When do expert decision makers trust their intuition?

Abstract

The aim of this study was to explore when experts trust their intuition. The Take-The-First heuristic suggests that experts generate a few options based on option validity that match the current situation and probably pick the first one they generated. In chess, the rated quality of moves can be used to analyze fast and slow decisions. We provided players with strategic (long-term) and tactical (short-term) situations and asked for fast choices, further candidate moves, and the best choice. We divided the participants into three groups based on expertise. Results indicate that chess players at lower skill levels were more vulnerable in tactics than in strategy, especially under time pressure. Masters scored better than near-experts on intuitive and final decisions, and whereas near-experts profited from more time, the masters did not. This finding implies that Take-The-First is both boundedly and ecologically rational. Conclusions are made regarding trusting the intuitions of experts.

Keywords

chess, intuition, Take-The-First, option generation, fast and frugal heuristics

Introduction

Decision making is one of the most important components of performance in organizations as well as in individuals. Decisions, however, frequently need to be realized in situations that are ambiguous and uncertain, and multiple ways to move forward need to be generated. How those decisions are made has been scientifically debated and often dichotomized, such as in fast and slow processing (Kahneman, 2011).

Theories on decision processes and how options are generated have received attention in studies of individual decisions in various contexts, such as chess (Blanch et al., 2020; Klein et al., 1995) and areas of business and management (e.g., Butler & Scherer, 1997). In some of the experimental situations, participants had to generate options and then select from them, as opposed to being given a set of choice alternatives (Johnson & Raab, 2003). Whether choosing among many options improves performance (more-is-better effect) or diminishes performance (less-is-more effect) is heavily debated and may depend on the person, the task, and situational factors (for a meta-analytical account, see Chernev et al, 2015; Scheibehenne et al., 2010).

We tested in an option-generation paradigm if study results previously seen as contradictory might appear more consistent if we considered the decision maker's expertise level (a person factor), whether the need is for a short-term tactic or a long-term strategy (a task factor), and if the decision is made under time pressure (a situation factor). We tested assumptions from a general bounded and ecological rationality approach (Gigerenzer et al., 1999). Specifically, we applied the Take-The-First heuristic (hereafter, TTF) to predict the less-is-more effect for experts' short-term decisions under time pressure and the more-is-better effect for long-term decisions made by near-experts under no time pressure (Johnson & Raab, 2003). Understanding factors that influence performance in generating options will provide a theoretical contribution to the two—less-is-more or more-is-better—camps and thus advance when one or the other camp predicts behavior well. We argue that our empirical contribution will have practical implications for individual choices in multiple applied contexts.

Less-Is-More Versus More-Is-Better in Option Generation

The less-is-more effect is often motivated by the concept of bounded rationality, which argues that humans are limited by their (a) capacity to process information, (b) time, and (c) motivation (Simon, 1972). Simple heuristics are composed of three building blocks, or rules: a search rule, a stopping rule, and a decision rule (Gigerenzer & Gaissmaier, 2011). Of the many simple heuristics that describe and guide human behavior, TTF is the best choice for a test of less-is-more (Raab & Gigerenzer, 2015). Using these heuristics has often been described as relying on intuition (Gigerenzer, 2008), thus our choice of the title of this paper.

TTF is based on the concept of simple heuristics and contains the above-described building blocks. Empirical evidence has accumulated in the nearly 20 years since the first publication (Johnson & Raab, 2003), with applications in about 190 papers (searched on WebofScience, April 2022) such as consumer choice (Nordgren & Dijksterhuis, 2009), law (von Helversen & Rieskamp, 2009), and medicine (Wegwarth et al., 2009). Furthermore, TTF was applied to varying expertise (Raab & Johnson, 2007), task and situational conditions such as time pressure (Musculus et al., 2019).

In the case of TTF, the search rule specifies looking for the most valid option given the specific situation at hand. Experts generate options in the order of their validity, stopping after three or four options and choosing the first one in more than 60% (Johnson & Raab, 2003). The search rule generates options from memory and external sources, but experts have a larger probability of success when taking the first generated option, compared to people with less expertise. Generating more than one option has been indicated as adaptive (Johnson & Raab, 2003; Stone et al., 2022). Explanations of person, task, and situation factors have been attributed to extensive learning in the domain, allowing for immediate recognition of similarities between previously experienced situations and the current one (Raab & Johnson, 2007).

The more-is-better effect is predicted by concepts of rationality that assume people can process information in parallel (Glöckner et al., 2012) and have an almost unlimited memory capacity (e.g., long-term working memory model; e.g., North et al., 2011). Under rational choice theory, people make choices based on logic and all information available thus require intentional and effortful analyses (Anand, 1993).

Meta-analytical reviews of choice overload (i.e., difficulty making a decision when offered many options), however, found quite a range of effect sizes. In a meta-analysis of about 5,000 participants across 50 studies, the effect sizes ranged from $d = -2$ to $d = 2$ (Scheibehenne et al., 2010). Scheibehenne et al. (2010) suggested that this variance is due to very different personal, task, and situational factors among the studies. In addition, understanding the choice strategies requires more than measuring the final choice outcome and therefore adding decision-process data is warranted (Scheibehenne et al., 2010, p. 420).

We argue that an obvious approach would be to explore whether a less-is-more effect or a more-is-better effect is present, which requires a systematic variation of person, task, and situation and measures of choice outcome and quality with decision-process information.

Chess as a Decision Task

Chess problems have been used as decision tasks in applied cognitive psychology (Gobet, 2018), as they provide a meaningful way to objectively measure expertise (Elo, 1978) and to vary the task (short-term tactic vs. long-term strategy) and the situation (time pressure or no pressure in regular or fast game tournaments). How can the debate on less-is-more and more-is-better effects be advanced using chess as a test bed? We argue by implementing the described chess tasks, expertise levels and time-pressure situative variations we can test whether a less-is-more or a more-is-better effect is stable over these manipulations. In addition, we can show when generating few or many options produces positive or negative performance throughout the conditions allowing us to specify under which main and interaction effects one theoretical perspective is supported by empirical evidence.

