Expertise and Decision-making: An Analysis of Expert Capacities through the Iowa Gambling Task

Journal of Expertise
2024. Vol. 7(3)

ISSN 2573-2773

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Abstract

This research conducted with chess players and non-chess players examines the efficiency of decision-making capacities of both populations. Experts are characterized by superior performances by individuals in a wide range of domains. Salthouse (1991) has shown that decision-making capacities could be an important aspect of expertise in many fields, including chess. In this study, decision-making capacities were tested through a computerized version of the Iowa Gambling Task (IGT, Bechara et al., 1994) on a population differing in terms of expertise level in chess. Our study shows that expert chess players attain better IGT results than non-chess players or amateur chess players. A complementary cluster analysis, rarely used in IGT research, revealed differences in terms of strategies between our three experimental groups.

Keywords

expertise, decision-making, chess, expert-novice differences

Introduction

The deliberate practice framework of Ericsson et al. (1993) is an influential theory in the field of expertise in cognitive psychology. These authors stated that to become an expert in a domain, an individual should invest within a personal development perspective. Obviously, that individual needs to practice, but needs to do so with the intention of developing their capacities within a given domain. This theory also postulates that abilities acquired in a field of expertise cannot be generalized. In other words, it cannot be used in other fields. According to a literature synthesis by Ericsson (2014), expertise can be characterized by exceptional abilities in a field, frequently reproducible by a narrow group of people practicing it for at least 10 years.

In accordance with Salthouse (1991), we believe that before trying to understand the mechanisms underlying the development of expertise, researchers need to list the difficulties novice individuals face when they are confronted with a task and have to find a way to overcome them. Indeed, Salthouse depicted expertise development as a circumvention of limitations by an individual. These limitations differ according to field needs and have to be clearly identified in order to understand how they can be overcome. Salthouse's thinking is worth bearing in mind because it forces the researcher to pinpoint precise constraints that are observed in his domain of interest. In other words, Salthouse defines experts by comparison with what novices don't know how to do. In many fields (e.g. Ericsson & Smith, 1991; Drury-Hudson, 1999; Postal, 2012), the problem facing novices will be "not knowing what to do during the task." This is especially the case when it comes to chess, in which novices will not be able to make a decision when faced with all available options. Indeed, in chess, players are confronted with real choices. In addition to making these choices, they have to execute the action, which requires focusing their cognitive resources to answer correctly under environmental constraints. Consequences that arise from their actions are immediate, and the context changes constantly, preventing the player from having total control over the situation. A new decision is expected at each turn, which requires the player to re-evaluate the situation, including their opponent's next move. In this respect, goals are simultaneously the origin and the output of this shifting context. In view of this description, decision-making seems to be an essential ability for chess players.

We also believe that decision-making capacities could be an important factor to consider when we try to understand expertise development in chess. To elaborate further on that explanation, we can notably cite the Multifactorial Gene-environment Interaction Model (MGIM; Ullén et al., 2016) which considers that the development of expertise is based on both genetic factors and environmental factors in interaction. Within this model, some individual abilities (e.g., general IQ, working-memory capacity) can have an indirect effect on the development of expertise by influencing the deliberate practice of the domain or by modifying the neural structure. As we explained in the previous paragraph, we believe that there could be a major difference between the decision-making capacities of chess players compared to non-players. Our idea is therefore that individual differences in decision-making would be one of the environmental factors described in the work of Ullén et al. (2016), allowing to promote the development of players' expertise. In our research we therefore decided to focus on this specific population of chess players and to study their decision-making capacities through a test, the Iowa Gambling Task.

The Iowa Gambling Task

One of the most commonly used tasks in decision-making is the Iowa Gambling Task (IGT; Bechara et al., 1994). Originally, it was a clinical task used to reveal difficulties observed in patients that conventional neuropsychological tests failed to demonstrate.

This task found certain decision-making deficits that were not observed with other tests. In their paper of 1991, Saver and Damasio analyzed a clinical case population with lesions in the ventro-median (VM) part of the prefrontal cortex. These patients did not have problems in tests measuring the social cognition factors involved in decision-making evaluated in classical neuropsychology tests (e.g., "The means-ends problem-solving procedure"; "the cartoons ends predictions test"), but they were actually unable to make consistent decisions in their daily lives. However, Damasio showed that these tests did not explore the choice component of decision-making because participants did not need to execute the action themselves.

