An Analysis of Expertise-Induced Amnesia: Semantic and Episodic Recall of Chess Moves Across Different Skill Levels and Conditions

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Abstract

The chess domain was used to test the hypothesis for expertise-induced amnesia within a cognitive sport context, particularly examining the decrease in declaratively accessible episodic memories of chess moves as skill levels increase. While this hypothesis has been supported in a sensorimotor golf putting task (Beilock & Carr, 2001), it is untested in a cognitive chess task. Thirty adult participants were recruited online from chess clubs worldwide, classified into highly skilled (Elo rating over 1900) and competent (Elo rating under 1400) groups based on their skill level. Participants were then assigned to the rapid, random, or blitz condition. Rapid and random conditions varied by chess position configuration, while rapid and blitz conditions differed in time control. The random and blitz conditions also differed in both chess position configuration and time control. The study examined generic knowledge and episodic memories of online chess moves in competent and high skilled players across different conditions. Centipawn values of the best moves were calculated by Stockfish 14.1. De Groot's four phases were used by scoring how many of the phases (0-4) participants recalled when describing the thought process involved in making their chess move. The primary finding indicated that expertise-induced amnesia occurs in the cognitive sport of chess, suggesting an association between skill acquisition and automaticity. These findings align with previous research by De Groot (1946/1978) and Chase and Simon (1973a), emphasizing the importance of fast processes in chess skill. Furthermore, future research directions, limitations, and practical implications are discussed.

Keywords: chess skill, expertise-induced amnesia, De Groot's four phases, generic knowledge, episodic memories

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An Analysis of Expertise-Induced Amnesia: Semantic and Episodic Recall of Chess Moves Across Different Skill Levels and Conditions

The prediction of expertise-induced amnesia (EIA; Beilock & Carr, 2001) in the cognitive sport of chess is explored in this study. Making a chess move protocol was chosen because chess is a complex task in which considerable time and effort is required to become an expert player. Even at an expert level, selecting the best move to play in a chess position is not easy, and success depends heavily on a large knowledge base that consists of chess piece configurations and game scenarios that have been stored in long-term memory (LTM) from extensive experience (De Groot 1946/1978). The chess domain is used for the aim to test if EIA is supported in a cognitive sport and if attending to a proceduralised skill, diminishes episodic recollection of the performance. This aim has been tested and supported in a sensorimotor golf putting task (Beilock & Carr, 2001) but is untested in a cognitive chess task.

In this introduction, it is explained why chess is an important domain for understanding expertise. The cognitive processes that underlie chess expertise are then discussed in the Skill of Chess section. Theories that account for the decrements that can occur in skilled performance are then introduced through an example of a grandmaster chess player who failed to perform.

A short section on how to determine the proceduralisation of chess skill is followed by a more detailed discussion about the contrast in the knowledge representations controlling the execution of different skills at specific levels of expertise. Then there is an explanation on why expertise involves decreasing consciousness of one's actions, which results in an impoverished recall of the skill just performed.

This is directly followed by a section focusing on the first two experiments of Beilock and Carr's (2001) classic 'choking under pressure' study because the support for EIA is found in these two experiments. Then an alternative explanation to EIA is provided from the cognitive chess literature, which is titled Expertise-Heightened Memory.

A review of the research on random positions is then presented. Random positions should require highly skilled players to attend to the specific processes of skill execution and therefore hurt their performance. Time pressure should not affect highly skilled players if their skill is proceduralised, but another line of research suggests time pressure is a distraction for them, and both lines of research are reviewed in the Time Pressure section.

Finally, The Current Chess Study section explains how the present study will test automatization in high-level chess skill and the episodic memory for making a chess move, which should decrease with increasing chess skill. The conclusion is the aims and hypotheses of the present study.

The Processes Involved in Expert Decision-Making

An important question in cognitive science is: What are the processes that underlie expert decision making? (Ericsson & Staszewski, 1989; Van Harreveld et al., 2007). Every domain, from medical decision-making to engineering, has demonstrated that expertise involves both slow processes, such as selective search, and fast processes, such as the recognition of meaningful patterns (Ericsson & Staszewski, 1989; Van Harreveld et al., 2007). This contrast between fast and slow processes is conducive to the intellectually demanding sport of chess; therefore, research in chess is an important domain to understand what accounts for expertise (Blanch et al., 2020; Van Harreveld et al., 2007).

The Advantage of Expertise Research in Chess

Researchers have been contemplating the cognitive processes that support skill in chess since at least Binet's (1893/1966) study of Paul Morphy's extraordinary memory for his past chess games and robustly ever since De Groot's (1946/1978) classic findings. An advantage over other fields of expertise research is that chess uses the Elo rating system to measure skill level (Shanteau, 2015; Swann et al., 2015). The Elo ratings can be split into the following broad classes (HIARCS Chess Explorer, n.d.) as presented in Table 1.

Table 1

Elo Ratings of Chess Players

Class of player	Rating range
World Champion	2800+ Elo
World Champion contender	2700–2800 Elo
Super Grandmaster	2600–2700 Elo
Grandmaster	2500-2600 Elo
International Master	2400–2500 Elo
Master	2200–2400 Elo
Expert	2000–2200 Elo
Class A - Strong club player	1800–2000 Elo
Class B - Club team player	1600–1800 Elo
Class C - Club player	1400–1600 Elo
Class D - Hobby player	1200–1400 Elo
Class E - Beginner/Novice	1000–1200 Elo
Class F – Complete beginner	750–1000 Elo

Note. From HIARCS Chess Explorer (https://www.hiarcs.com/hce-manual/pc/Eloratings.html)

The level of skill is determined by a valid and reliable report which is based on Thurstone's Case V model (suitable for ranking data) because it quantifies a higher level of chess skill with a higher Elo score (Blanch et at., 2017; Elo, 1978; Glickman, 1995; Gobet, 2001; Rasskin-Gutman, 2009; Thurstone, 1994). The Elo rating's (M = 1,500) standard deviation is set at 200 points, and this range embraces players that would be considered of the same class. The scale is standardised across its range: A player with an Elo rating of 2000 would be expected to beat a player with an Elo rating of 1800 by the same margin (3:1). Before the 1972 World Chess Championship, Bobby Fischer's rating was 2785 and Boris Spassky's was 2675, which suggested that Fischer would win 13:7. Fischer won the chess championship 12.5:7.5. After the outcome of a competitive chess match, a player's Elo

rating is revised in proportion to the Elo chess rating of their respective opponents. The difference of the opponent's Elo rating either increases or decreases the player's own rating, depending on how much stronger or weaker the opponent was before the start of the game. The rating of a player can predict the result of their game with a high level of reliability (Ross, 2006). The advantage over other fields, such as physics, medicine, parenting, teaching, business managing, or driving, is that the Elo rating can determine the competitive chess skill of a player and the difference in skill from another player (Chabris & Simons, 2010; Charness, 1992; Gobet, 2001).

The Skill of Chess

De Groot (1946/1978) found that the important difference in skill between grandmasters (see Table 1 for Elo rating) and candidate masters (require a minimum Elo rating of 2200) is that grandmasters have superior recognition memory of the patterns of chess configurations rather than a greater ability to calculate variations (search). Research into the skill difference in expertise has supported De Groot's findings that the *crème de la crème* will search somewhat deeper than the *mere crème*, but there is no difference in how wide they search (Charness, 1981; Holding & Reynolds, 1982; Saariluoma, 1990). Specifically, in comparison to candidate masters, grandmasters calculate variations slightly deeper—namely, more moves ahead but the same number of variations and all the possible logical alternative lines of play (Charness, 1981).

Gobet and Simon (1996b) replicated and extended De Groot's (1946/1978) finding that fast pattern recognition has greater significance than slow search in answering the variability in chess skill (Gobet & Simon 1996b, 2000; Lassiter, 2000). Studies in *blitz* chess (this German word for lightening is used to describe fast play under five minutes or less) and simultaneous chess (i.e., a number of games played by one player who walks from board to board making their moves) have demonstrated that reducing the thinking time of highly skilled chess players does not have much effect on their performance as would be the case if search was the more important element in chess skill (Calderwood et al., 1988; Gobet, 1998b; Gobet & Simon, 1996c; Hooper & Whyld, 1984).

What precisely underlies these fast, intuitive processes is contested but is mostly considered to be forms of pattern recognition, which are understood as implicit, or nonconscious, processes that give highly skilled chess players the ability to rapidly match from memory a previously encountered chess configuration relationship with a present configuration (Chase & Simon, 1973a; Gobet & Chassy, 2009; Kiesel et al., 2009; Montero, 2019; Newell & Simon, 1972). In other words, highly skilled chess players have the ability to look at a chess position and quickly rule out other moves before "intuitively" choosing a good move (Campitelli & Gobet, 2004; De Groot, 1946/1978; Gobet, 2012; Klein et al., 1995; Masters, 1992; Montero, 2019).

In his book *The Grandmaster's Mind,* Amatzia Avni, an Israeli psychologist and a FIDE (International Chess Federation, translated from *Federation International des Echecs)* Master, examined how grandmasters found good chess moves. He interviewed 12 grandmasters between July 2003 and January 2004. In his introduction, he highlighted the need "to elicit knowledge that is hidden in an expert's mind" (Avni, 2004, p. 8). However, when Avni asked Grandmaster Alik Gershon, who was World Under-14 champion in 1994 and World Under-16 champion in 1996, if he had a systematic and logical thinking process about a chess move, Gershon answered, "In the majority of cases I can't articulate how I reach a certain decision. I rely on intuition" (Avni, 2004, p. 56). This intuitive form of knowledge is obtained from experiencing many chess positions and is an automatic, unconscious element of every performance of perception (Atkinson, 1993). An exemplary example of intuition in chess is positional judgement—which mostly relates to improving the function of your side—not only in cognitive psychology chess literature (Dreyfus & Dreyfus, 1988), but also in the classic chess literature (Kotov, 2012).