Tactical and strategic decisions

In chess, short-term tactical and long-term strategic decisions can be separated, and their effectiveness measured (van Reek et al., 1998). Former world champion Garry Kasparov distinguished strategic and tactical decisions in chess as follows: “While strategy is abstract and based on long-term goals, tactics are concrete and based on finding the best move right now. Tactics are conditional and opportunistic, all about threat and defense” (Kasparov, 2007, p. 41). Empirical evidence for tactical and strategic choices in chess is provided by studying different chess problems rather than experimentally manipulating decision processes. For instance, van Reek et al. (1998) analyzed the correctness of tactical, positional, and strategic decisions of computers and predicted an increasing time to calculate properly. They found that tactics take seconds, positional plays take minutes, and strategies can take minutes to hours. Indications on whether TTF applied to tactical and strategic chess decisions will allow us to generalize previous findings and whether a less-is-more or more-is-better perspective explains equally well choices in those tasks.

Expertise

The results of Klein (1989) showed that experts can understand problem situations and make decisions rapidly, in a matter of seconds. In chess situations calling for strategic thinking, the world champion understood the positions better after 5 s than a candidate master after 15 min (de Groot 1946/1965). This has been well documented, for instance, by Campitelli and Gobet (2010), who argued: “With routine problems, these decisions tend to be the correct ones, or at least reasonable ones. This phenomenon—often referred to as intuition—was first documented with chess masters” (p. 12).

Although previous research suggested that depth of search in chess does not increase much as a function of skill, new results show both the ability to search and the ability to use pattern recognition processes are relevant aspects of expert thinking, and long-term memory allows both extensive search and rapid evaluation (Campitelli & Gobet 2004; Campitelli et al., 2014). Gobet (1997) described in his SEARCH model that an expert combines pattern recognition, search, and mental imagery. The interaction of recognition and search leads to an increase in depth of search as a function of skill. Such arguments are often based on Simon's seminal studies that assumed that the main difference between weak and strong players is the number and size of chunks, that is, strategic ideas or tactical motifs. More specifically, according to the template theory (Gobet & Simon, 1996), high-level memory structures (schemas) are unconsciously created from simpler memory structures; schemas are structures with some invariable and some variable parts. The core of the template is a chunk, consisting of stable information, and templates can be used to store domain-specific information. A recent review of both anecdotal and evidence-based studies that indeed both tactical and strategic decision making are needed to excel at the master level (Gobet, 2018). For instance, it was found that masters see the board differently from weaker players. Masters see ideas, trajectories, concepts, and sequences of moves. They can rapidly perceive the key features of a problem much more quickly than near-experts (Gobet, 2018). Indications on whether TTF used by different expertise levels will allow us to test at what expertise level TTF is present and whether this a less-is-more explains choices better than a more-is-better perspective.

Time Pressure

Making decisions under time pressure is a characteristic of chess tournaments. Depending on the total number of moves in a game, this works out to about 4 s per move for blitz chess versus 2–3 min per move for a classical tournament game. Manipulating time pressure allows testing less-is-more or more-is-better as time pressure would reduce the number of options to be generated. Empirical evidence for less-is-more effects is scarce and conflicting evidence exists. For instance, research has shown on the one hand the advantage of fast intuitive choices in chess (Klein et al., 1995) and on the other hand that more deliberation improves choices in chess tasks (Moxley et al., 2012). Indications on whether TTF applied to different time pressure in chess decisions will allow us to test whether TTF is as well present when no time pressure is implemented and whether a less-is-more explains choices better than a more-is-better perspective.

In summary, the literature we examined suggests that a debate between less-is-more and more-is-better must be addressed empirically and systematically. We therefore used chess as a test bed that allowed us to vary person, task, and situation factors, measuring choice outcomes and decision processes with previous paradigms that have been established (Johnson & Raab, 2003). In our study we asked the following questions: Is the quality of fast decisions comparable to the quality of decisions made after significant thinking in chess? How often does the first thought of high quality depend on the type of situation (strategic, tactical)? Are there differences in fast and slow decisions between chess players of different levels of expertise?

The Current Study and Hypotheses

The hypotheses to test a less-is-more versus a more-is-better perspective are based on the main and interaction effects of a 3×2×2 design, with expertise as a between-subjects factor (master, expert, advanced) and task (strategic vs. tactical situation) and decision time (short vs. long) as within-subject factors. Dependent variables of chess behavior are quality of moves, number of candidate moves, and order of generated moves (see Data Analyses for details). We sampled chess players of the European University Chess Championship. Having participants with different levels of expertise (master, expert, and advanced) allowed us to test chess situations in which multiple options could be generated and in which we could measure expertise objectively.

Based on previous research (e.g., Johnson & Raab, 2003), we described above that TTF allows specific predictions for a general less-is-more perspective. We predicted for quality of moves expertise effects (Hypothesis 1, H1) and decision time effects (Hypothesis 2, H2):

H1: Players with higher Elo ratings will score better (e.g., Klein et al., 1995),

H2: A longer decision time will help make better decisions (Moxley et al., 2012).