The inefficiency of these tests in discriminating VM patients among the general population could be imputed to their lack of engagement in decision-making. The author argues for a more ambiguous and involving task to evaluate the deficit of VM patients, one which should include a better integration of the emotional component in the decision-making process. In the IGT (Bechara et al., 1994) participants have to make a choice when faced with four decks of cards at each turn. Participants begin the task with $2,000 and have to win as much money as possible by choosing one card a time from any of the four decks. Some cards win them money, and other cards lose them money. The cards are organized in such a way that some decks are advantageous (more gain in the end) and others are disadvantageous (decks C and D versus decks A and B). Participants discover the value of the card (gain or loss) after turning it. In the classical version of IGT, there are a total of 100 trials (Bechara et al., 1994). The purpose is for the participant to understand which of the decks are advantageous over the long term and to pick those in order to maximize profits. Indeed, two decks (A and B) offer immediate high gains but also future high losses (called disadvantageous decks by Bechara et al., 1994) while the other decks (C and D) offer immediate low gains but future low losses (called advantageous decks by Bechara et al., 1994). Each deck's gains are constant along the task, which means that participants will win the same amount of money in each selection. The frequencies of losses fluctuate according to the deck. For example, with ten selections in a row in deck A participants will win $100 at each selection and lose $250 for half of them. The final outcome of those ten selections is a global loss of $250. In terms of expected value, decks A and B will lead to a loss of money whereas decks C and D will result in a gain. In short, to perform this task well, participants have to pick the advantageous decks C and D and neglect decks A and B (see Table.1 for a more detailed description of decks).

Table 1. Description of deck characteristics in the Iowa Gambling Task

	Deck A	Deck B	Deck C	Deck D
Gains	100$	100$	50$	50$
Losses	250$	1250$	50$	250$
Loss frequency	05/10	01/10	05/10	01/10
Earnings for 10 trials	-250$	-250$	250$	250$

However, the two advantageous decks and the two disadvantageous decks are not identical. Thus earnings in IGT are not sufficient to understand fully the strategies employed by participants and for this reason account needs to be taken of other differences between the decks in analyses. In fact, the decks also differ according to the frequency of gains and losses. Based on an average of ten trials, decks A and C will offer a low gain frequency (5 gains / 5 losses) and decks B and D a high gain frequency (9 gains / 1 loss). Some authors have demonstrated that at the beginning of the task, participants are influenced first by short-term benefits and will pick decks A and B to reap greater gains. From then on, selections will turn to decks B and D which are the high gain-frequency decks (Chiu et al., 2008). This implies that decision-making is influenced by the values of the gains and losses but also by the frequency of the gains, and that the strategy used by participants evolves during the task. A longer version of IGT than the original task (Bechara et al., 1997) is suggested by Steingroever et al. (2013) to study this evolution of strategies. They showed that 100 trials are not sufficient to explore each deck and learn the most advantageous choices. They recommend a longer version of the task. For a better understanding of how the task works and the need for an extended version, we will give an example of participant selections. At the beginning of the task, there is no difference between decks for participants. They look the same and participants have to begin by picking cards to identify the best strategies. But, by the coincidence of their initial choices, some participants will focus on the disadvantageous decks (A and B) longer than others. They may unfortunately incur a loss when they try one of the advantageous decks (decks C and D) first, leading them to reject those decks. In the task, it is possible to make as many selections as one wishes on the same deck, so participants may focus for too long on certain decks despite good selection strategies. With an increase in the number of trials, by contrast, participants will have time to overcome this issue and try to pick advantageous decks.

Horstmann et al. (2012) identified different strategies corresponding to three different response patterns (called "clusters") within the healthy population. Two strategies are right, and one was classified as wrong (loss at the end of the task). In their article, the authors showed that two clusters, Clusters 1 and 3, correspond to a right strategy through the exclusive selection of one of the two advantageous decks (respectively decks C and D). Conversely, Cluster 2 is wrong and shows a selection of high gain-frequency decks (decks B and D). Quite surprisingly, only 25% of the healthy general population performed well in this task by choosing the positive clusters 1 and 3. In other words, 75% of them were not able to overcome their conception of high gain-frequency established at the beginning of the task.

Last, according to Gansler et al. (2011), the transition between the high gain-frequency conception and the right solution can be identified. Relying on Brand et al.'s research (2007) and the distinction established between decision-making under uncertainty and decision-making under risk, Gansler et al. (2011) showed that, in the IGT, the transition point identified is this changeover from uncertainty to risk-informed decisions. In the literature, this turning point is called the inflection point (Gansler et al., 2011). This awareness of risk is particularly important in the decision-making task and may explain the performance and the strategy used by participants.