The perceptual quality of intuition is elucidated by pattern recognition (Gobet & Chassy, 2008; Kiesel et al., 2009). A chunk in chess is a unit of information that a player has stored in LTM containing a meaningful grouping of some of the chess pieces on squares that appear on a chessboard as well as associated moves and theories (Chase & Simon, 1973a). For example, a chunk of a standard White castled position would be the unit Rf1, Kg1, Pf2, Pg2, Ph2. A lot of research

supports the idea that highly skilled chess players rely on an intuitive, nonconscious process and has concluded that the difference in chess skill level is importantly explained by how fast and easily a player can access chunks from their chess knowledge (Chase & Simon, 1973a). This conclusion has been challenged by another line of research that argues that slow processes, such as search, are more important in high-level skill in chess (Chabris & Hearst, 2003; Gobet & Simon, 1996c, 1998; Holding, 1985, 1992; Holding & Pfau, 1985; Montero, 2019).

Highlighted in this research is the process of *conscious evaluation*—such as looking ahead to the outcome of a sequence of chess moves as well as strategizing—as the important factor in the selection of a good chess move rather than pattern recognition (Bilalić et al., 2008b; Charness, 1981; De Groot, 1946/1978; Gobet, 1986, 1998a; Montero, 2019; Saariluoma, 1995). Thus, skilled chess players' use of fast and slow processes is widely accepted by researchers (Montero, 2019). What is contested is which of these types of processes are more important to a highly skilled player's performance in chess (Chabris & Hearst, 2003; Gobet & Simon, 1996c; Holding & Pfau, 1985; Montero, 2019).

Expertise Development

Knowing the changes that occur as expertise develops is an essential part of understanding the relevance of fast and slow processes to chess skill. The development of problem-solving strategies is important to understand as these are assumed to be crucial in the acquisition of expertise (Anderson, 1993; Bilalić et al., 2008a; Voss & Post, 1988). Fast, nonconscious processes are more important for an expert's performance than they are for an amateur's performance, according to a line of research that emphasizes the role of automatization in high-level skill (Beilock & Carr, 2001). Declarative and implicit knowledge are assumed to be the two main ways information is stored (Anderson, 1983, 1987). Declarative knowledge (also known as propositional knowledge) collects facts and rules that one is conscious about; thus, one is capable of articulating it. Implicit knowledge (also known as practical knowledge, procedural knowledge, or non-declarative knowledge) involves one's ability to do something, to produce actions for the task using (declarative)

representations, and it is the knowledge applied when not consciously performing a task, and therefore one is incapable of articulating it (Anderson, 1982, 1987; Krivec et al., 2021; Masters, 1992).

The standard view in expertise research is that these two types of knowledge form a developmental progression when acquiring a high-level skill (Anderson, 1982; Patel, et al., 1999, p. 5; Masters, 1992, p. 622). Firstly, declarative knowledge is attained through conscious attention of information about the skill, and then this information is stored in LTM. Secondly, the skill is practiced repeatedly until it becomes proceduralised or automatic, thus one is not consciously attending to the skill. Finally, the skill should leave fragmentary memory traces of a consciously retrievable memory.

In addition to expert chess players' superior knowledge of chess patterns and the storage of chess configurations in LTM, expert chess players have also in cognitive studies produced results that support the neural efficiency hypothesis, which describes the phenomenon that skilled chess players show lower brain activation and therefore have neurally more efficient brain functioning of the frontal cortices than those less skilled players when working on the same chess related task (Blanch et al., 2020; Blanch et al., 2017; Grabner et al., 2006; Saariluoma et al., 2004). This efficiency is an important neural resource for building skilled and complex mental images—the type of images only an expert can construct (Saariluoma, 1995; Saariluoma et al., 2004). These skilled images are different from the ordinary images associated with mental imagery because in the domain of chess they may entail hundreds of moves, and over 10,000 piece locations (Saariluoma, 1995; Saariluoma et al., 2004). They are assumed to be different because of a chess player's immense pre-learned visuospatial chunks and proceduralised or automatic processing actions (Saariluoma et al., 2004). Expert chess players are superior to novices at generating these skilled images because of the developmental progression of acquiring skilled images (Saariluoma et al., 2004).

Kiesel et al. (2009) investigated whether chess expertise enhances perceptual processing to an extent that supports complex visual stimuli to bias behaviour unconsciously. Expert and novice

chess players judged whether a chess configuration either represented a checking or non-checking chess configuration. The experts, but not the novices, displayed a subliminal response priming effect, this is, they were faster responding when prime and target displays were congruent (both checking or both nonchecking) rather than incongruent. These perceptual chunks facilitate complex visual processing outside of conscious awareness and are understood as implicit, or nonconscious, processes that allowed for the fast judging of the presented chess configurations from memory of a previously encountered chess configuration (Chase & Simon, 1973a; Easvaradoss et al., 2018; Gobet & Chassy, 2009; Kiesel et al., 2009; Montero, 2019; Newell & Simon, 1972).

There are also important distinctions between novices and experts in chess problem-solving (Grabner et al., 2006; Saariluoma et al., 2004). Expert chess players increase the effectiveness and speed of slow processes, in comparison to novices, because of their engagement with thorough training and practice exercises, and the fact that they also play games more often (Blanch et al., 2015; Campitelli & Gobet, 2011; Grabner et al., 2007; Howard, 2012, 2013; Simon & Chase, 1973a; Van Harreveld et al., 2007). In the same way as other sports, demanding preparation—such as physical fitness, solving tactics, opening preparation, and playing training games—in chess is fundamental for a highly skilled sports performance (Blanch, 2018; Canadian, 2007; Eccles et al., 2009).

Theories to Explain Decrements in Skill Performance

The Candidates Tournament is a contest that, since 1950, has determined the challenger for the World Chess Championship. In the decisive penultimate game of the Candidates quarterfinal in 1977 between Vlastimil Hort (German chess grandmaster) and Boris Spassky (Russian chess grandmaster, who was the 10th World Chess Champion, holding the title from 1969 to 1972), Hort had reached a winning position in which he was likely to force Spassky to resign and, with about half a minute left in the game, instead of making the decisive move he sat "entranced at the thought that the match was his" and lost the game on time (Levy, 1977, p. 33). This failure to perform would also contribute to his performance in the next game, in which he was in an advantageous position but

could not capitalize because he could not get his loss to Spassky in the previous game out of his head. Spassky would advance to the semi-final.

Decrements in skill performance are thought to happen in various task domains where motivation for optimal performance is at a premium (Beilock & Carr, 2001; Beilock, Kulp et al., 2004; Lewis & Linder, 1997; Masters, 1992). Why do highly skilled performers sometimes fail under pressure in their domain? Two competing lines of theory—self-focus and distraction—offer explanations.

Self-focus theories argue that performance pressure increases anxiety and self-consciousness to perform optimally, which results in heightened attention on the skill processes and their step-by-step control (Beilock & Carr, 2001; Beilock, Kulp et al., 2004). Accordingly, self-focus theories would argue that Hort had tried to have conscious control over the moves he needed to play to beat Spassky with the idea that being careful will make sure of the win (Beilock, Kulp et al., 2004). Highly skilled players play the endgame at great speed, using memorised patterns of moves that are processed as one chunk of information (Krivec et al., 2021; Sigman et al., 2010). Attention to performance by a highly skilled player should disrupt the proceduralised or automated processes of their high-level skills that typically operate beyond the capacity of working memory during performance (Baumeister, 1984; Beilock & Carr, 2001; Beilock, Kulp et al., 2004; Kimble & Perlmuter, 1970; Langer & Imber, 1979; Lewis & Linder, 1997; Masters, 1992).

The counterargument to self-focus theories proposed by distraction theories is that pressure overloads working memory with thoughts about the situation and its importance, vying with the attention that is usually given to the performance (Beilock, Kulp et al., 2004; Carver & Scheier, 1981). Distraction theories would suggest that the pressure on Hort created a dual-task environment in which controlling the execution of his moves and worries about his performance competed for the attentional capacity previously applied entirely to processing the sequence of winning moves (Beilock & Carr, 2005; Beilock, Kulp et al., 2004; Lewis & Linder, 1997; Wine, 1971).

On the one hand, if high-level chess skill becomes proceduralised or automatic by use of fast processes, then it should be relatively robust against conditions that draw attention away from making moves as in distraction theories (Lewis & Linder, 1997; Masters, 1992). For instance, Reingold et al. (2001) studied the outcome of distractors on highly skilled chess players' reaction times in check detection tasks. The results showed that distractors had no effect in highly skilled players; hence, the results supported proceduralised or automatic processing of the positions in which highly skilled players made their move.

On the other hand, if chess skill is controlled by declarative knowledge (slow processes) that is attended to when making a chess move, then it is likely to break down under pressure from distraction (Hill et al., 2010). For example, Harreveld et al.'s (2007) results suggested that blitz time pressure induces anxiety for a highly skilled player, and, therefore, distraction theory suggests anxiety would occupy a highly skilled player's working memory (Sarason, 1988) and create a dual-task condition in which anxiety-related thoughts are processed alongside the evaluation of the position that is required to execute a move.

However, it is important to note that self-focus theories and distraction theories may apply in different situations during a chess game and, hence, could turn out to be integral rather than mutually exclusive. Therefore, research is warranted to illuminate the roles of fast and slow processes in the performance of highly skilled players and particularly to test the hypothesis of self-focus theory in a chess move protocol.

How to Test the Proceduralisation of Chess Skill

A comparison between reports of generic, schematic, or prescriptive knowledge and episodic memories—a form of declarative knowledge and explicit memory—of a chess move by highly skilled and competent Elo rated players can be used to determine the proceduralisation of chess skill. The aim is to establish a specific feature of a cognitive substrate in chess skill—the declarative receptiveness or openness to introspection, memory, and description of the skill's processes and procedures at distinct skill levels. Importantly, explicit episodic memory is dependent

on the existence of attention (Beilock & Carr, 2001; Craik et al., 1996). If making a chess move becomes proceduralised through practice and therefore task control structures are mostly not consciously attended to during performance of skill, then episodic memory for the specific steps of the procedure should be impoverished.