Based on the specific definition of TTF, the main effects above should be informed by interaction effects. We predicted two-way interactions of Expertise × Task (Hypothesis 3, H3), Expertise × Decision Time (Hypothesis 4, H4), Task × Decision Time (Hypothesis 5, H5), and Expertise × Number of Generated Options (Hypothesis 6, H6) rather than three-way interactions:

H3: Masters will produce a relatively higher quality of moves in the strategic task compared to the tactical task in comparison to advanced players and experts. Given that strategic planning requires high expertise in pattern recognition (Chase & Simon, 1973), the effect of task differences will be pronounced in experts and masters,

H4: There will be stronger effects of shorter decision times for advanced players and experts than for masters given according to the TTF, masters rely on their fast intuition (e.g., Raab & Johnson, 2007),

H5: There will be stronger effects of shorter decision times for tactical than for strategic situations (Johnson & Raab, 2003),

H6: Masters will generate slightly fewer options than advanced or expert players. Based on TTF, qualitative and not quantitative difference between the options generated in different expertise levels can be predicted (Hepler & Feltz, 2012; Raab & Johnson, 2007). However, according to the less-is-more principle (Gigerenzer et al., 1999), higher level of expertise allows to generate fewer options. H6 was formulated taking the above into consideration.

Finally, and based on the option-generation process of TTF, we predicted a non-random option-generation process (Hypotheses 7, H7):

H7: Candidate moves will be generated in an ordered fashion, based on move quality, starting with the strongest one. With this prediction we expect our results will replicate and extend earlier results that did not differentiate tactical and strategic choices with and without time pressure in chess (Klein et al., 1995) or other time pressure environments in sports (Johnson & Raab, 2003).

Method

Participants

Thirty-four participants (26 men, eight women; Elo rating: *M* = 2,142, *SD* = 376; age: *M* = 29 years, *SD* = 13) participated in the study. Most participants (27) were players in the European Universities Chess Championship held in Budapest in 2019. The remaining seven participants were rated chess players at a similar level and age. The participants were divided into three groups of skill level based on the Elo rating system of the FIDE. Ten individuals with a rating under 2,000 (seven men, three women; Elo rating: *M* = 1,659, *SD* = 284; age: *M* = 29 years, *SD* = 18) were placed into the group we called advanced players. Fourteen individuals with a rating between 2,000 and 2,399 (nine men, five women; Elo rating: *M* = 2,227, *SD* = 105; age: *M* = 27 years, *SD* = 12; three international masters and four FIDE masters included) were placed into the group we called experts. Ten individuals with a rating over 2,399 (all men; Elo rating: *M* = 2,506, *SD* = 71; age: *M* = 30 years, *SD* = 11; six grandmasters and four international masters included) were placed into the group we called masters. All participants agreed to take part in the research anonymously and to contribute to the research. The Ethics Committee of the Hungarian University of Sports Science approved the study.

Materials

We pretested chess positions in which tactical and strategic motives could be separated. From a preselected list of examples in different chess books and from top tournament games, the six most appropriate examples were selected by consensus of two grandmasters who were chess coaches. The results of the pilot experiment showed that four of the preselected positions would produce a good case for an ill-defined task that would allow participants to generate multiple options. Four chess positions were presented to the participants as diagrams, each printed on a separate page (see Supplementary Material, Figure S4-8; for the solutions, see Figure S9). Two of the solutions were based on a tactical blow and two were based on long-term strategic ideas. The participants did not get information about the type of the positions.

Procedure

For each problem the participants went through the following three steps: First, they made a fast decision: The participants had 15 s to write the best move in the diagrammed position. During the above-mentioned pilot experiment, we concluded that less time would not be enough for mapping the position but more time would give participants the opportunity to calculate concrete lines. Second, they set up candidate moves: The participants got an extra 45 s to write down their candidate moves (the moves they considered before making a detailed calculation). Third, they made a slow decision: After an additional 4 min of calculating, the participants wrote down their moves and main lines of choices. They had the opportunity to keep or change their fast decisions.

Data Analyses

Dependent Variables

Quality of Moves. To evaluate the quality of the possible moves, we followed the method of Klein et al. (1995) and constructed a 5-point rating scale. Each rating was given by the consensus of two grandmasters who took the evaluations of the Stockfish 12 chess engine into account. The evaluation was more objective than it was in previous experiments (Klein et al., 1995) because since that time both hardware and chess software have improved a lot. Today's chess engines[1] are much stronger than any human player or any engine in the 20th century (Silver et al., 2017). Stockfish 12 is one of the leading chess engines with an estimated Elo rating of over 3,200. Scoring was based on the following criteria: 5 points: the best move in the position, the first step of a complex tactical combination or a deep strategic plan; 4 points: good move with a definite goal; 3 points: a conscious move that holds the balance; 2 points: inaccurate move that might cause problems; 1 point: blunder that leads to a clearly lost position.

Number of Moves. Number of candidate moves was analyzed with a mixed-effect Poisson regression model. The response variable was number of candidate moves, which we assumed to have a Poisson distribution. For fixed effects, task (strategic or tactical), expertise level (advanced, expert, master), and their interaction were observed. Random effects consisted of by-subject and by-item random intercept and by-subject random slope for task. Initially, data were checked for outliers (with an alpha level of 5%). Two data points (0.7% of all data) were considered outliers, which were disregarded in the analysis. The outlier-free distribution is visualized in the Supplementary Material. Note as well that first, random effects were examined and if the correlation between the by-subject intercept and the by-subject slope was very high (e.g., r = 0.9 for number of options generated) the random slope was dropped from the model. Next, we assessed whether both random intercepts were needed in the model (see Table S1 in the Supplementary Material for number of options generated). If results of the likelihood ratio test showed that there was no difference between the three models, the simple random model was preferred. Further, we examined the fixed effects, which revealed that none of the fixed effects was of significance (see Table S2).

[1] A computer program that analyzes chess positions and generates a move or list of moves that it regards as strongest

Serial order of generated Moves. Serial order of generated moves was analyzed with a regression model by comparing an ordered (vs. random) generation of moves with a decline in quality of moves by position in the sequence of candidate moves.