The Role of Cognitive Abilities in IGT Performance and on Expertise

Some research has underlined a greater influence of cognitive abilities, measured by the intellectual quotient (IQ), rather than a benefit related to an emotional component to explain IGT performance (Demaree et al., 2010; Webb et al., 2014). However, in a wide-ranging meta-analysis, Toplak et al. (2010) reported that the majority of studies on this topic do not show any significant effect of IQ on IGT performance. Even though some executive functions seem to have a major influence on the score at the end of IGT (Brand et al., 2007), the majority of the variability explaining this score cannot be credited to IQ differences (Toplak et al., 2010). Furthermore, according to expert research there seems to be no consensus about the question of the influence of IQ on expertise development. Djakow et al. (1927, cited by Gobet & Campitelli, 2002) showed there was no correlation between general IQ and expertise level and many researchers consider the influence of intelligence as entirely negligible (Ericsson et al., 2007; Ericsson & Ward, 2007). Furthermore, while a positive IQ-chess correlation was established by Bilalic et al. (2007) with young chess players, this correlation seems to have affected practice and motivation only for the first practice steps.

Then, with the participants who continue the chess practice further and improve their performances, they found a negative IQ-chess correlation, so deliberate practice is a much more efficient explanatory factor in that sub-sample. More recently, a meta-analysis (Burgoyne et al., 2016) showed that several cognitive characteristics are positively correlated with expertise (e.g. fluid reasoning, processing speed). Despite this positive correlations the authors found a non-significant result between chess skills and full-scale IQ. Nevertheless they specify that this result could be attributable solely to one study in their meta-analysis (Bilalic et al., 2007). In a complementary analysis they show that the correlation becomes positive by withdrawing this study. All these considerations brought together seem to indicate that the literature goes to the direction of a positive IQ-chess correlation but is still inconclusive on this point. Therefore the question of intelligence influence in expertise development needs to be considered in further research even if recent studies mainly indicate that there is a link between IQ and expertise (Grabner, 2014). Most of these studies highlight that differences between experts and the rest of the population are domain-specific (Burgoyne et al., 2016). It seems important to find other aspects that could be more developed in the expert population. In this respect, the thinking of Salthouse (1991), who described expertise as a circumvention of limitations, seem extremely appropriate. He compiled a summary of the main limitations of novices in many fields and observed that, in many of them, decision-making seems to be a clear bound (in particular when it comes to chess). Therefore, we will focus on decision-making in an experimental evaluation, for the reasons given above.

In this study, we address the decision-making capacity of chess players. Our study also offers new evidence showing that better performances in IGT can be related to good decision-making capacities and not only to a good understanding of the task, as proposed by Maia and McClelland (2004).

The main objective is to show that, as well as deliberate practice, some internal factors are worth observing in expert performance. We focused on one of them in view of its relevance to our theory and its significance in chess. Nevertheless, we remain confident in the existence of many other executive and cognitive functions which may influence expertise development (e.g. Burgoyne et al, 2016). Moreover, we also want to show the transitional aspect of expert capacities in other fields that allows their use in several constraint situations that are remote from the expert domain. Indeed, it is commonly accepted that the development of expertise is long and that expert capacities will develop gradually. Some studies, for example with the use of neuroimagery techniques (Guida et al., 2012) have shown functional brain reorganization with the development of the expertise (around 6 years of practice) linked with the establishment of knowledge structures that are not domain specific, and this development seems to be happening also for some cognitive processes, such as working memory, even if the task is not familiar (Smith et al., 2021). The reasoning is the same for the decision capacities linked with the development of expertise.

According to these assumptions, we postulate that success in IGT will be greater with an increasing level of expertise in chess. Experts will select the advantageous decks (C and D) more readily and will reach the inflection point earlier than other groups. This means that they will implement better strategies during the task. As in Horstmann et al. (2012), we postulate that experts will be more strongly represented in Clusters 1 and 3, which represent the selection of one of the two advantageous decks (respectively decks C and D).

Method

Participants

We assessed decision-making capacities within a sample of 29 subjects (males exclusively to avoid sex influence) divided into three groups according to their level of expertise in chess.

The first group is composed of expert chess players with more than ten years of practice (n_1 = 9), selected from among players with an ELO (ranking of chess players) currently exceeding 2300 points or having gained the FIDE Master Title (players having already exceeded 2300 points in their career). In this population, we have a range of players with between 2280 (with the FIDE Master Title) and 2627 points. Some of the participants in this group were recruited during the Malakoff chess tournament and others in the Paris and Bordeaux areas.