Generic, Episodic, and Procedural Chess Skill Representations

Chess skill knowledge about making a chess move is declaratively accessible in two particular ways (Beilock & Carr, 2001; Gobet & Jansen, 2006; Vasyukova & Mitina, 2013). Firstly, there is generic knowledge, which involves principles or prescriptive learning regarding how a chess move is made (Chassy & Gobet, 2011; De Groot, 1946/1978; Gobet, 1998a; Gobet & Jansen, 2006; Holding, 1985). Secondly, there is episodic knowledge, which involves a specific memory—an autobiographical report of the move made (Beilock & Carr, 2001; Vasyukova & Mitina, 2013). Classical theories of skill acquisition and automaticity predict sharp contrasts in the way these two forms of declaratively accessible representations are influenced by changes in chess expertise (Beilock & Carr, 2001; Fitts & Posner, 1967; Lewandowsky & Thomas, 2009; Speelman & Maybery, 2013, pp. 93–98; Toner et al., 2015; Williams & Fords, 2008).

On the one hand, declaratively accessible generic chess knowledge should increase with increases in chess expertise because, as Holding (1985, 1989, 1992) argued, chess knowledge is one of the main differences in chess skill between experts and novice players. Holding explained that experts' superior chess knowledge supports their evaluation and search of a move. Experts have more chess knowledge about strategies, tactics, principles, and chess openings than novices (Bilalić et al., 2009; Charness, 1991; Chassy & Gobet, 2011; Grabner et al., 2006; Saariluoma et al., 2004; Van der Maas & Wagenmakers, 2005). Pfau and Murphy (1988) found that chess knowledge was highly correlated to chess rating. It would therefore be extremely surprising if expert chess players could not describe the principles, strategies, and tactics of a chess position in as much detail or explain the best move in the position as thoroughly as novice chess players (Ericsson & Lehmann, 1996; Gobet, 1998; Heisman, 2009). Further, expert chess players' non-conscious generic or

prescriptive reports of their chess move should be more extensive and analytical about the general chess knowledge needed to make the move than the generic reports of novices (Charness, 1991; Chassy & Gobet, 2011; Ericsson & Lehmann, 1996; Gobet, 1998; Heisman, 2009; Holding, 1989; Van der Maas & Wagenmakers, 2005).

On the other hand, declaratively accessible episodic memories of a chess move should decrease with increasing expertise. Why would this occur? It is widely supported that pattern recognition is an automatic function of deliberate practice (Chassy & Gobet, 2011; De Groot & Gobet, 1996; Lane & Chang, 2018; Reingold et al., 2001; Saariluoma, 1984, 1985, 1990).

Thus, a chess move is mostly controlled at the time by procedural knowledge, which reduces the need to attend to the specific processes by which the move unfolds, and it is very much like introspection (Anderson, 1987, 1993; Beilock & Carr, 2001; Chassy & Gobet, 2011; Fitts & Posner, 1967; Krivec et al., 2021; Proctor & Dutta, 1995; Toner et al., 2015) because, as Kriegel (2013) recalled, indirect introspection happens later and requires recollection of past events sustained by episodic memory or procedural memory (Piccinini, 2003). The ability to recollect making a chess move will be impaired because of the very strong link between attention and episodic memory (Beilock & Carr, 2001). This link is supported by research that has shown that the successful, explicit retrieval of information from memory is reliant on attention to this information at the time of encoding (Beilock, 2007; Craik et al., 1996; Naveh-Benjamin et al., 1998).

Equally, in highly skilled players' working memory (Beilock & Carr, 2001; Charness, 1976; Peterson & Peterson, 1959; Robbins et al., 1996; Simon & Chase, 1988) and LTM (Beilock & Carr, 2001; Craik & Lockhart, 1972; Lane & Robertson, 1979), distracting or limiting the attention given to the chess move that is being encoded for storage diminishes the following explicit memory of the move made in the position (Beilock & Carr, 2001). The impairment of limiting attention mostly affects recall but also disrupts cued recall and recognition (Beilock & Carr, 2001). Consequently, well-practiced chess moves made by experts are performed with less attention to processes, procedures,

and the regulating structures that control them at the time the move is made and, subsequently, should leave less detailed episodic memories of the move that was made (Beilock & Carr, 2001).

In comparison, the shortage in well-practiced chess moves by novice chess players are controlled explicitly by declarative knowledge that is maintained in working memory and attended to sequentially when making a chess move (Anderson, 1987, 1993; Beilock & Carr, 2001; Dreyfus, 2004; Fitts & Posner, 1967; Toner et al., 2015). As a consequence of attending to this knowledge, it should be possible to produce an explicitly retrievable episodic report of the chess move—a declaratively accessible memory of the move as an autobiographical recollection that consists of the sequential operations by which the move was made (Beilock & Carr, 2001).

The Effect of EIA on Golf Putting and Chess Moves

Dan Heisman is one of the United States' top chess instructors, who has used the De Groot "think out loud" exercises for over 40 years. The De Groot exercises are used by researchers to determine how chess players select their best moves during a competitive chess game. Heisman's book *The Improving Chess Thinker* uses results from the De Groot exercises by chess players with different skill levels to provide insights, tips, and principles to help players to increase their Elo rating. In one of the exercises included in the book, participant M-1 is asked to think aloud as they find the best move for the De Groot position A (see Heisman, 2009, pp. 137–138)—this position is also included in this present study. Participant M-1 had an Elo rating of 2300 and had recently caused a major upset by beating Grandmaster Hikaru Nakamura.

M-1 demonstrated once again their exceptional ability by playing a critical move in the De Groot position A. However, after quickly finding this significant move, M-1 did not provide an account of the move as Heisman (2009) would have expected:

> …his analysis is a little vague…subject M-1 did not verbalize an evaluation, but it's a good bet he could tell you the material count, which side he felt was better, and why. When a player gets to that level, board vision becomes so proficient that this base information is usually quickly assimilated and escapes the necessity for conscious verbalization. (pp. 137–138)

Was it really as Heisman hypothesised a case of M-1 not needing to consciously verbalise their move or was it because of the lack of conscious attention as a result of M-1's well-practiced skills becoming so proceduralised, or automatic, that M-1 was not consciously attending to their actions as they unfolded? There are many instances of highly skilled persons not being able to report how their actions unfolded. For example, a New York principal ballet dancer could not verbally explain what had happened after a performance, tennis player Maria Sharapova could not provide a verbal account of her groundstrokes that beat Martina Navratilova, and after a performance of Giselle, the male lead Eric Bruhn could not verbally describe what he had done (Høffding & Montero, 2019; Montero, 2016).

An accepted explanation in cognitive science for the lack of a verbal account of a highly skilled performance by a performer or athlete was provided by the research of Beilock and Carr (2001) that emphasises the function of automatization in high-level skill and what they referred to as EIA, which they described as occurring due to "declaratively accessible episodic memories of any particular performance should decrease with increasing expertise" (p. 702). This explanation supports, for example, that as M-1's skill in chess increases, M-1 will be able to consciously recollect less and less about what they actually did when making the move in the De Groot position A—less and less about the step-by-step process of the move. The concept of EIA suggests that the better one is at something that has a procedural skill component, the less one will recall about what one has done.

If the development of expertise involves decreasing consciousness of one's actions, then there should be a contrasting correlation between skill and recall. Or more specifically, then M1's vague analysis of their move would be due to M-1 having available very little to no consciously accessible accounts or memories of the unfolding chess move since EIA involves consciously accessible and accountable (declaratively accessible) recall of events (episodic memories).

In addition to anecdotal evidence from experts, elite sportspeople, and performing artists, EIA is supported by two experiments that tested the amount of detail reported in experts' and novices' explanations on how to perform a golf putt (Beilock & Carr, 2001).

Experiments 1 and 2 from Beilock and Carr's (2001) The Fragility of Skilled Performance

In Experiment 1[1], expert golfers, who were members of an intercollegiate golf team, and novice golfers, who were college students with no golf experience, had 70 trials of putting a golf ball from the same location as accurately as possible by making the golf ball stop in a red tape marked square on a carpeted indoor putting green 1.5 m away from the putting location. After 20 putts, participants were asked to fill out a questionnaire about a generic description of a golf putt that aimed to elicit information from both groups of participants about the steps involved in a successful golf putt. After a further series of 30 putts, both groups of participants were asked to fill out an identical questionnaire about the steps involved in a successful golf putt. Then, after completing the final putt, both groups of participants were asked to complete a questionnaire that asked them to describe the actions involved in performing their final putt—the episodic recollection.

The results showed that the experts' episodic descriptions were briefer than their generic accounts, and their episodic descriptions were also shorter than those provided by the novices, despite their generic accounts of their putts being longer than the ones provided by novices. These results supported the prediction of EIA—the more skilled one is at doing a task, then one's recollection (episodic memory) of the task should be impoverished—that experts give shorter descriptions of their putts than novices because experts recollect less about the putts.

In Experiment 2, the same hypothesis was tested, and the same comparison of novices' and experts' generic and episodic accounts of their putts were made. There were three differences from the design of Experiment 1. Firstly, to contend with participants becoming conditioned to the repetitive task of putting from the same specific spot on the green, all participants instead putted

[1] Omitted from this section is a summary of Experiments 3 and 4 from Beilock and Carr's (2001) classic choking under pressure experiments because, firstly, the support for EIA is found in Experiments 1 and 2, and, secondly, Experiment 2 is the basis for the experiment in the current chess study.

from nine different spots that had different distances and angles from the target. Secondly, the expert golfers in Experiment 2 were university students that had two or more years of high school varsity golf experience. Finally, participants completed two episodic questionnaires. As was the case in Experiment 1, the first questionnaire was unexpected, but the participants were instructed prior to the last putt and subsequent questionnaire to monitor their actions diligently for later recall. Additionally, there was a trial that involved a funny putter, which is a regular putter head attached to an S-shaped curve and randomly weighted putter shaft. The hypothesis based on EIA was that expert golfers would provide less information than the novices about a putt made with a regular putter but not less when made with a funny putter because the funny putter should disrupt the proceduralistion of the experienced golfers' putts.