Analyses of Main and Interaction Effects

Given that calculating averages from Likert scale data might distort the results, we analyzed the data with a more reliable statistical method: ordered mixed effect logistic regression. The model contained expertise level, decision time, and task as fixed factors. Random intercepts of subject and item were added. All regression tables (see Tables S1–S15) can be found in the Supplementary Materials and the main results of these analyses are presented in the main text. First, random effects were examined: The effects of item and subject were compared to the initial model separately. Only a random effect of item was found to be of relevance (see Table S3). Second, significance of the fixed effect was tested, which showed that expertise, decision time, Level × Task interaction, and Time × Task interaction affected quality of moves significantly (see Table S4). Third, removing the nonsignificant fixed effect did not change the model significantly ($df = 4$, likelihood ratio = 8.7, $p = .070$). Parameter estimates of the final parsimonious model are shown in Table S5. Fourth, a pairwise comparison with Tukey correction was carried out to analyze contrasts specified by the predictions.

Data Processing

Statistical analysis was carried out using the open-source R language and environment. Outliers and normal distribution were checked. For the analysis of quality of moves regarding expertise level and decision time (H1–H2), an ordered mixed effects logistic regression was constructed using the *ordinal* package *clm* and *clmm* functions, the *car* package *Anova* function, the *stats* package *anova* function, and the *lsmeans* package *lsmeans* function. For number of candidate moves (H6), generalized linear models (GLMs) with Poisson family distribution and log link function were built using the *lme4* package *glmer* function. GLMs were compared with the *anova* function of the *stats* package. While decision and inference were not based solely on *p* values, in keeping with convention we state that the level of significance was set at $p < .05$.

Manipulation Checks

Our manipulation checks indicate that the option-generation paradigm and the chosen tasks do produce different options between participants and chess situations. For the four chess tasks, we found an average number of generated options of *M* = 3.11 (*SD* = 1.40) per participant. On average per task, the number of different first options generated by all the participants was *M* = 8.25 (*SD* = 1.30). This indicates that these situations can produce different option-generation strategies between participants with high levels of chess expertise and that the chess situations are ambiguous, producing different intuitive and deliberative choices among individuals. The mean score of the quality of moves indicated in addition that the task was of medium difficulty, as the mean decision quality on a 5-point Likert scale was 3.21 (*SD* = 1.16).

Results

Descriptive data reveal that expertise and decision time produce main differences in move quality and number of options generated (see Table 1).

Table 1

Descriptive Values (Mean and Standard Error) for Main Effects of Expertise and Decision Time on Move Quality and Number of Move

Factor	Factor level	Quality of moves	Number of moves
Expertise	Masters	3.75 (0.43)	3.58 (1.20)
	Experts	3.26 (0.37)	3.04 (0.98)
	Advanced players	2.60 (0.46)	2.75 (1.22)
Decision time	Short	3.05 (0.43)	–
	Long	3.36 (0.41)	–

Expertise (H1)

As expected, the differences between the expert levels were found (see Figure S1): Masters performed better than experts, who performed better than advanced players. On tactical tasks, masters scored better than experts and experts scored better than advanced players (see Table S6). The ordered logistic mixed effect regression confirmed that experts scored better than advanced players but did not confirm a significant difference between the performances of masters and experts. On strategic tasks, masters scored better than experts and experts scored better than advanced players. However, according to the ordered logistic mixed effect regression, there were no significant differences between the groups. In sum, masters produced better quality moves for strategic (nonsignificant) and tactical (significant) tasks compared to advanced players and experts.

Decision Time (H2)

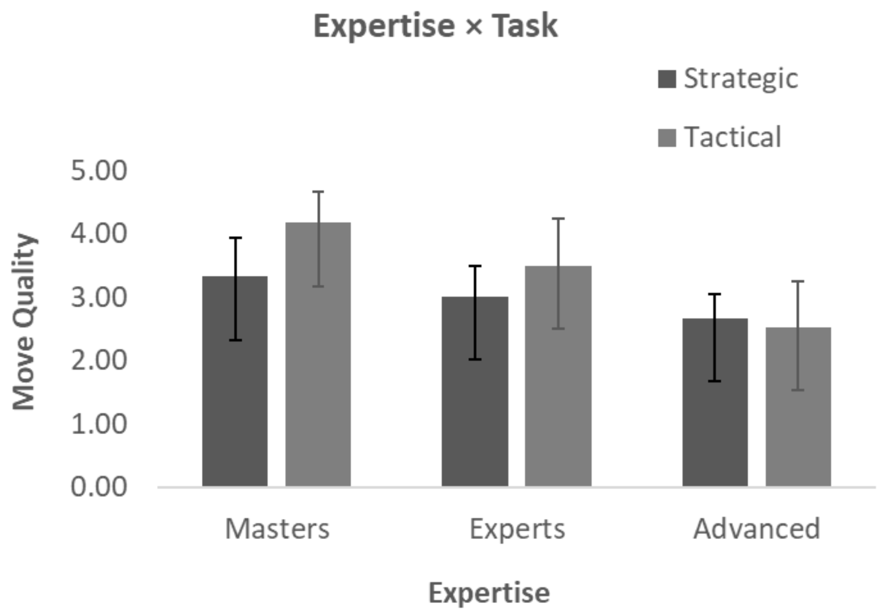
According to the statistics, decision time affected quality of moves (see Figure S2). More time yielded better moves ($p = .004$).

Expertise × Task interaction (H3)

The Expertise × Task interaction shows that the difference in the quality of moves between masters and experts/advanced players is larger in tactical than in strategic situations (see Figure 1, Table S7). In other words, the difference between tactical and strategic situations was small for experts and advanced players but substantial for masters. Given the hypothesis that for strategic choices (compared to tactical) the advantage of masters should be larger and not smaller, this finding requires further discussion (see below).