Another group in our study includes amateur chess players who practice regularly (n_2 = 10) and who were selected from among players with an ELO below 2100 points with no lower bound. This choice was based on a particular assumption about the ELO rating. Indeed, it is commonly accepted that a difference of 200 ELO points is enough to separate different levels of players. This is accepted in the literature, whereby a standard deviation (*SD*) of 200 points is used to compare different groups of players (e.g., Ericsson & Charness, 1994; Charness et al., 2005; Gobet & Charness, 2006) and is also accepted by the players themselves. They consider that a difference of 200 points between two players is enough to predict the result of a game before it starts. To sum up, this population was constructed with a 200-point cut off below our Expert group. We selected a very high-level Expert group (ELO comprised between 2280 and 2378) and, with our criteria, some of the Amateurs may have had an ELO rating higher than 2000. For many studies, 2000 points is sufficient to be classified as an expert (e.g., Bilalic et al., 2009) and this methodological choice could have affected our study. Fortunately, none of the amateurs selected had a ranking above 1886. In sum, this group comprised players with an ELO rating between 1000 and 1886. Participants in this group were recruited during the Malakoff chess tournament in France and from a chess club in Bordeaux called "l'échiquier bordelais."

Finally, the last group comprises chess novices with little or no experience in chess (n_3 = 10). Participants in this group were recruited from the University of Bordeaux in France.

A possible influence of age in our study was also duly noted. The Expert and Amateur chess players are older (respectively 35.8 and 38 years old on average) than our Novice group (29.9 years old on average) and this could influence our data. However, results in the literature suggest that IGT performance show a u-inverted relation with age (Cauffman et al., 2010). This means that, even if age did influence IGT performance, the results would be better for younger than older participants. This research by Cauffman et al. (2010) was conducted on a population between 10 and 30 years of age; for older people, we can only speculate by drawing on the trend in these results. Another study (Wood et al., 2005) compared young adults (between 18 and 35 years old) and older adults (over 65 years old) and shows that, despite a difference in the strategies employed, both populations were able to perform well in IGT. These considerations suggest that the difference in age in our sample would not bias our results. In addition, our experimental groups were controlled for educational level.

Material and Procedure

Our evaluation was done with a computerized version of IGT using E-prime (version 2.0.10) that was longer than the classical one (300 trials instead of 100). The task was also adapted for French participants (dollars become euros). Using their mouse, participants have to pick one of the four decks which appear on the screen. After each selection, feedback is sent to participants to inform them about their gains and losses. During the experiment, participants are also informed of their earnings from the beginning of the task with a crossbar and a square which show the total gains from all past trials. At the end of the 300 trials, we also asked participants which deck was the most advantageous in their opinion.

We compared participants' choices according to their level in chess (Novices, Amateurs or Experts). We had several hypotheses concerning these choices. First, we thought that Experts would select more advantageous decks (C and D) than Amateurs, themselves more than Novices, so Experts would win more money than Amateurs and themselves more than Novices. We also hypothesized that the inflection point (where individuals begin to select more advantageous than disadvantageous decks) would be reached fastest by Experts, then Amateurs, and finally Novices. Last, Experts were expected to be represented more strongly in Clusters 1 and 3, as identified by Horstmann et al. (2012), than Amateurs or Novices.

We measured not only the earnings at the end of the IGT (first dependent variable) but also the strategy used by the chess players all along the task. To do so, we conducted different analyses. First, we compared the selection of advantageous decks and disadvantageous decks (second dependent variable) and the inflection point (third dependent variable) during the first hundred trials according to the level of expertise of the participants. Next, we analyzed more precisely the selection of the decks, considering each deck individually (fourth dependent variable) throughout the task (for the 300 trials). Finally, we analyzed the clusters selected (fifth dependent variable) according to the different levels of chess players.

Analyses were conducted with the Rstudio software (version 3.3.0) with which we performed a variance analysis (ANOVA and Kruskall-Wallis) on the IGT final gains (earnings at the end of the IGT), on the number of selections of each deck and on the inflection point. Post-hoc analyses were performed with the T-test or Wilcoxon test. We applied the Bonferroni-Holm correction on the significance threshold due to the repeated tests. The inflection point was identified by the intersection of two lines respectively representing the increasing selection of advantageous decks and the decreasing selection of disadvantageous decks. For greater precision in the trial relative to the inflection point, we used Excel's "IntersectComplex" function to associate this graphic coordinate point with its trial. Clusters were formed by a simple visual analyses of the data which offered a new technique to identify strategies at the end of IGT, whereby we asked participants "what was the most advantageous deck in their opinion" and calculated when they picked the deck (or decks, sometimes) in more than 90% of cases. For example, if during the test a participant began to select deck A in more than 90% of cases (in a block of 20 trials), and this during all remaining trials, the participant will be assigned on the cluster with other participants selecting deck A in more than 90% of cases. However if the participant decides to select other decks again before the end of the task, leading to select deck A in less than 90% of cases, that participant will not be added to this cluster. This example is for one deck only, but we also consider the possibility of selecting several decks with the same considerations than before. Finally, if a participant finished the task without being able to identify his favorite deck and selecting it in more than 90% of cases, he will be assigned to a last cluster composed with participants who neither identify their favorite deck.