The results once again supported EIA because expert golfers provided less information about their putts than the novices golfers when using the regular putter but not less when using the funny putter. As Beilock and Carr (2001) explained, the results of these two experiments suggested "that highly practiced, well learned task components are encoded in a procedural form that supports real time performance without requiring step-by-step attentional control. Reduced attention leads to a reduction in declaratively accessible memory for details of the performance" (p. 714).

Neither of these experiments tested if recall of a proceduralised skill is impoverished in contrast to a consciously controlled one. Beilock and Carr (2001) assumed that recall of a consciously controlled skill is better than that of a proceduralised one. The aim of the experiments testing EIA was to examine if experts' recall of a skilled performance is diminished in comparison to the novices' performance recall (Høffding & Montero, 2019). Participants in these studies were allocated into one of two groups based on skill level rather than the level of proceduralisation of their domain relevant skill (Høffding & Montero, 2019). Specifically, the experiments' objective was to test if the more skilled you are, the poorer your recall is about what you have just performed because of the explanation that expertise exists within increased proceduralization (Høffding & Montero, 2019).

The Chess Counter to EIA: Expertise-Heightened Memory

Research in chess expertise provides a counterexample of the explanation and hypothesis of EIA by demonstrating that expert chess players have a heightened memory of skill-relevant information (e.g., Chase & Simon, 1973b; Ericsson & Lehmann, 1996; Høffding & Montero, 2019). There are also examples of this with other skills, such as miniature golf (Bäckman & Molander, 1986), waiting tables (Ericsson & Polson, 1988; Huet & Mariné, 2005), architectural drawing (Akin, 1986), hiking (Kam et al., 2012; Kawamura et al., 2007), and computer program coding (McKeithen et al., 1981).

The main feature of expertise that is usually universally accepted is an improved memory for domain-relevant information (Herzmann & Curran, 2011). Undeniably, the results of heightened memory research are mainly about the recall of generic knowledge of domain-relevant information rather than recall of how one performed an action in their domain of skill, such as M-1's ability to remember the material count of the De Groot position A in contrast to the step-by-step account of the move he made.

Contradictions to this are found in chess research because many expert chess players are outstanding at recalling the moves they made and why. For instance, as Alfred Binet (1893/1966) showed, most of the best chess players at the time could recall every move from games they had played even if from many years earlier. Perhaps even more amazing is that Bobby Fischer could remember most of his blitz chess games—5 min for each player—at the conclusion of the unofficial Speed Championship of the World at Herceg Novi, Yugoslavia, in 1970. Fischer recalled more than 1,000 moves and the scores from his 22 games, and he also recalled the moves from a blitz game that he played 15 years earlier, aged 15-years, against Russian player Evgeni Vasiukov in Moscow (Frank Brady Endgame).

Research on expertise in chess implies that EIA is not applicable to all skills as it suggests that expert chess players should generally remember less about their performance than much lower ranked club players. Therefore, there is a genuine tension between EIA and expertise-heightened

memory in the domain of chess research, given the evidence of expert chess players' recall of chess-relevant information (Høffding & Montero, 2019).

Examining Expertise Through Random Chess Positions

A classic result from random chess position research is that experts lose their heightened memory for chess-relevant information when the position is randomised, namely, it is not a possible configuration from a real game (Gobet & Simon, 1996a). This hallmark of expertise study was first captured in Chase and Simon's (1973b) study of chess memory and has since been extensively cited in cognitive psychology textbooks (Gobet, 2017; see Goldstein, 2019, chapter 12, for an example). The main relationship between skill and domain-relevant information has been replicated in diverse domains, such as the game of Othello (Wolff et al., 1984), electronics (Egan & Schwartz, 1979), computer programming (McKeithen et al., 1981), and basketball (Allard et al., 1980).

Random chess positions are commonly used as a control of participants' non-chess memory capacity, and only a few researchers have used them to test theories of expertise. Holding and Reynolds (1982) used semi-random positions to test if expertise in chess consists of pattern recognition of configurations that are related to valid moves. They tested this by comparing the memory scores and move-choice protocols of players in six United States Chess Federation (USCF) rating classes from category V through to expert. There were four participants in each class, and the rounded mean of each class's Elo rating was 1,065; 1,317; 1,501; 1,709; 1,914; and 2,129.

One practice position and three test positions were presented on an actual chess set. The De Groot position (De Groot, 1966, p. 42) was used for the practice position to prime players to the procedure. The three test positions were a configuration of 24 pieces—one bishop, one knight, and two pawns were removed from each side to replicate the position of an average game between move 20 and 25. Generally, most exchanges and gains are made between move 20 and 25 (Holding, 1980).

The random positions were configured by using a random number table to choose and assign pieces' placements until positions were reached that met the constraints that (1) neither king

was in check, (2) no pawn occupied the first or eighth ranks, and (3) no piece was attacked by pawns or otherwise attacked while undefended. The constraints were the same as the ones used in this current chess study.

Holding's (1979) evaluation scale was used, which asked participants for positional judgements that awarded a score out of 10 for the weaker side and out of 20 for the stronger side. Each score had a verbal anchor, for example, a score of 14 informed the participant that it represented a "clear advantage".

In each position the participant was exposed to the board for 8 s and then the pieces were removed. The participant attempted to reconstruct the position. The experimenter recorded the reconstruction and then corrected incorrect piece placements. The participant was then asked for an immediate evaluation score. Following this, the participant had 3 min to make their best move playing as White. When the clock time was up, the participant reported the best move and then had 2 min to offer an explicit sequence of best moves for White and Black. Finally, the participant was asked for a considered evaluation score.

The findings supported generic chess knowledge as the primary difference in chess skill. Memory scores for the reconstructed positions showed no significant correlation with the USCF rating of a participant. The results showed that the best moves chosen by skilled participants were independent of recall.

The remembered pieces by participants when reconstructing the positions were compared to the non-remembered ones that were moved in the best move task. The difference between the remembered and non-remembered pieces was significant but in an unexpected direction, namely, that the remembered pieces the participants had failed to move were more than the non-remembered pieces they did move.

If move choices are based on memory, then the remembered pieces should have significantly outnumbered the non-remembered pieces when moved. Therefore, the results showed that the best moves chosen by skilled participants were independent of their recall performance.

Also, even when skilled participants' pattern recognition (fast processes) was disrupted by a semi random position, they still made the best move. The results support memory about generic knowledge at the evaluation phase of a game as the difference in chess skill rather than any type of pattern recognition hypothesis.

Research into the recall of random positions since Chase and Simon's (1973b) classic result that experts lose their heightened memory for chess-relevant information has not produced the same result; in fact, it has shown that a randomised position does not take away stronger players' superiority over weaker players (Gobet & Simon, 1996a). However, the difference in skill when recalling a random position was reported by Gobet and Simon (1996a) as around one piece per additional 400 Elo points, which is relatively small in comparison to the recall of game positions that usually result in about five pieces for an increase of 400 Elo points. Therefore, random positions should disrupt the proceduralistion of an experienced chess player's move selection, like the funny putter did in Experiment 2 of Beilock and Carr's (2001) golf putting experiment.

Bilalić et al.'s (2010) study sought to clarify the mechanisms and neural basis behind two processes that support expertise: object and pattern recognition. Bilalić et al. found through the analysis of eye movement that experts in the chess related search task focused instantly and solely on the relevant aspects in the standard positions where the relations between chess pieces were undisturbed, whereas novices examined the whole position. Once the researchers disturbed the relation of the pieces by placing them in random positions, there was a significant drop in experts' performance, which suggested experts could access their superior complex pattern recognition processes. Novices could not use pattern recognition processes in either the standard or random position type because they lacked the previously stored knowledge that is essential to the knowledge structures for pattern recognition. Using functional magnetic resonance imaging to measure eye movements and neural response, it was shown that many brain areas were significantly more activated in experts than in novices, and the analyses of this data indicated that experts' knowledge about individual objects (chess pieces) is responsible for their superior performance over

novices. The results highlighted that object recognition—a basic process that is often neglected in expertise research—is also crucial to an experts' performance.

The results of Sala and Gobet's (2017) meta-analysis showed that experts (Elo rating of above 1999) have an advantage over novices when random positions are presented for recall. The advantage could not be interpreted by theories emphasizing high-level memory structures (e.g., schemata) or holistic processing of stimuli because random material does not contain large structures nor wholes. In comparison, theories hypothesising the existence of small memory structures—such as chunks—predict this result because some chunks are still present by chance in random positions. The outcome supports the hypothesis that human memory mechanisms are somewhat based on small memory structures, such as chunks.

Understanding Performance Under Time Pressure

Burns (2004) compared highly skilled chess players' performance in blitz tournaments with their standard chess rating and showed a strong correlation between +0.78 and +0.90. The findings found that slow processes, such as depth and breadth of serial search of possible moves and responses, do not improve greatly as a player's level of skill increases. Generally, the findings suggest that experts will still succeed under time pressure to a greater extent than novices. This was also the case in the sensorimotor skill of golf putting in which experts achieved better results under time pressure (Beilock, Bertenthal et al., 2004). The debriefing's post-performance suggested that the time pressure caused the novices to be nervous, to lack the time to plan their action and be prepared, whereas experts found that the time pressure helped their performance because it stopped them from thinking too much and focusing on perfection (Beilock, Bertenthal et al., 2004).

However, Van Harreveld et al.'s (2007) results challenged the common claim in cognitive science that experts will perform better than novices under time pressure. Their results suggested that when playing under time pressure, the standard Elo rating is less predictive of the outcome of a blitz chess game. This result was not replicated in rapid chess games (25-30 min) in which a player's

Elo rating was more predictive of their performance. The reason as to why the outcome is similar for a standard and rapid chess game was left as an open question.