Figure 1

Descriptive Values for Two-Way Interaction Effects of Expertise and Task for Move Quality

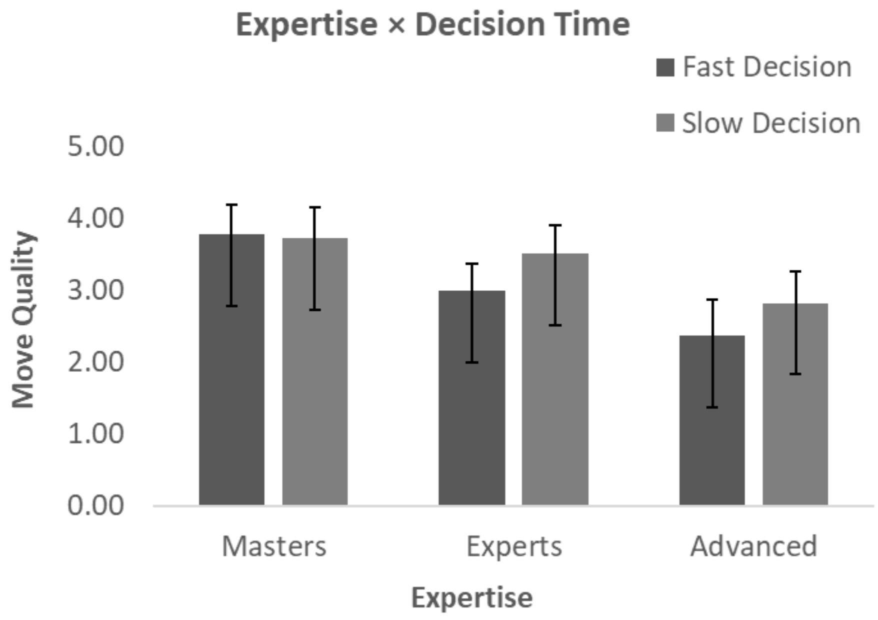


Expertise × Decision Time interaction (H4)

The Expertise × Decision Time interactions show that masters produced relatively better choices when they had a short decision time compared to experts and advanced players (see Figure 2). The decision time and expertise interactions indicate a trend (p = .07) that may require follow-up studies with a larger sample and/or a more sophisticated move quality characterization. At the master level, there was no difference between the quality of fast and slow decisions in either tactical or strategic situations. In contrast, for advanced players and experts, the difference between the quality of fast and slow decisions in both situations were well-defined (see Figure 2).

Figure 2

Descriptive Values for Two-Way Interaction Effects of Expertise and Decision Time for Move Quality

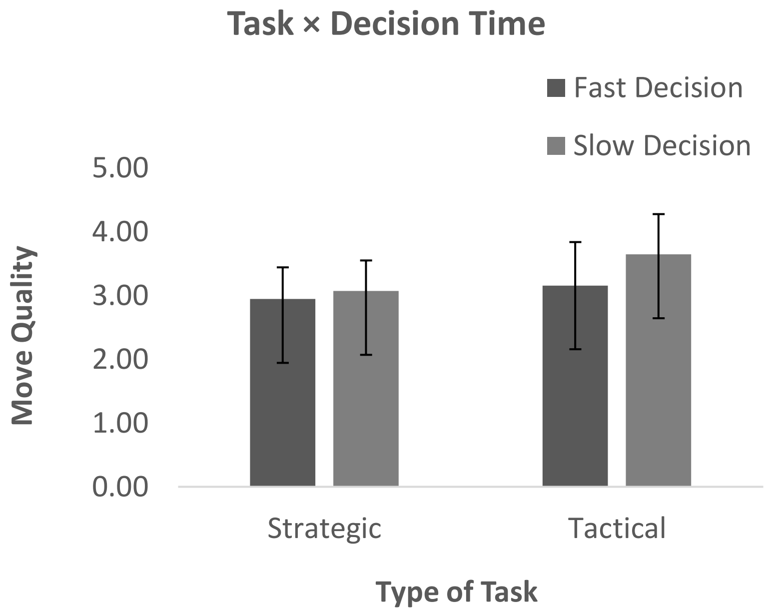


Task × Decision Time interaction (H5)

The Task × Decision Time interaction reveals that for tactical situations, longer decision time is more crucial than for strategic tasks (see Figure 3). Significance levels indicate that fast and slow decisions differed only in tactical and not in strategic situations (see Table S8). It should be noted, however, that this interaction is mostly driven by the data from experts and advanced players, as masters have equally good-quality moves for both the two task types and the two decision time levels.

Figure 3

Descriptive Values for Two-Way Interaction Effects of Task and Decision Time for Move Quality



Number of generated options (H6)

For the number of generated options, fixed effects revealed that the number of candidate moves did not differ between expertise groups. Although the differences were nonsignificant, we tested expected values and their confidence intervals across levels of expertise (see Table S9). Confidence intervals considerably overlapped in the case of advanced players and experts, as well as experts and masters. Yet, it is noteworthy that confidence intervals of advanced players and masters shared only a small proportion. In contrast to predictions of a less-is-more account, masters generated more options (see Figure S3).

Order of generated options (H7)

For the order of generated options, initially data were explored to reveal the proportion of missing data (see Table S10 for the number of valid cases per group per candidate move). The quality of the first three candidate moves was compared regarding level of expertise. Again, an ordered mixed effect logistic regression analysis was applied with rating of the moves as response variable and serial position (first, second, or third) and expertise and their interaction as fixed predictors. Item and subject were added as random effects. First, relevance of random terms was examined (see Table S11). Models with a single random effect did not differ from the initial full model; thus, based on our design and hypotheses the random effect of subject was kept. Second, fixed effects were analyzed, which showed significance of serial position, expertise level, and their interaction (see Table S12). A proportional odds assumption that was checked with a scale test (see Table S13) showed no violation (see Table S14 for parameter estimates). Third, a post hoc pairwise comparison of the interaction term with Tukey's *p*-value adjustment revealed that for masters, the first candidate move was significantly better than the second and third candidates, but the second and third did not differ (see Table S15). Advanced players and experts did not show sequential effects in the quality of their moves in their option generation. The latter finding could be due to the relatively large number of missing data points in the second and more prominently in the third candidate moves (see Table S10). In sum, an ordered (vs. random) generation of moves was confirmed in the case of masters, with a decline in quality of moves in the sequence of the option generation. In advanced players and experts, future research may replicate current trends.