For ease of reference, the term "groups" represents the independent variable comparing chess expertise (Novices, Amateurs and Experts), the term "deck selection" represents the independent variable comparing selections according to deck differences (e.g., advantageous decks vs. disadvantageous decks) and "time" represents the third independent variable, the blocks of trials (5 blocks of 20 trials for the 100 trials analysis or 6 blocks of 50 trials for the 300 trials analysis).

Results

In the first instance, we conducted an analysis of the total earnings obtained by each group at the end of IGT. Due to the non-normality of the data, we conducted a Kruskall-Wallis test. We obtained a trend effect of groups on total earnings, $H(2) = 5,54$, $p = .062$, $(1\text{-}\beta) = .12$. Post-hoc analysis showed that Experts' earnings ($M = 6533.33$; $SD = 1402.45$; 95% CI [5455.12, 7611.54]) were significantly higher than Amateurs' earnings ($M = 4995$; $SD = 2338.41$; 95% CI [3322.2, 6667.8]; $p = .013$) and Novices' earnings ($M = 4212.5$; $SD = 2484.04$; 95% CI [2435.53, 5989.48]; $p = .002$). No difference was found between Amateurs and Novices.

For the following analyses, we considered the other two independent variables, named "time" and "deck selection," in order to study the strategies employed by the three groups. The dependent variable for all further analyses will not be earnings but will be the participants' selection of cards (sum of number of cards selected from each deck).

To begin with, we conducted an analysis of the first 100 trials (Figure 1), as has been done in the literature, by comparing precisely the selection of decks A and B (disadvantageous) and decks C and D (advantageous) over time (five blocks of 20 trials), and by determining the inflection point in these first 100 trials.

An ANOVA was conducted on participants' choices according to their group (Novices, Amateurs or Experts), deck selections (advantageous by summing the number of cards selected from decks C and D vs. disadvantageous by summing the number of cards selected from decks A and B), and time (trials 1-20, trials 21-40…).

First, we found a significant interaction effect between deck selection (advantageous vs. disadvantageous) and time, $F(4,26) = 14.85$, $p < .001$, indicating a change in selections during the first 100 trials. Indeed, the advantageous decks were more often selected than the disadvantageous decks over time. The interaction between groups and deck selections is also significant, $F(2,26) = 4.92$, $p < .01$. The selection of advantageous decks is greater for the Experts (M = 12.98; SD = 4.96; 95% CI [11.49, 14.47]) than for the Novices (M = 11.26; SD = 4.06; 95% CI [10.11, 12.41]) and Amateurs (M = 11.08; SD = 5.71; 95% CI [9.46, 12.70]). The results concerning the disadvantageous decks are reciprocal to those for advantageous decks (see Table 1).

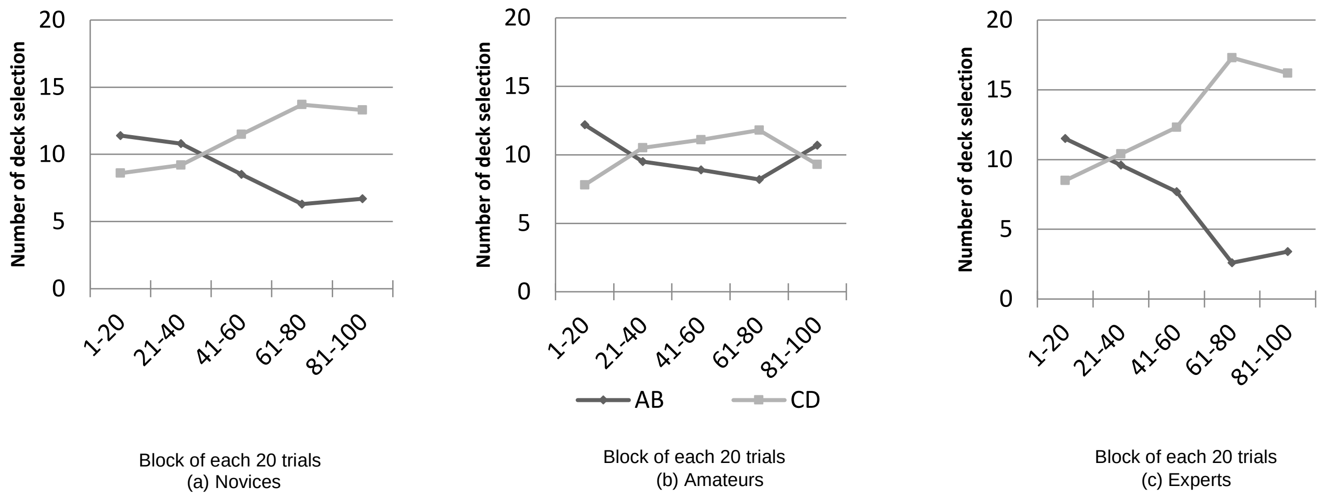

Figure 1 (a, b, c). Number of selections of advantageous (CD) and disadvantageous (AB) decks by Novice (a), Amateur (b) and Expert (c) groups and representation of the inflection point at the intersection of curves (respectively in trials 47, 36 and 36).