Possibilities as to why a player's strength is reduced when playing blitz chess were offered. Firstly, the increase of playing tempo increases the chances of making a crucial blunder—indeed crucial enough to end the game effectively because the blunder has no remedy even for strong players. If the hypothesis that the time pressure of blitz chess increases the probability of blunders regardless of a player's strength is correct, then this increase is more detrimental to stronger players because weaker players regularly make blunders in standard chess. Secondly, another hypothesis offered by Van Harreveld et al. (2007) is distraction. During a blitz game, the player needs to manage the stress that is associated with blitz. The world championship (441 matches held in 1999, 2000, 2002, 2004) data suggested that the higher the rating of the player, the more stress the player will encounter due to not being able to take advantage of their higher Elo rating.

Grandmasters were asked by Calderwood et al. (1988) to rate the quality of the moves they made in blitz and standard chess games. Their results also supported the idea that greater time pressure decreases the predictiveness of a grandmaster's Elo rating. Further, Chabris and Hearst (2003) have shown that grandmaster players make more and bigger mistakes playing blitz than they do playing standard chess.

The Current Chess Study

Previous research and theories that emphasise the function of automatization in high-level skill suggest that the episodic memory for making a chess move should decrease with increasing skill. Therefore, we should see highly skilled chess players give briefer episodic descriptions than their generic accounts of a chess move in a standard position.

To test this idea, we recruited highly skilled chess players and competent players, then allocated them to one of three groups—rapid, random, and blitz—and presented them with four positions sequentially. Highly skilled chess players' generic knowledge of the first two chess moves

and episodic recollection of the last two specific chess moves were compared with the generic knowledge and the episodic recollections of competent chess players. Knowledge and recollection were assessed during either a 4 min time control[2] with a standard chess position (rapid group), a 4 min time control with a randomisation of the standard chess position (random group), or a 40 s time control with a standard position (blitz group).

If well-practiced chess moves are supported by procedural knowledge—as theories of pattern recognition and skill acquisition would predict, then highly skilled players should give longer, more generic descriptions of the move they made in a standard chess position compared with accounts given by competent players but should have shorter, less detailed episodic recollections of a particular move. Since proceduralisation decreases the requirement to attend to the particular processes by which the execution of the chess move unfolds, highly skilled players' episodic recollection of the processes involved in the real time performance should be less detailed than competent players' episodic recollection.

Because the random positions are not configurations from a real game and have an improbable chance of occurring in a real game, they should require the highly skilled chess players to alter their well-practiced chess skill to compensate for the random position, demanding them to give attention to the move's execution processes. If chess skill is proceduralised, then the disruption caused by making a move in a random position should lead highly skilled chess players to produce more elaborated episodic accounts as opposed to their move in a standard position. The random position should require the highly skilled players to use slow processes, such as calculating variations. The episodic account of a highly skilled player's move in a random position should be like the episodic account of a competent player's move in either position because competent players are less likely to recognise patterns and therefore do not instantly know how to use their skills and

[2] Time control in this chess study is the time allotted to a participant during which they must make a move. A participant that does not complete the move is said to have exceeded the time control.

principles (procedural knowledge) to construct the best move because they have not repeatedly performed in similar situations in past training.

Furthermore, according to the theories of skill acquisition, competent players' domain concepts are more likely to be explicitly monitored in real time because their knowledge should still be declarative. Therefore, making a move in a random position should not produce different episodic memory accounts in comparison with making a move in a standard position because in both cases competent players are likely to attend to their performances in a way that should support explicit episodic memory.

Distraction theories suggest that the stress that is associated with making a chess move in the standard position in under 40 s causes pressure that fills working memory with thoughts about the situation and its importance that vie with the attention ordinarily assigned to execution. Time pressure should create a dual-task environment in which controlling the execution of the chess move and worries about performance compete for the attentional capacity once dedicated entirely to making the best chess move. If chess skill is automatic and proceduralised, players should be able to withstand the attentional demands of time pressure, as explicit attention to step-by-step skill procedures is unnecessary when using fast processes to make a good chess move. Hence, highly skilled players should give longer, more generic descriptions of the move they made under time pressure in a standard chess position compared with accounts given by competent players. Conversely, they are likely to give shorter, less detailed episodic recollections of a particular move.

The aim of this chess study is to test automatization in high-level skill, and the hypotheses are:

1. a) Highly skilled chess players making a move in a standard position will perform equally well in the two-time conditions of blitz and rapid.

   b) In the two-time conditions, highly skilled chess players in comparison to competent players will produce longer, more detailed generic descriptions of their move in a standard position, but they will provide less detailed episodic recollections.

2. a) Highly skilled chess players should produce more elaborated episodic accounts when making a move in a random position than highly skilled chess players making a move under the two-time conditions in a standard position and the competent chess players in all three conditions.

   b) There will be no difference in the detail of the episodic accounts of a chess move made by competent chess players in a random position and those in a standard position.

3. The highly skilled chess players in each of the three conditions should make more Stockfish evaluated best moves in each of the positions than the competent players in their respective conditions.

Method

Participants

Ethics approval for the chess study was obtained from the Massey University Human Ethics Committee before recruitment began (Ethics Notification Number: 4000024503).

We conducted power analyses to determine the sample size we wanted of 120 participants. This sample size was not reached in the recruitment time frame. Participants were recruited via an email that was sent to chess clubs around the world, describing the chess study and inviting participants to take part if they meet the criteria of either having a FIDE rating above 1900 or a national rating below 1400 and had played 15 rated games. However, there were two exceptions. One participant had not played many FIDE rated tournaments but actively played USCF tournaments and had a USCF rating of 2300. Generally, USCF ratings are 50 to 100 points higher than the FIDE equivalents because the system they use is a modification of the Elo system in which the *K*-factor varies, and it gives bonus points for superior performance in a tournament. Another example was a participant whose chess club was inactive and who had not played competitive chess for several months but had a New Zealand Chess Federation rating of 1400 and played chess actively online.

Initially, on 22 September 2022, only an email was sent to chess organisations. This email had the same content as the webpages that were sent in October 2022. The webpages were emailed with an introductory email. The webpage version for the New Zealand chess organisations (see Appendix A) offered $15 compensation for participation, whereas the webpage version for international chess organisations (see Appendix B) did not offer compensation to participants. Then, from January 2023 onwards, an introductory email was sent with a webpage and chess blog that was written for recruitment. Chessable published the blog[3] (see Footnote for the URL to the blog) in their chess science section.

Of the 30 adult participants who completed this study, six were females and 24 males, aged between 20 and 75 years (M = 49.7, SD = *16.6*) with an Elo rating between 997 and 2300 (M = 1,628.9, SD = 468.9).

The sample was comprised of participants who played in the English Chess Federation (n = 10, 33%), participants who played in the New Zealand Chess Federation (n = 8, 27%), participants who played in the USCF (n = 5, 17%), participants who played in the Australian Chess Federation (n = 4, 13%), one participant who played in the Turkish Chess Federation (Türkiye Satranç Federasyonu), one participant who played in the Irish Chess Union, and one participant played in the German Chess Federation (Deutscher Schachbund).

Several participants were published authors, cognitive scientists, professors, and teachers. There was also a psychology student, a CEO, and a social worker. Various participants were chess coaches and teachers and/or FIDE arbiters and trainers. Others were published authors of books and articles—primarily in chess but also in fields such as education, social skills, Safety Culture and Safety Quality.

[3] https://www.chessable.com/blog/cognitive-skill-studies-and-chess/ Cognitive Skill Studies and Chess - Chessable Blog

There were two International Masters[4], three Candidate Masters[5] and one National Master[6]. The level of chess skill of each participant as represented by their Elo rating is presented in Table 2.

Table 2

Participants' Elo Rating and Related Chess Information

Skill level	Elo rating	Participants *n*	Chess Federation	Age range
Highly skilled	2200–2300	2	ECF, USCF	45–70
	2100–2199	4	ACF, ECF, NZCF, TCF	20–62
	2000–2099	6	ACF, ECF x 4, NZCF	35–71
	1900–1999	3	ACF, NZCF x2	23–28
Competent	1300–1400	4	ECF x2, ICU, NZCF	58–75
	1200–1299	3	ECF, NZCF x2	28–70
	1100–1199	3	ACF, ECF, USCF	59–75
	997–1099	5	GCF, NZCF, USCF x3	37–55

Note. ECF = English Chess Federation, USCF = United States Chess Federation, ACF = Australian Chess Federation, NZCF = New Zealand Chess Federation, TCF = Turkish Chess Federation, ICU = Irish Chess Union, GCF = German Chess Federation

[4] The title International Master is awarded to strong chess players who are below the level of grandmaster. Instituted by FIDE along with the Grandmaster title in 1950, it is a lifetime title, usually abbreviated as IM in chess literature.

Like the Grandmaster title, the usual way to obtain the title is to achieve three required title norms over 27 or more games and a FIDE rating of 2400 or more. In general, an IM norm is defined as a performance rating of at least 2450 over 9 or more games. In addition, the field must have an average rating of at least 2230, must include at least three International Masters or Grandmasters, and must include players from a mix of national federations. There are also several other ways the title can be awarded, see the FIDE Handbook for further details: https://handbook.fide.com/chapter/B012022

[5] The Candidate Master title is awarded to players who achieve an established classical FIDE rating of 2200 although the title is also given to players who perform well at continental or national events. As of 2020, there are roughly 1,700 active Candidate Masters—a small percentage of the millions of chess players worldwide.

[6] Some national chess federations award titles such as National Master (NM). National chess federations are free to set whatever standards they want for such titles, which are not recognized by FIDE. The United States Chess Federation (USCF) awards the Title of National Master to anyone who achieves a USCF rating of 2200. In the United States, the title of National Master is awarded for life, regardless of whether the rating of a National Master subsequently goes below 2200. In August 2002, this position was codified (after being recognized as the existing status quo) by the USCF Policy Board with the passage of a motion stating, "Any USCF member who has had a regular post tournament rating of 2200 or higher (published or not) has demonstrated a significant level of chess ability and is recognized by being automatically awarded the lifetime title of National Master".