In sum, we found main effects for expertise and decision time. In addition, we found four two-way interactions of expertise, task, decision time, and number of generated options. Results indicate that the manipulations produced reliable changes in the quality of moves, numbers of moves, and sequence effects of moves generated (H7).

Discussion

The goal of the current study was to examine how decision makers of different expertise take advantage of their intuition in strategic and tactical situations with shorter or longer decision time. Based on the TTF heuristic we favored a less-is-more perspective and compared it to a more-is-better perspective that would suggest an advantage of more options generated and more time to generate those options for performance. A new result of our study compared to the previous research is that we informed the less-is-more or more-is-better perspective by testing them against each other for a combination of fast and slow decisions, short-term tactical and long-term strategic decisions at different levels of expertise.

Both less-is-more and more-is-better perspective predict expertise effects we found (H1) and confirm previous results that players at higher expertise levels made better decisions (e.g., Klein et al., 1995), indicating the tasks were sufficient to measure expertise.

Whereas the more-is-better perspective would predict unfavorable effects of time pressure the less-is-more approach does not. Our results supported our hypothesis (H2) that a longer decision time (4 min) helps players make better decisions, compared to decisions made under time pressure (15 s) in favor of a more-is-better perspective (Moxley et al., 2012). This effect is mainly driven by the tactical tasks in which the difference between slow and fast decisions was strongest (see H5).

Based on the study of Chase and Simon (1973), we predicted that higher expertise would be more pronounced in strategic than in tactical tasks (H3). The results did not support the hypothesis but the opposite: The difference between the groups was more pronounced in the tactical than the strategic tasks. This may be since the tasks were too difficult for the groups with lower Elo points. Further, in strategic positions there were fewer opportunities to make large mistakes whereas each decision had a greater weight in tactical choices. Further research is needed to answer the question of whether greater expertise is more prominent in strategic or tactical situations.

We predicted that masters would benefit relatively less from more time than experts and advanced players (H4). In line with a less-is-more approach, we predicted that TTF would work in masters under time pressure. Importantly, at the master level, no difference was found between the quality of fast and slow decisions: Masters performed equally well in fast and slow decisions and thus coped well under time pressure. The results indicate that advanced and expert players, unlike masters, did not know enough patterns or were not able to retrieve them fast enough to cope with time pressure. This finding supports the conclusion of Chase and Simon (1973) that chess experts can map out the characteristics of the situation and find the correct plan even in a short time. Longer reflection time, however, benefitted advanced players and experts and allowed them to calculate variations better whereas for masters decision time plays a smaller role. In the case of decisions made under time pressure, while the good performance of the masters was explained by their knowledge of a large number of schemas, the opposite can be said for advanced players and experts. Thanks to their knowledge of thousands of schemas, masters saw the essence of the situation even after only a brief overview. Our results also support the conclusion of Blanch et al. (2020) that the performances on fast and slow tasks are more similar at higher levels of expertise. Previous research nicely supports a general line of argument. For instance, Moxley et al. (2012) examined chess players at two different levels. The strength of the stronger group ("experts," average rating of 2194) was like that of the expert group we examined (average rating of 2227). Our results support the conclusion of Moxley et al. (2012) that both advanced (tournament) players and experts benefit from extra deliberation. However, we also examined a third group—masters (average rating of 2506)—which adds to the discussion of intuition in high-level expertise groups and for this group may not support fully a more-is-better perspective. Although we achieved similar results to Moxley et al. (2012) in the first two groups (players benefited from extra deliberation), we had an additional important finding: Masters no longer benefited from the extra time. Our results support the use of TTF: Decision makers at high levels of expertise made good decisions instantly (Johnson & Raab, 2003; Raab & Johnson, 2007). We can conclude that TTF worked well, as the top-level chess players made relatively good fast decisions but players at lower levels such as advanced players made good decisions only after decent thinking. Further research can provide an answer to the question of in what types of situations the masters' intuition works well and in what types it does not.

We predicted that there would be stronger effects of shorter decision times for tactical than for strategic chess situations (H5). Results showed that the prediction was correct. In tactical chess situations, each move is important such that a single mistake can be decisive. In these situations, calculation plays a big role, for which proper thinking time is essential favoring a more-is-better perspective. In contrast, specific calculation is less necessary in strategic situations, so time also plays a smaller role not favoring a more-is-better perspective.

Based on a less-is-more perspective and considering two previous studies (Johnson & Raab, 2003; Klein et al., 1995), we predicted that the masters would generate slightly fewer options than the experts or advanced players (H6). When we examined the number of generated candidate moves, we found a surprising result, just the opposite of what we predicted. Players at the higher level of expertise always generated more candidate moves in both strategic and tactical situations. In our research the more-is-better effect (Rietzschel et al., 2007) outweighed the less-is-more effect (Johnson & Raab, 2003). The number of generated options depends on the characteristics of the situation (type and complexity of the task, time to make a decision) and the cognitive system (Hepler & Feltz, 2012). We think that in the case of such complex problems, the limited time was not enough for the groups at the lower levels of expertise to set up as many candidate moves as they normally would. Likewise, when faced with complex problems, higher level experts may generate more moves compared to fast game situations in which they would disregard lower quality moves to gain time for fruitful game developments. In the case of simple problems, experts may propose only one option, the best one, as evident in Variation 1 of the recognition-primed decision model (see Phillips et al., 2011, p. 304, Fig. 15.1). However, the number of different options generated as the first option in expertise groups indicated indeed that multiple options are potentially relevant in our chess tasks. Follow-up experiments that allow more decision time are needed to judge if chess players at high levels of expertise generate more or fewer options than chess players at lower levels (see as well Gobet, 2018). In addition, the number of generated options (or ideas) is a well-established measure in research on creativity. Therefore, it may be useful to consider creativity research and its measures in future research on individual and expertise differences in option generation (Del Missier et al., 2015).

