechsler test (Wechsler, 1944) has a scale for verbal IQ and a scale for performance IQ (i.e., non-verbal IQ); in turn, several tasks of performance IQ directly tap visuo-spatial IQ. Finally, a composite score measures general IQ. Measures of verbal IQ include subtests tapping general knowledge, knowledge of vocabulary, and memory for numbers. Measures of performance IQ contain subtests such as arranging a number of pictures so that they tell a coherent story, matching as many digits as possible with the appropriate symbols, and so on. Performance IQ also contains measures of visuo-spatial IQ, such as completing pictures which have one missing part, forming certain designs with nine coloured blocks, and simple jigsaw puzzles. It is worth mentioning that most of the performance IQ tests either have a time limit or offer time bonuses for rapid completion.

Children’s IQ and chess

Two studies have investigated the potential relationship between chess skill and intelligence. Frydman and Lynn (1992) submitted 33 young Belgian chess players (mean age = 11 years) to the Wechsler test. They found that the average general IQ of their sample (121) was higher than the population mean (100); most of the effect was accounted for by the performance IQ (mean = 129), which was clearly higher than the verbal IQ (mean = 109). Finally, there was some evidence that better players had higher performance IQ scores than the weakest players (top third = 131 vs. bottom third = 124).

The second study was carried out by Frank and D’Hondt (1979), who randomly allocated 90 children from Zaire (around 14 years old) either to a chess playing class or a control class, for one year. Four psychometric tests, totalling 18 subtests, were given to the children both before and after the intervention. The design allowed Frank and D'Hondt to test both whether some aptitudes predict chess skill after one year, and whether chess training might improve some of these aptitudes.

There was evidence that some abilities do predict chess skill. Five sub-tests were found to reliably predict chess skill at one year: Ôspatial aptitude', Ônumeric ability' (2 sub-tests), Ôadministrative sense', and Ôoffice work'. There was also evidence that chess skill may improve aspects of intelligence. The treatment group did better than the control group in the post-test on the sub-tests Ônumerical ability' and Ôverbal ability'.

Adults' IQ and chess

In 1927, Djakow, Petrowski, and Rudik (1927) studied eight of the best grandmasters of the time. They did not find differences with a control sample on general intelligence or visuo-spatial memory, with the exception of memory tasks where the material to be recalled was closely related to chess. More recently, Doll and Mayr (1987) subjected a group of chess masters (N = 27, age = 25.7 years) and a control group of non-chessplayers (N = 88, age = 24.8 years) to the "Berlin Structural Model of Intelligence" test, a well validated IQ test. The masters did better in the measure of general intelligence, as well as in tasks related to ÔInformation-processing capacity for complex information', ÔWorking speed', and ÔNumerical thinking'. Surprisingly, given the fact that chess is a highly visuo-spatial game, the masters did not do better in the visuo-spatial task.

Further research into visuo-spatial abilities in chess gave mixed results. Interference tasks with chess problem solving and memory (Saariluoma, 1992) showed that a visuo-spatial concurrent task has strong effect, but that a verbal concurrent task has no effect. However, Waters, Gobet & Leyden (2000) found no evidence for higher visuo-spatial with chess players in a memory task using non-chess material.

In summary, research into intelligence and chess has uncovered good evidence for higher general and performance IQ for chess players. While this could be explained by the talent hypothesis, it could also be explained by the fact that chessplayers receive a lot of practice in thinking under time pressure, as all competitive chess is played using a clock in order to limit thinking time. Thus, chessplayers may have acquired generalisable skills about how to handle time constraints. However, no superiority was found with chess playing adults on visuo-spatial tasks, while there was some evidence of superiority with chess playing children on visuo-spatial tasks.

The neurobiology of chess talent

Geschwind and Galaburda's theory (1985)

Geschwind and Galaburda (1985) developed an influential theory of the neuroanatomical substrate of talent. Their aim was to explain a complex pattern of results linking, among other things, phenomena such as talent in visuo-spatial domains (e.g., music or mathematics), brain lateralisation, dyslexia, proneness to allergies, and handedness. The theory is rather complicated, and, given limits in space, we will limit ourselves to its main components. It is known that the right hemisphere of the brain normally underpins visuo-spatial abilities (e.g., Kosslyn & Koenig, 1992). Geschwind and Galaburda reasoned that better development (e.g., pattern of cortical connections) of the right hemisphere should lead to better performance in visuo-spatial tasks. The key step is to propose that great exposure or high sensitivity to intrauterine testosterone in the developing male foetus leads to a less developed left hemisphere than usual, and, as a compensation, to a more developed right hemisphere. Hence, males should be more represented than females in visuo-spatial domains such as mathematics, music, and chess, and left-handers should be more represented in these fields than in the general population. We now consider the available evidence for testing Geschwind and Galaburda's theory in chess.

Effects of brain lesions on chess skill

A direct consequence of the theory is that lesions to the right hemisphere of the brain should affect chess skill more than lesions to the left hemisphere. Cranberg and Albert (1988) collected data about eight players with chess activity before brain damage. They found that the ability to play chess is preserved in patients even with large left-hemisphere lesions, and that small right-hemisphere lesions did not affect chess skill either. However, because they did not present evidence for the effect of large right-hemisphere lesions, their study is inconclusive.