A significant interaction was found between groups, time, and deck selection, $F(8,26) = 2.60$, $p < .01$, $\eta_p^2 = .074$. This means that during the task, participants' selections over time evolved differently as a function of the group. The three groups began the task by picking more disadvantageous decks than advantageous decks; rapidly the trend reversed, and all groups began to select fewer disadvantageous decks and more advantageous decks, but the difference between the advantageous and disadvantageous decks was very marked according to the group and the time. As early as block 4 (trials 61-80), Novices (M = 13.70; SD = 3.95) and Experts (M = 17.33; SD = 2.83) selected significantly more advantageous than disadvantageous decks (respectively, $t(9)$ = -2,96, p = .015 and $t(8)$ = -7,77, $p < .001$). By contrast, no significant differences were noted for Amateur selections over the first 100 trials and the curve indicated that Amateurs' selections were again reversed, with a tendency to pick disadvantageous decks at the end of the first 100 trials.

We determined the inflection point with Excel's "IntersectComplex" function, and an ANOVA was conducted on it according to the group and the time. The inflection point is located at the intersection between the upward advantageous decks line and the downward disadvantageous decks line. Excel's function identified the graphic coordinates of this point, and we then associated them with a trial. The difference in rapidity reaching the inflection point for each group was calculated (see also Figure 1). In this respect, Novices obtained a value of 2.34, corresponding to trial 47. Likewise, Amateurs and Experts reached the inflection point near trial 36 (respectively, 1.81 and 1.78 with the function). There is a group effect, indicating that Amateurs and Experts reached the inflection point significantly earlier than Novices, $F(2,26) = 8.27$, $p = .0016$.

To evaluate the strategy employed by the groups during the IGT, we conducted the analyses over 300 trials (distributed into 6 blocks of 50, see Fig. 2) according to the level of expertise and the selection of decks, considering all 4 decks and not only the difference between the advantageous and disadvantageous decks.

There is a significant interaction effect between deck selection and time, $F(5,31) = 25.99$, $p < .001$, pointing to a change in selection during the task, with decks C and D being more and more frequently selected as time progressed. The interaction between groups and deck selection is also significant, $F(2,31) = 13.61$, $p < .001$. The selection of advantageous decks (C and D) was greater for the Experts ($M = 40.78$; $SD = 10.67$) than for the Amateurs ($M = 37.05$; $SD = 13.55$), which was greater than the Novices ($M = 33.65$; $SD = 11.05$). There is no interaction between decks, time and group.

Further, we performed analyses for each deck independently, because they are different from the others in terms of frequency and long-term outcomes, with the groups and the time as independent variables. There is a significant group effect for deck A, $F(2,15) = 3.80$, $p = .024$, for deck B, $F(2,15) = 9.60$, $p < .001$, for deck C, $F(2,15) = 10.63$, $p < .001$ and for deck D, $F(2,15) = 6.34$, $p = .002$. Analyses were performed with a T-test for a pair-wise comparison of groups in each deck. We showed that the differences were significant for deck B from which Experts ($M = 4.37$; $SD = 6.86$) made fewer selections than Amateurs ($M = 9.02$; $SD = 10.63$; $p = .05$) and Novices ($M = 10.08$; $SD = 7.26$; $p < .001$). For deck C, we showed that Novices ($M = 12.92$; $SD = 11.61$) made fewer selections than Amateurs, ($M = 23.70$; $SD = 17.73$; $p < .001$) and Experts, ($M = 24.70$; $SD = 15.98$; $p < .001$). For decks A and D we observed that Novices selected significantly more cards from these decks (for deck A: $M = 6.27$; $SD = 6.27$; for deck D: $M = 20.73$; $SD = 15.26$) than Amateurs (for deck A: $M = 3.93$; $SD = 5.15$; $p < .05$; and for deck D: $M = 13.35$; $SD = 15.12$, $p < .001$). There is no interaction between decks, time and group, $F(10,31) = 1.20$, $p > .10$.