Finally, and based on TTF and a less-is-more perspective we predicted that chess moves would be generated in an ordered fashion according to the quality of the moves (H7). For each participant and each chess problem, we evaluated the first three candidate moves and compared the ratings. If the candidate moves were set up randomly, there would be no significant difference in the results for the three moves. For experts and advanced players, no relationship was found between the move quality and the serial positions of candidate moves. However, the statistical evaluation supports that for masters, the first candidate move was stronger than the second and the third. These results confirm the conclusions in earlier work (Johnson & Raab, 2003; Klein et al., 1995) that decision makers at high levels of expertise generate options in a qualitative order, starting with the strongest choice and supporting a less-is-more perspective. Thus, experts do trust their intuitions and, in most cases, with good reason.

In sum we found evidence for both a less-is-more and a more-is-better perspective of decision making. From the results it seems important to specify the TTF predictions to the highest expertise level in which several effects are in line with TTF. However, the more-is-better approach seems to hold well for the other expertise levels tested and for specific combinations of conditions we implemented. A fair summary may require overcoming a black-white discussion of opposing perspectives but rather help to understand when or for whom a less-is-more or a more-is-better perspective explain empirical evidence well.

Limits of the Study and Recommendations for Further Investigation

Although our new methodological paradigm is a plus, our study has a few limitations. The number of participants was large enough to reveal reliable results, but conceptual and exact replications and larger samples may outweigh the costs of studies with enormous sample sizes (LeBel et al., 2017). It was difficult to make an exact evaluation of move quality. The 5-point Likert scale might not be the most accurate way to evaluate chess moves, and it probably does not properly represent differences in quality. For further investigation, we recommend using a more accurate evaluation method based on the exact evaluations of modern chess engines.

Within the studied groups, the knowledge gap was probably too large, which may have distorted the results. In future studies, we recommend that the expertise difference within each group should not exceed 200 Elo points. We also think that the differences in results between groups would become clearer if the skill levels of the groups were more widely separated.

We may have obtained a more reliable result if we had been able to include more test items in our experiment. However, given the European Universities Chess Championship in which we tested experts in real-life situations, this was not doable. In addition, we wanted to give the players enough time for the slow decisions under these constraints and ended up opting for four items (two strategic and two tactical).

We also need to acknowledge that task 4 is not clearly a strategic example. Although the best move leads to a strategic pawn sacrifice, the second-best move is a tactical idea that forces a few sequences of moves and leads to complications. Considering the above mentioned, we think that the task is acceptable as a strategic example.

Despite these few limitations, our results indicate that whether experts can trust their expertise depends on not just personal experience with the task but also the type of task and the time available for a decision, a combination of bounded and ecological rationality.

Conclusions

We examined how decision makers take advantage of their intuition in both strategic and tactical situations with shorter or longer decision time. The results suggest that compared to masters, the highest level of expertise studied here, for those at advanced but lower levels of expertise, intuition does not work well, and players need time to calculate multiple lines of chess moves. However, it turned out that masters' intuitive choices were not worse than their choices after a deep think. We also analyzed the decisions in strategic and tactical situations separately. According to our results, chess players at lower skill levels were more vulnerable in the latter, especially under time pressure. We have extended the previous research with athletes (Johnson & Raab, 2003; Raab & Johnson, 2007) with chess players and have come to a similar conclusion: An expert's first thought is a good option in most cases.

References

Anand, P. (1993). *Foundations of rational choice under risk*. Oxford University Press.

Blanch, A., Ayats, A., & Cornado, M. P. (2020). Slow and fast chess performance across three expert levels. *Psychology of Sport and Exercise, 50,* Article 101749. https://doi.org/10.1016/j.psychsport.2020.101749

Butler, A. B., & Scherer, L. L. (1997). The effects of elicitation aids, knowledge, and problem content on option quantity and quality. *Organizational Behavior and Human Decision Processes*, 72, 184–202. https://doi.org/10.1006/obhd.1997.2737

Campitelli, G., & Gobet, F. (2004). Adaptive expert decision making: Skilled chess players search more and deeper. *ICGA Journal, 27*(4), 209–216.

Campitelli, G., & Gobet, F. (2010). Herbert Simon's decision-making approach: Investigation of cognitive processes in experts. *Review of General Psychology, 14,* 354–364.

Campitelli, G., Gobet, F., & Bilalić, M. (2014). Cognitive processes and development of chess genius: An integrative approach. In D. K. Simonton (Ed.), *The handbook of genius* (pp. 350–374). Wiley-Blackwell.

Chase, W. G., & Simon, H. A. (1973). Perception in chess. *Cognitive Psychology, 4,* 55–61.

Chernev, A., Böckenholt, U., & Goodman, J. (2015). Choice overload: A conceptual review and meta-analysis. *Journal of Consumer Psychology*, *25*(2), 333–358. https://doi.org/10.1016/j.jcps.2014.08.002

de Groot, A. D. (1965). *Thought and choice in chess*. Mouton. (Original work published 1946)

Del Missier, F., Visentini, M., & Mäntylä, T. (2015). Option generation in decision making: Ideation beyond memory retrieval. *Frontiers in Psychology*, *5*, Article 1584. https://doi.org/10.3389/fpsyg.2014.01584

Elo, A. (1978). *The rating of chess players, past and present*. Batsford.

Gigerenzer, G. (2008). *Gut feelings: Short cuts to better decision making*. Penguin Books.