Defined by their chess skill, participants were assigned either to the highly skilled group (Elo range from 1922–2300) if they had an Elo rating over 1900 or the competent group (Elo range from 997–1350) if they had an Elo rating under 1400. Participants were then assigned to the rapid condition, random condition, or blitz condition of their respective skills.

Random assignment was done by assigning participants in numerical order: 1 Rapid, 2 Random, and 3 Blitz. However, this procedure could not be maintained consistently due to 10 participants assigned to a condition not completing the study, another participant's data was removed from the study because they had taken screenshots of the positions and used them to answer the questionnaires, and other participants who did not complete the study in a timely fashion. Therefore, in some cases, the researcher had to assign two participants in a row to the same condition to ensure each condition had roughly the same number of participants. Table 3 provides the demographics and chess information of the chess study participants of each group.

Table 3

Demographics and Chess Data of the Groups' Participants

Group	Sex		Age range		Elo range		Federation		Master Title	
		n	*M*	*SD*	*M*	*SD*		*n*		*n*
Highly skilled										
Rapid	Male	5	50.2	16.9	2,018	41.5	ACF	1	FIDE	1
							ECF	3	Candidate	
							NZCF	1		
Random	Male	4	43.2	17.1	2,147.2	65.2	ECF	3	Candidate	1
	Fem	1					NZCF	1	International	2
							TCF	1		
Blitz	Male	5	43.0	16.6	2,075.8	133.7	ACF	2	Candidate	1
							NZCF	2	National	1
							USCF	1		
Competent										
Rapid	Male	2	54.6	18.1	1,200.4	126.1	ECF	2		
	Fem	3					NZCF	2		
							USCF	1		
Random	Male	4	53.6,	17.6	1,247.0	144.1	ECF	I		
	Fem	1					ICU	1		
							NZCF	2		
							USCF	1		
Blitz	Male	3	54.0	4.3	1,085.0	118.9	ACF	1		
	Fem	2					ECF	1		
							GCF	1		
							USCF	2		

Note. ACF = Australian Chess Federation, ECF = English Chess Federation, NZCF = New Zealand Chess Federation, TCF = Turkish Chess Federation, USCF = United States Chess Federation, ICU = Irish Chess Union, GCF = German Chess Federation

Materials

The four standard positions used were complex positions that should require considerable look-ahead search and evaluation. The important criteria for selecting these positions were that they required chess players to search deeply for the best move. This was critical as it needed also to be demonstrated that fast processes are as important in positions that require deep search.

According to Campitelli and Gobet (2004), the reason that previous studies have not demonstrated a relationship between deep search and chess skill was that the positions used in these studies did not require extensive search. However, the De Groot position A (see Appendix C) was included in this study even though Campitelli and Gobet suggested that it does not require a deep search to find the best move. Table 4 presents the descriptive information of each position.

Table 4

Four Standard Chess Positions

Standard position	Description
1 Groot A	This is the position that De Groot (1946/1978) used for much of his conclusions. It is the most likely position to be recognised by chess players in this study as it is widely available in the chess literature (Campitelli & Gobet, 2004). The position is considered analytical and usually involves the kind of analysis tree found in *Thought in Chess* (De Groot, 1946/1978) when finding a move. Dr Max Euwe (chess player, mathematician, author, and chess administrator) in his protocol of De Groot A calculated 1…Bxd5, which is considered the strongest move for this position as is explained in the result section of this study (De Groot, 1946/1978).
2 Fisher/Karpov endgame	The principles for playing the Fisher/Karpov endgame are applicable to most endgames, such as activating your pieces, restricting the opponent's pieces, and searching for ways to attack the opponent's position with the king (Barden, 1980). But this endgame also includes some specific principles, such as avoiding moves that lead to the knight being exchanged for the bishop to reach a rook endgame when the defender has good chances, instead the aim should be to eliminate rooks for a Bishop-Knight endgame that is advantageous (Barden, 1980). This is not an endgame for chess players that have not had many years of chess experience and

Standard position	Description
	are not a strong chess player (Barden, 1980.). Fisher's precise play made this game one of his most celebrated wins, and the move that Fisher made Rc1 is considered the strongest for this position as is explained in the results section of this study.
3 R. Rozanky—S. Kagan, Tel-Aviv 1973	This position is based on the 1973 game, but Avni (2004) has shifted the rook from c1 to b1 to prevent another winning method. The basic analysis is that White's king's defences are weak, combining Black's rooks would establish a strength of power that could create pressure down across the h file and that Black's king is antithetical to Black's plans, so it should be moved. Gershon did mention some of the analysis but did not say anything about the rest as "I rely on intuition; I know that in this position, this is the move" (Avni, 2004, pp. 60–61). However, the move he made ..g5 is not considered the best as will be shown in this study's results section.
4 De Groot C	According to Campitelli and Gobet (2004), this position is much more difficult to analyse than the De Groot A. Further, Heisman (2009) noted from his De Groot exercises that "de Groot C position gave even the Grandmasters difficulties" (p. 139), and even he admits after having the position analysed by a computer that he found it difficult to figure out why the computer thought its best moves were superior. In contrast to non-analytical positions, analytical positions like the De Groot C rely on general principles of strategic play, and the initial assessment by a FIDE master of the De Groot C was that the material is equal, the queen is on a strange square, a target is the white knight on f3 and that Black is behind in developing its pieces but its king is safer.

Note. To view positions, see Appendix C for De Groot A, Appendix D for Fisher/Karpov endgame, Appendix E for R. Rozanky—S. Kagan, Tel-Aviv 1973, Appendix F for De Groot C.

Creation of the Stimuli

Randomising of the Standard Chess Positions. The set of positions (refer to Appendices G, H, I, & J to view random positions) was configured by blindly selecting chess pieces by hand out of a bag and assigning their placements to a square on a physical chessboard until positions were reached that met the following constraints: (1) neither the white or black king is in check, (2) no

black pawns occupy the first, second, or eighth rank, and no white pawns occupy the first, seventh, or eighth rank, (3) no piece is attacked by pawns or is otherwise under attack while undefended. The constraints were imposed on the randomization to avoid illegal relations between chess pieces.

Rapid and Blitz Time Controls. Five participants from Dan Heisman's De Groot experiments were used to gauge a rough time control for the rapid and blitz time conditions in this experiment. The position chosen was the De Groot A position. Only those participants for whom Heisman had recorded the exact time it took them to make a move were included. For example, participants with times recorded as "30 minutes+" (Heisman, 2009, p. 110) or "time unknown" (Heisman, 2009, p. 122) were not included. The five participants were selected by starting at the highest skill level (FIDE Master, Elo 2300) in Dan Heisman's De Groot A experiment. The five participants that were included had an Elo rating that ranged from 1800 to 2300 (*M* = 1,948, *SD* = 190.82). The time it took to make a move ranged from 5 to 20 min (*M* = 10.1, *SD*= 5.5).

The time control for the 2023 FIDE World Championship match in Astana had a time control of 120 min[7] for the first 40 moves, followed by 60 min for the next 20 moves, and then 15 min for the rest of the game with an increment of 30 s per move, starting from move 61. The FIDE Rapid World Championship had a time control of 15 min[8] plus 10 s increment per move, starting from move one. The FIDE Blitz World Championship had a time control[9] of 3 min plus 2 s increment per move, starting from move one. Taking all this into consideration, 4 min appeared roughly the time a player would allocate to the move under Rapid time control and 40 s under Blitz time control.

The Forsyth-Edward Notion is the method used to describe all the online chess positions in this study. It was first published by Scottish newspaper journalist, David Forsyth (1854-1909), who was the chess editor of the Glasgow Weekly Herald (Hooper & Whyld, 1984; Iqbal, 2020). He emigrated to New Zealand where he was one of the compilers of an early regular column for the

[7] https://en.chessbase.com/post/world-championship-2023-live#:~:text=The%20title%20match%20in%20Astana,move%20starting%20from%20move%2061.

[8] https://handbook.fide.com/files/handbook/wrbc_regulations_2022_open.pdf

[9] https://handbook.fide.com/files/handbook/wrbc_regulations_2022_open.pdf

game of Go in a newspaper (Iqbal, 2020). The format for the Forsyth-Edward Notion is to form a type of “Cartesian coordinate system” that reads the chessboards vertical files tiled “a” through to “h” (from left to right) and horizontal ranks numbered 1 through to 8 one square at a time (Hooper & Whyld, 1984; Iqbal, 2020). Each piece is shown by its initial letter—capitals for White, for example, “Q” for the queen and lower case for Black, for example, “q” for the queen. Empty squares are numbered, for example, a white queen and rook detached by one square would be shown as ‘Q1R’ and if by two squares, ‘Q2R’ (Iqbal, 2020). When a rank is complete a slash (‘/’) is used before the next rank. After the final square of the last rank is described, there is a space continued with a “w” or “b” to show which side is to move (Hooper & Whyld, 1984; Iqbal, 2020).

A bespoke online application was created by the School of Psychology computer technician to present the participants with the chess tasks and record their responses. Details about the application are provided in the Procedure.

Procedure

Participants emailed the researcher expressing their interest to participate in the chess study. They were informed by an email from the researcher that they required a computer or laptop for the study and were asked to provide their age, gender, Elo rating, and chess federation they belong to. Other demographics the participants shared unsolicited were also collected. The researcher verified their age, gender, and Elo rating on the FIDE or their respective chess federations database. Based on their Elo rating and by numerical order, participants were assigned to the appropriate group: highly skilled rapid, highly skilled random, highly skilled blitz, competent rapid, competent random, or competent blitz.

Subsequently, a link to the study with an access code for their assigned condition was emailed to each participant: “Rapid” if assigned to the highly skilled rapid group or the competent rapid group, “Random” if assigned to the highly skilled random group or competent random group, or “Blitz” if assigned to the highly skilled blitz group or competent blitz group.

Participants then logged on to the study and could read about their rights, the purpose of the study, what their participation will involve, possible benefits and risks, and what happens after the study or if they changed their mind about participating. Once they pushed the button to consent, the next screen appeared with an explanation on how to move a chess piece, that the release of the piece within the rules of chess made the move final and they would move on to the next position. They were informed that the next position was a practice position and that they could practice as many times as they liked before moving on to Position 1.