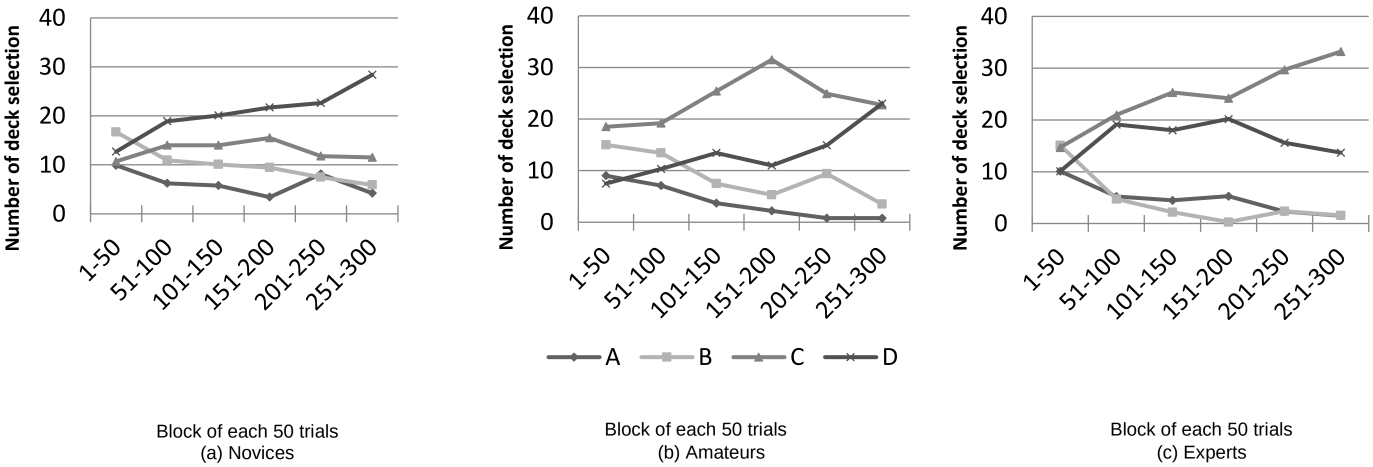

Figure 2 (a, b, c). Number of selections as a function of decks (A, B, C, D), block (each block represented 50 trials) and for each level of expertise (a = Novices, b = Amateurs, c = Experts).

To understand the task better in its entirety, we compared the difference between the three groups for each of the six blocks of 50 trials. For the first block (trials 0-50), the number of cards selected from each deck (A, B, C or D) did not differ significantly according to the groups and deck selections (Novices: $M = 23.40$; $SD = 4.01$; Amateurs: $M = 26.00$; $SD = 10.90$; Experts: $M = 24.78$; $SD = 5.07$). As early as the second block (50-100), the Experts ($M = 40.00$; $SD = 9.25$) differed from the Amateurs ($M = 29.50$; $SD = 13.46$), $p = .039$ (effect of groups and deck selection is significant, $F(5,52) = 10.77$, $p < .001$) and from the Novices for the third block (100-150; Experts: $M = 43.33$; $SD = 8.03$; Novices: $M = 34.10$; $SD = 10.00$), $p = .018$ (effect of groups and deck selection is significant, $F(5,52) = 27.61$, $p < .001$). By comparing the selections for each group according to the block, we observed that the

Novices rapidly stopped progressing and selections remained steady. The Amateurs showed an improvement in their performance from the third block (*M* = 38.80; *SD* = 9.15). At the end of the 300 trials, their selections (*M* = 45.70; *SD* = 7.83) were similar to those of the Experts (*M* = 46.90; *SD* = 6.31), who selected the advantageous deck from the second block and showed a slight improvement through to the end.

Finally, we are interested in the clusters used by the different groups. To determine the types of clusters, we asked participants what was the most advantageous deck in their opinion and calculated when they picked it (or them, sometimes) in more than 90% of cases. In this way, we identified four clusters (see Table 2).

Table 2. Percentage of selection from each deck at the end of IGT and percentage of participants in each cluster according to their expertise level.

	Cluster 1				Cluster 2				Cluster 3				Cluster 4			
Decks	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Selection of decks	1	2	95	2	16	21	27	36	0	1	6	93	1	2	46	51
Novices	10				50				40				0			
Amateurs	44				11				44				0			
Experts	44				11				22				22			

Cluster 1 corresponded to the selection almost entirely of deck C (considered as advantageous and low gain-frequency). Cluster 3 corresponded to the selection almost entirely of deck D (advantageous and high gain-frequency). Cluster 2 showed a distribution among decks B, C and D (with the selection of the two advantageous decks and the deck with high gain-frequency). The last cluster, the fourth, corresponded to the selection of decks C and D (considered as advantageous decks). Fifty percent of Novices still preferred the wrong Cluster 2 at the end of the task. In contrast, only eleven percent of Experts and Amateurs preferred this one (significant difference with novices, X_2 (2) = 24.93, $p < .001$). The rest of our Novice group accounted for ten percent of the sample in Cluster 1 (selection of deck C) and forty percent in Cluster 3 (selection of deck D). Twenty-two percent of Experts accounted for Cluster 4, which, we noticed, contained no Amateurs or Novices.