Gigerenzer, G., & Gaissmaier, W. (2011). Heuristic decision making. *Annual Review of Psychology*, *62*, 451–482. https://doi.org/10.1146/annurev-psych-120709-145346

Gigerenzer, G., Todd, P. M., & the ABC Research Group. (1999). *Simple heuristics that make us smart*. Oxford University Press.

Glöckner, A., Heinen, T., Johnson, J. G., & Raab, M. (2012). Network approaches for expert decisions in sports. *Human Movement Science*, *31*, 318–333. https://doi.org/10.1016/j.humov.2010.11.002

Gobet, F. (1997). A pattern-recognition theory of search in expert problem solving. *Thinking & Reasoning*, *3*(4), 291–313. https://doi.org/10.1080/135467897394301

Gobet, F. (2018). *The psychology of chess*. Routledge. https://doi.org/10.4324/9781315441887

Gobet, F., & Simon, H. A. (1996). Recall of random and distorted chess positions: Implications for the theory of expertise. *Memory & Cognition*, *24*, 493–503. https://doi.org/10.3758/BF03200937

Hepler, T. J., & Feltz, D. L. (2012). Take the first heuristic, self-efficacy, and decision-making in sport. *Journal of Experimental Psychology: Applied*, *18*(2), 154–161. https://doi.org/10.1037/a0027807

Johnson, J. G., & Raab, M. (2003). Take the first: Option-generation and resulting choice. *Organizational Behavior and Human Decision Processes*, *91*, 215–229. https://doi.org/10.1016/S0749-5978(03)00027-X

Kahneman, D. (2011). *Thinking fast and slow*. Penguin Books.

Kasparov, G. (2007). *How life imitates chess*. W. Heinemann.

Klein, G. A. (1989). Recognition-primed decisions. In W. Rouse (Ed.), *Advances in man-machine systems research* (Vol. 5, pp. 47–92). JAI Press.

Klein, G., Wolf, S., Militello, L., & Zsambok, C. (1995). Characteristics of skilled option generation in chess. *Organizational Behavior and Human Decision Processes, 62*(1), 63–69. https://doi.org/10.1006/obhd.1995.1031

LeBel, E. P., Campbell, L., & Loving, T. J. (2017). Benefits of open and high-powered research outweigh costs. *Journal of Personality and Social Psychology*, *113*(2), 230–243. https://doi.org/10.1037/pspi0000049

Moxley, J. H., Ericsson, K. A., Charness, N., & Krampe, R. T. (2012). The role of intuition and deliberative thinking in experts' superior tactical decision-making. *Cognition, 124,* 72–78.

Musculus, L., Ruggeri, A., Raab, M., & Lobinger, B. (2019). A developmental perspective on option generation and selection. *Developmental Psychology, 55*(4), 745–753. https://doi.org/10.1037/dev0000665

Nordgren, L., & Dijksterhuis, A. (2009). The devil is in the deliberation: Thinking too much reduces preference consistency. *Journal of Consumer Research*, *36*, 39–46. https://doi.org/10.1086/596306

North, J. S., Ward, P., Ericsson, A., & Williams, A. M. (2011). Mechanisms underlying skilled anticipation and recognition in a dynamic and temporally constrained domain. *Memory*, *19*, 155–168. https://doi.org/10.1080/09658211.2010.541466

Phillips, J. K., Klein, G., & Sieck, W. R. (2004). Expertise in judgment and decision making: A case for training intuitive decision making. In D. J. Koehler & N. Harvey (Eds.), *Blackwell handbook of judgment and decision making* (pp. 297–315). Blackwell.

Raab, M., & Gigerenzer, G. (2015). The power of simplicity: A fast-and-frugal heuristics approach to performance science. *Frontiers in Psychology, 6,* Article 1672. https://doi.org/10.3389/fpsyg.2015.01672

Raab, M., & Johnson, J. G. (2007). Expertise-based differences in search and option generation strategies. *Journal of Experimental Psychology: Applied, 13,* 158–170. https://doi.org/10.1037/1076-898X.13.3.158

Rietzschel, E. F., Nijstad, B. A., & Stroebe, W. (2007). Relative accessibility of domain knowledge and creativity: The effects of knowledge activation on the quantity and originality of generated ideas. *Journal of Experimental Social Psychology*, *43*, 933–946. https://doi.org/10.1016/j.jesp.2006.10.014

Scheibehenne, B., Greifeneder, R., & Todd, P. M. (2010). Can there ever be too many options? A meta-analytic review of choice overload. *Journal of Consumer Research*, *37*(3), 409–425. https://doi.org/10.1086/651235

Silver, D., Hubert, T., Schrittwieser, D., Antonoglou, I., Lai, M., Guez, A., Lanctot, M., Sifre, L., Kumaran, D., Graepel, T., Lillicrap, T., Simonyan, K., & Hassabis, D. (2017). *Mastering chess and shogi by self-play with a general reinforcement learning algorithm*. arXiv. https://arxiv.org/abs/1712.01815

Simon, H. A. (1972). Theories of bounded rationality. *Decision and Organization, 1*(1), 161–176.

Stone, C., Mattingley, J. B., Rangelov, D. (2022). On second thoughts: changes of mind in decision-making. *Trends in Cognitive Sciences*. https://doi.org/10.1016/j.tics.2022.02.004

van Reek, J., Uiterwijk, J. W. H. M., & van den Herik, H. J. (1998). Planning a strategy in chess. *ICCA Journal, 21*(3), 183–192.

von Helversen, B., & Rieskamp, J. (2009). Predicting sentencing for low level crimes: Comparing models of human judgment. *Journal of Experimental Psychology: Applied, 15*, 375–395. https://doi.org/10.1037/a0018024

Wegwarth, O., Gaissmaier, W., & Gigerenzer, G. (2009). Smart strategies for doctors and doctors-in-training: Heuristics in medicine. *Medical Education*, *43*, 721–728. https://doi.org/10.1111/j.1365-2923.2009.03359.x