The next screen was the practice position—a position from the "Elementary Tactics" chapter of *Teach Yourself Chess* (Hartson, 1996, p. 47)—and once they had made a move, they could press the reset button to practice making a move in the same position again or push the next button to move on to Position 1.

The instructions were the same for all groups, except for the amount of time they had to make a move as this was 4 min for the rapid and random conditions, whereas in the blitz condition it was 40 s. All groups participated in identical tasks of making a move in four positions and answering a questionnaire after each position for this chess study. The differences between the rapid and random condition were the configuration of the chess positions. The difference between the rapid and blitz condition was the time control. The difference between the random and blitz condition was the configuration of the chess position and the time control.

Participants were informed on a screen prior to Position 1 that they would have 4 min (rapid and random conditions) or 40 s (blitz condition) to make a move, and the instructions provided (see Appendix K for rapid & random conditions, see Appendix L for blitz condition) were devised from the instructions that Heisman (see 2009, p. 18) gave his participants before they participated in the De Groot exercises. The participants were further informed that a timer would appear on the screen displaying the time counting down. The instructions informed the participants that they should pretend they were playing at The World Chess Championship. They should not do more or less analysis than they would if playing in the World Chess Championship. It was also emphasised that

this was not a “play and win” problem but rather an interesting position from a real game and so to look for a “winning” move as opposed to a “best” move may be a futile effort.

The next screen informed the participants which colour they were playing. Once they pushed the next button, Position 1 was presented. The position was what De Groot had labelled “A” (see Appendix C) if participants were assigned to the rapid or blitz conditions, and if they were assigned to the random condition, then Position 1 (see Appendix G) was a randomised configuration of the De Groot A position. The button for the next screen was only active after they had made a move or after the time had run out.

They then filled in a generic memory questionnaire (see Appendix M) that asked them to write down their analysis of the position they just had seen. To move to the next screen, the participants needed to write something into the questionnaire text box.

The Position 2 instructions (for the rapid & random conditions see Appendix N, for the blitz condition see Appendix O) summarised the instructions for Position 1 (see Appendix K for rapid & random condition, see Appendix L for the blitz condition) but also instructed participants to try and analyse the chess position as they made their move because once they had made their move, they would be asked to fill in an identical questionnaire (see Appendix M) to the one they previously had answered. The participants had to make a move in under 4 min if assigned to the rapid or random conditions, or in under 40 s if assigned to the blitz condition.

The next screen informed them which colour they were playing. Once they pressed the next button, Position 2 appeared and they either had 4 min for the rapid and random conditions or 40 s for the blitz condition to make a move. Position 2 was the Fisher/Karpov endgame (see Appendix D) if participants were in the rapid or blitz conditions, and if they were assigned to the random condition, then Position 2 (see Appendix H) was a randomised configuration of the Fisher/Karpov endgame. To move to the next screen, they either had to make a move or the time lapsed. The next screen presented the same generic questionnaire as the first one (see Appendix M), and the

participants needed to write something into the questionnaire text box to allow them to move on to the next screen.

The following screen had the same full instructions that were presented to the participants prior to Position 1, namely, that they would have 4 min (rapid and random conditions) or 40 s (blitz condition) to make a move and that they should pretend they were playing at the World Chess Championship (for rapid & random conditions see Appendix K, for the blitz condition see Appendix L). The next screen informed them which colour they would be playing.

Once they clicked the next button, Position 3 appeared. If in the rapid and blitz conditions, Position 3 (see Appendix E) was the adjusted R. Rozanky—S. Kagan (Tel-Aviv, 1973) game (see Table 4 for details), while in the random condition, Position 3 (see Appendix I) was a randomised configuration of the R. Rozanky—S. Kagan game position. Participants had to either make a move or run out time to activate the next button to proceed to the next screen, where they filled in an episodic questionnaire (see Appendix P). This questionnaire asked them to pretend that their friend had just walked into the room and describe the move they had just made in enough detail for their friend to be able to duplicate the move by doing it just like they had done. Once again, participants needed to write something into the questionnaire box to be able to proceed to the next screen.

The instructions for Position 4 then appeared, summarising the instructions for Position 1 (see Appendix N for rapid & random conditions, see Appendix O for the blitz condition). Participants were also informed to try and pay close attention to the action involved in making their move because they would be asked to fill in another questionnaire identical to the one, they had just completed regarding their memories of this move. Participants had to make a move in under 4 min if assigned to the rapid or random condition, or in under 40 s if assigned to the blitz condition.

Participants then pushed the start button, and Position 4 appeared. If participants were assigned to the rapid or blitz condition, Position 4 was the one that De Groot had labelled “C” (Appendix F), while if they were assigned to the random condition, Position 4 (Appendix J) was a randomised configuration of the De Groot C position.

Once again, they needed to either make a move or run out time to access the next screen. After the next screen had informed them which colour they were playing, they pushed the next button, and Position 4 appeared. They then filled in an episodic questionnaire identical to the previous one, and to be able to proceed to the next screen, they needed write something into the questionnaire box. Finally, the final screen appeared, thanking them for completing the study.

Design

The study used a 3 (chess task: rapid, random, blitz) x 2 (skill: highly skilled and competent) between-subjects design. Comparisons were made between skill, task environment, and time pressure to test automatization in high-level skill. The difference between the rapid and random condition were the configuration of the chess positions.

The difference between the rapid and blitz condition was the time control, while the difference between the random and blitz condition was the configuration of the chess position and the time control. Highly skilled chess players' performance under a rapid 4 min time control was compared with highly skilled chess players' performance under a blitz 40 s time control.

The best Stockfish evaluated moves made by highly skilled chess players under a rapid time control were compared to those made under a blitz time condition for each position, as well as across all positions.

Highly skilled chess players' generic descriptions of their moves in a standard chess position were compared to the competent chess players' descriptions in the rapid and blitz conditions. The generic descriptions of chess moves by highly skilled players in a standard position were compared to their episodic recollections in the rapid and blitz conditions. Additionally, the episodic recollections of highly skilled players' moves in a standard chess position were compared to the descriptions provided by competent chess players in the rapid and blitz conditions.

The episodic accounts of highly skilled chess players' moves made in a less familiar random chess position were compared with those made by highly skilled chess players in a familiar standard

chess position and with the episodic accounts of the moves made by the competent players in all three conditions—blitz, rapid, and random.

Competent chess players' episodic accounts of the move they made in a standard position under the two different time conditions were compared with the episodic accounts of the move made in a random position for any differences.

The Stockfish-evaluated best moves of highly skilled chess players in the three conditions were compared with the Stockfish evaluated best moves of competent chess players in the respective conditions, both within each position and across all positions.

The generic and episodic memory questionnaires' tasks measured De Groot's four phases of the thought processes of a chess move. Stockfish—a free and open-source chess engine—measured the performance by evaluating the quality of each move made by a player.

Results

Quality of Chess Move Measure

To calculate the best moves in all the positions, Stockfish was used (Romstad et al., 2008). Since October 2020, Stockfish, based on its Elo rating, is the strongest central processing unit chess engine in the world according to the computer chess rating list (https://ccrl.chessdom.com/ccrl/4040/). On 8 June 2023, Stockfish's Elo rating was 3541. Stockfish has consistently ranked first or close to the top of most chess rating lists and has won the Top Chess Engine Championship 13 times and the Chess.com Computer Chess Championship 19 times.

Stockfish evaluates positions with a value called centipawns—the value usually corresponds to 1/100th of a pawn, but Stockfish's value of a centipawn is 1/213 of a pawn (Kagkas, 2021). Centipawns is the method most used for board evaluations (Sabatelli et al., 2018). When Stockfish presents a numerical score in the value of centipawns for the best move or moves in a position, it assigns a positive signed value to indicate an advantage for

White, and a negative signed value to indicate an advantage for Black. For example, the indication of White being up a pawn in a position would be displayed as +213 at the user interface, which means White is up 213 centipawns, and a value of 0 means equality (Ishaq, 2020; Kagkas, 2021). It must also be noted that -213 generally does not mean that Black is up one more pawn than his or her opponent on the chess board but rather that—taking all the factors of the position into consideration—Black has an advantage that is comparable to being up a pawn (Kagkas, 2021).

Stockfish uses alpha-beta pruning for its search algorithm, and this is not a natural way highly skilled human chess players would internalise piece values because their evaluations use generic chess principles and patterns recognition and based on their abstract evaluation of them, judge the best move on the appropriate strategic plans (Ishaq, 2020; Kagkas, 2021; Sabatelli et al., 2018).

In summary, the difference between Stockfish's evaluation of the best move and a highly skilled chess player's is that Stockfish has a concrete and quantified definition of both the characteristics and the evaluation of the best move, whereas in the case of a highly skilled chess player these characteristics are considered an instinctive and non-quantified manner, which is usually loosely expressed like "White is slightly better" or "Black is winning" (Kagkas, 2021). The characteristics that Stockfish's evaluation function uses to determine whether a chess move is in favour of one side over the other side include a raw materials count, imbalances (e.g., bishop vs. knight), piece evaluation, mobility, king safety, possible threats from the opponent, passed pawns, the number of squares your pieces cover, and control (Ishaq, 2020).

The centipawn values of the best moves in all the positions of this current chess study were calculated by Stockfish 14.1[10] on 24 February 2022. The centipawn value of the best moves for each position according to Stockfish 14.1 are presented in Table 5 in algebraic notation with centipawn value in brackets.