Discussion

Our main objective was to study the decision-making capacities of chess experts. In line with the literature, we put forward the hypothesis that decision-making capacities increase with the level of expertise. We used a computerized modified version of the IGT to study the decision-making capacity of three groups of chess players. We observed higher earnings in IGT according to expertise. To explain this, we studied the different strategies used by each group by means of certain indicators (deck selections, inflection point, and cluster analysis). In the first place, although we observed no difference between the three groups at the beginning, disengagement from disadvantageous decks seems to be more efficient with higher expertise levels. Furthermore, the inflection point was reached earlier by Experts and Amateurs and hence they seemed to be aware of the risk associated with certain decks earlier than Novices. However, the Amateurs appeared unconfident in their choices and extensively investigated other decks. Like Experts, but with less efficiency, Novices constantly disengaged from disadvantageous decks starting from the inflection point. Our Cluster analysis identified several strategies engaged by each group. Three of them were nearly the same as in the study by Horstmann et al. (2012). Cluster 2 represents a wrong strategy with the selection of high gain-frequency rather than advantageous decks. Clusters 1 and 3 show a practically exclusive selection of one of the two advantageous decks, respectively deck C and deck D. In contrast, our new identified cluster (cluster 4) is characterized by a switch between the advantageous decks (C and D). For the Experts and Amateurs, the distribution between Clusters 1 and 3 seemed to be equal and participants' engagement in one of them could be related to first-trial chance. Half of the Novices were still engaged in Cluster 2 and did not establish a good strategy. The last point of interest in our cluster analysis was the discovery of Cluster 4, in which only some Experts engaged. The other groups were not represented in it. The Experts and Amateurs were consequently more strongly represented in clusters in which selections turned toward advantageous decks. Thus, an increasing level of expertise in chess seems to offer a greater chance of overcoming the difficulties faced in the IGT. But how can we explain this ?

A good explanation could be provided by Bechara et al. (1997). In their opinion, decision-making takes two parallel paths. The first one is a "reasoning" path that directly confronts facts (extracts from the actual situation) with available options that will be considered to test the possible consequences offered by each. The other path is "emotional" and provides pieces of information related to previous emotional experiences of comparable situations. These experiences work on the reasoning strategies to guide the process leading to the decision. In some cases, they also can limit the number of available options. In much narrower situations the decision can even pop into the mind through the mere activation of anterior emotional experiences. In accordance with this model, we think that a greater integration of anterior emotional experiences in the steps involved in decision-making could explain the better results of experts in IGT. Indeed, as we have seen, IGT was created to distinguish VM patients from the healthy population (Saver & Damasio, 1991). VM patients are unable to take suitable decisions in ambiguous situations requiring emotional involvement, as in the IGT. Therefore, the good decision-making capacity of experts in IGT could conversely be attributed to this integration of emotion in reasoning strategies.

Our results do not provide sufficient elements to confirm this theory, but we think that it is an important aspect to emphasize. These results need to be considered in future studies in which further analyses of emotional components are required. A wide range of measurements is necessary to understand fully the potential importance of emotions in the expert's reasoning, from self-reported measures to physiological analyses (e.g. electrodermal response, heartbeat dynamics). It also seems important to replicate our results with other decision-making tasks and expert populations.

In conclusion, IGT results improve with an increase in level of expertise in chess. There is every reason to believe either that chess may develop decision-making capacities or that good decision-making capacities may engage people in the development of expertise. These better results are achieved through the rapid implementation of better strategies and especially the specific strategies of experts. As in the Ullén et al. (2016) study, we think there is more than deliberate practice to consider in order to understand expertise development. However we have to admit that we only found a correlation and our result could theoretically be in either direction. Either decision-making capacities have improved through chess practice or chess practice was easier for people with good decision-making capacities. Our study cannot conclude on this point, but we show that decision-making could be involved in expertise development and may be an important factor to consider.

Our proposal of a better integration of anterior emotional experiences in the process of experts' decision-making needs to be tested in other studies. But this assumption is potentially the reason why the human brain is and always will be better than computers. In future studies we will also have to identify whether it is possible to generalize these results to experts in many fields or whether they are limited to our expert chess population.

Authors' Declarations

The authors declare that there are no personal or financial conflicts of interest regarding the research in this article.

The authors declare that the research reported in this article was conducted in accordance with the Ethical Principles of the *Journal of Expertise.*

The authors declare that they are not able to make the dataset publicly available but are able to provide it upon request.

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Received 17 May 2019
Revision received 15 July 2024
Accepted 9 September 2024