Images of the chess brain

Another consequence of the theory is that chess playing should engage the right hemisphere more than the left. Nichelli et al. (1994), using positron emission tomography (PET), studied brain activation in 10 right-handed males, who had been playing chess for more than 4 years. They used simple tasks, such as Black/White discrimination, spatial discrimination, rule retrieval, and checkmate judgement. They found that these tasks called for the activity of a network of several interrelated, but functionally distinct, cerebral areas, but did not uncover any evidence for a predominant role of the right hemisphere.

Onofrj et al. (1995) used single photon emission computerised tomography (SPECT) to study brain activation in a more complex task: trying to solve a chess problem mentally. They found non-dominant dorsal-prefrontal activation and also a lower non-dominant activation on the middle temporal cortex. These results are in line with what is known about these two areas from the study of different tasks: the dorsal prefrontal cortex is typically activated in problem solving activities involving planning, and right mid-temporal lobe activation is typically observed during memory retrieval of non-verbal information. As predicted by Geschwind and Galaburda's theory, the four right-handers presented activation in the right hemisphere. However, contrary to the prediction, the left-handed subject presented similar activation in the *left hemisphere.* An important limit of this study is that Onofrj et al. used only one position, and that this position (Lasker-Bauer, Amsterdam, 1889) is likely to have been known to the subjects.

Handedness and chess

Another prediction of Geschwind and Galaburda's theory (1987) is that the percentage of non-right-handers should be higher in the chess playing population than in the general population. Cranberg and Albert (1988) sent a questionnaire to about 400 US chessplayers figuring in the US Chess Federation ranking list. They targeted the 200 best US players (Elo rating > 2250), and the 200 weakest amateurs (Elo rating < 1275). The questionnaire asked players to identify their handedness, with four options: right-handed, left-handed, ambidextrous, or left-handed as a child and later switched to right-handed. For the 266 players who answered, they found that 18% were non-right-handers. This percentage significantly differs from the percentage in the general population, which has been estimated to lie between 10% and 13.5%. However, no differences were found between the group of strong players and the group of weak players, although they were separated by more than five standard deviations.

A weakness of Cranberg and Albert's (1988) study, however, is that they used a rather informal method to measure handedness. In a replication, Gobet and Campitelli (2001) used a well validated questionnaire, the Edinburgh Handedness Inventory (Oldfield, 1971), with 101 male players in Buenos Aires (from 1490 to 2473 Elo). The results were quite similar to what was found in the previous study: 17.9% of the chessplayers were non-right-handers, and there was no skill difference between strong and weak players.

Another source of evidence for the biological substrate of talent, which is perhaps related to the question of handedness, comes from the season of birth. Gobet and Campitelli (2001) found that the month of birth may affect chess skill: in the International rating list of January 2001, grandmasters from the northern hemisphere were more likely to be born in the first half of the year than in the second half (57.2% vs 42.8%). This result is also valid with other categories of players figuring in the international list.

Conclusions

The goal of this article was to review the available data about the possible links between chess talent and intelligence, and between chess talent and biological (including innate) mechanisms. The literature on intelligence indicates that chess players' IQ is higher than that of the general population, but, surprisingly, does not offer any evidence that adult chess players have better visuo-spatial skills (some evidence of higher visuo-spatial skills was found with children). Waters, Gobet and Leyden (2000) suggest that, while visuo-spatial skills may be important in the early development of chess skill, other skills, such as motivation, become important over time. Note also that the direction of causality is unclear, and each of the three possible scenarios below is in part supported empirically: (1) chess improves intelligence; (2) more intelligent individuals play better chess; or, (3) a third variable (e.g., motivation, ability to think under time pressure) mediates intelligence and chess skill.

Some predictions of Geschwind and Galaburda's (1985) theory of talent were supported by the empirical data. The brain-lesion studies confirmed the prediction of the relative minor role of the left hemisphere in chess playing, but did not offer strong evidence for the predominant role of the right hemisphere. The brain-imaging studies offer some (weak) evidence for the role of the right hemisphere. Finally, two studies found that the incidence of non-right-handers is higher in the chess population than in the population at large.

Taken together, these results suggest that there exists biological determinants of expertise in chess. As mentioned above, there also exists massive evidence for the role of practice/study as well as for the importance of the environment. The safer tentative conclusion is that both sources of variability are important. For example, the famous chess school of Botvinnik, while offering a high standard of coaching for all its pupils, produced players with widely different skill levels.

The correct question for further research is not to quantify the respective role of Ônature' and Ônurture', as has often been done in the past in research into talent and intelligence, but to explain how these two components interact dynamically as a function of time. Given the potential complexity and the dynamic character of these interactions, we believe that the best way forward is to build mathematical models or computational systems. Once constructed, such models or systems could be applied to test the development of talent in other board games as well.

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Endnotes

[1] Binet did not use his test with chessplayers, however.