[10] https://stockfishchess.org/blog/2021/stockfish-14/

Table 5

Stockfish's Best Moves and Their Centipawn Values

To move	Configuration	Position	Best moves (centipawn values)
White	Standard	1	Bxd5 (+3.42), h4 (+0.99), Qe2 (+0.77)
White	Standard	2	Rc1 (+2.18), a4 (+1.14)
Black	Standard	3	Qc8 (-2.69), Rh8 (-2.36), Rh7 (-2.33)
Black	Standard	4	h6 (-0.16), Bd7 (-0.16)
White	Random	1	Nb6 (+2.06), a4 (+1.74), f4 (+1.65), Ba6 (+1.65), b5 (+1.61)
White	Random	2	h5 (+1.14), Re8 (+0.61)
Black	Random	3	Bd6 (-6.9)
Black	Random	4	Bd1 (-2.9). Nf8 (-1.87)

Only moves that were evaluated by Stockfish to have an advantage in centipawn values were included for scoring in each position. Moves that Stockfish evaluated as equal (0) or that were disadvantageous in centipawn values were not included.

Quality of Participants' Chess Moves

Rapid and Blitz Conditions

Table 6 presents the rapid and blitz groups' descriptive statistics of the overall centipawn value and clearly shows that the highly skilled players had larger centipawn values than the competent players. The positive and negative signs for the centipawn values are discarded from this point on in the report because the mean of the centipawn value of the moves evaluated by Stockfish as the best is reported not for example wherever the move was advantageous for White or Black.

Table 6

Stockfish Centipawn Values of Rapid and Blitz Groups

Group	Stockfish centipawn value		
	M	*SD*	95% CI
Highly skilled rapid	0.62	0.97	0.620, 0.562
Highly skilled blitz	0.46	0.97	0.463, 0.428
Competent rapid	0.23	0.59	0.232, 0.261
Competent blitz	0.10	0.47	0.109, 0.208

Note. Stockfish evaluates positions with a value called centipawns, which corresponds to 1/213 of the value of a pawn (Kagkas, 2021; Sabatelli et al., 2018).

Highly skilled chess players making a move in a standard position performed equally well in the two-time conditions of blitz and rapid. The highly skilled chess players in each of the three conditions performed better than the competent players in their respective conditions overall, but this was not observed in each position.

The only group to make a move with a centipawn value in Position 1 was the highly skilled blitz group (M = 0.68, SD = 1.36) with a 95% CI of [0.684, 1.119] as the other three groups (M = 0.00, SD = 0.00) made no moves that had a centipawn value.

The highly skilled rapid group (M = 1.53, SD = 0.86) had the largest centipawn value for Position 2, with a 95% CI of [1.536, 0.76]. This was followed by the highly skilled blitz group (M = 0.66, SD = 0.87) with a 95% CI of [0.664, 0.769], the competent rapid group (M= 0.45, SD = 0.55) with a 95% CI of [0.456, 0.49], and the competent blitz group (M = 0.00, SD = 0.00).

The highly skilled rapid group (M = 0.94, SD =1.15) with a 95% CI of [0.944,1.013] also had the largest centipawn value for Position 3. Following this, both the highly skilled blitz and competent rapid groups (M = 0.47, SD = 0.94) had identical centipawn values for their moves, with a 95% CI of [0.472 ±0.827], succeeded by the competent blitz group (M = 0.43, SD = 0.87).

Once again, the highly skilled blitz group (*M* = 0.03, *SD* = 0.06) with a 95% CI of [0.032, 0.0561] was the only group to make a move with a centipawn value, this time for Position 4, as the other three groups (*M* = 0.00, *SD* = 0.00) made no moves with a centipawn value.

The ability to spot weaknesses, improve your pieces, and other positional factors in each of the position is as important as the total centipawn value of all moves. All highly skilled players make use of positional play, and this understanding should result in the highly skilled rapid group making a quality move without deep preparation in each position and, overall, have the highest centipawn value of all moves since they have an additional 3 min and 20 s thinking time than the highly skilled blitz players. However, in line with theories of skill acquisition and automaticity, the highly skilled blitz chess players were the only group to make a quality move in each position.

Table 7 presents the percentage of best Stockfish moves that were made by the rapid and blitz groups across all four positions.

Table 7

Percentage of Best Stockfish Moves Made by the Rapid and Blitz Groups Across all Positions

Group	Best moves
	%
Highly skilled rapid	25
Highly skilled blitz	21
Competent rapid	13
Competent blitz	4

As shown in Table 7, the highly skilled groups had a higher percentage of best Stockfish moves in comparison to the competent groups as was predicted by the level of chess skill in each group. The highly skilled rapid group had the highest percentage out of all the groups, thus, supporting the prediction that the highly skilled chess players making a move in a standard position will perform equally well in the two-time conditions of blitz and rapid. The highly skilled rapid group had the highest percentage of all the groups, whereas, as shown in Table 8, the highly skilled blitz group were the only group to have a percentage of best Stockfish moves across all four positions.

Table 8 presents the relative frequency of best Stockfish moves made by each group across all four positions.

Table 8

Relative Frequency of Best Moves Across all Four Positions

Group	Position 1	Position 2	Position 3	Position 4
	%	%	%	%
Highly skilled rapid	0	80	40	0
Highly skilled blitz	20	40	20	20
Competent rapid	0	40	20	0
Competent blitz	0	0	20	0

The highly skilled groups had a higher percentage of best Stockfish moves or the same percentage as the competent groups in all the positions. However, as Table 8 shows, the highly skilled rapid group only had a higher percentage of best Stockfish moves than the other groups in Position 2 and 3. The highly skilled blitz group was the only group to make a move in Position 1 and 4 that was according to Stockfish to be the best move in those positions.

Random Condition

The highly skilled random group (*M* = 0.46, *SD* = 0.90) with a 95% CI of [0.461, 0.398] had a slightly higher centipawn value in comparison to the competent random group (*M* = 0.37, *SD* = 1.50) with a 95% CI of [0.3755, 0.659] across all positions.

Neither of the random groups (*M* = 0.00, *SD* = 0.00) made any moves with a centipawn value in Random Position 1.

The highly skilled group (*M* = 0.68, *SD* = 0.55) with a 95% CI of [0.684, 0.49] had a larger centipawn value than the competent group (*M* = 0.12, *SD* = 0.24) with a 95% CI of [0.122,0.214] for Random Position 2.

For Random Position 3, the competent group (*M* = 1.38, *SD* = 2.76) with a 95% CI of [1.38,2.419] had a larger centipawn value than the highly skilled group (*M* = 0.00, *SD* = 0.00).

Only the highly skilled group (*M* = 1.16, *SD* = 1.42) with a 95% CI of [1.16,1.245] made moves that had a centipawn value in Random Position 4, as the competent group (*M* = 0.00, *SD* = 0.00) made no moves with a centipawn value.

Table 9 presents the relative frequencies of best moves made by both random groups.

Table 9

Percentage of Best Moves Made by Random Groups

Group	Position 1	Position 2	Position 3	Position 4
	%	%	%	%
Highly skilled random	0	60	0	40
Competent random	0	20	20	0

As can be seen in Table 9, the highly skilled chess players made more good moves in comparison to the competent players regardless of the condition. This was true across all positions except for Random Position 3.

Generic and Episodic Memory Analysis

De Groot's four phases of the thought processes involved in moving a chess piece were used by scoring how many of the phases (0-4) participants recalled when describing the thought process involved in making their chess move. Table 10 shows the four phases noted by De Groot (1946/1948) during his classic study of the cognitive requirements and the thought process involved in choosing the best chess move and provides a description of the phases.

Table 10

De Groot's Four Phases of the Thought Processes Involved in Moving a Chess Piece

Phase	Description
1 Orientation (problem formation)	The player conducts an assessment and evaluation of the position and hypotheses an aim to achieve.
2 Exploration	The player examines a few lines of play with various moves to examine the possible continuations of play.
3 Investigation	Searches are deeper to validate one move or another. The stronger chess player's analysis is more robust and specific than the weaker players and is aligned with the aim set in the Orientation phase.
4 Proof	The player tries to proof that either the move selected is the best possible to achieve their aims, or at best better than the other candidate moves found.

The statements in each participant's memory protocol were compared with De Groot's proposed set of the four phases involved in making a chess move. If a participant recalled a thinking process that referred to one of the four phases (see Table 10), it was counted as one of the phases. For example, the idea given by one participant: "Taking control of the c-file" and Phase 1: "Orientation (problem formation)—the player conducts an assessment and evaluation of the position and hypothesises an aim to achieve." were coded as a match with Phase 1 (Orientation) because they both referred to the same phase (i.e., what they are trying to achieve).

Similarly, the thought given by another participant: "Considered Kf2; Rc1; a3; a4 or b5. Couldn't see an immediate tactic." and Phase 2: "Exploration – the subject tries out a couple of lines in various moves to see what is out there as possibilities" were deemed a match because they both referred to the same thought process (i.e., exploration of moves).

If two ideas recalled by a participant described one of the phases proposed by De Groot, they were combined and counted as one of the phases. For example, one participant reported two ideas, “Not [stopping] a check; keeping the position for black safe” and “stopping ideas of back rank mate or perpetual checks”. These ideas were combined to match Phase 4 of De Groot’s thought process that referred to “prove that the move found was the best available to meet the objectives”.

Finally, if an idea recalled by a participant did not match any of De Groot’s four phases and was not part of the thought process of a chess move (e.g., “40 seconds was way too quick!”), it was not counted as a phase. Even though such non-thought processes are a genuine part of the autobiographical account, they are not part of the precise objective of prediction testing for EIA.

Table 11 presents examples from the rapid condition of a highly skilled chess player’s and a competent chess player’s generic description of the De Groot A position coded with the four phases of the thought processes involved in making a chess move. Note that the competent player does not have a generic description of a proof phase. There was no generic or episodic description of all four phases by a competent player in any of the positions.

Table 11

Comparison of Generic Descriptions Coded with De Groot's Four Phases at Different Skill Levels

Phase	Rapid skill level	
	Highly skilled chess player (Elo 2019)	Competent chess player (Elo 1248)
1 Orientation	"White has an isolated d-pawn which is strongly blockaded. White's chances will be mainly on the k-side with an attack there. Black's pieces well placed both for defence and attack on q-side."	"The kingside structure looks a little too firm to try break into at the moment; so coming in through the slightly less cohesive queen side seemed like a good way to make a little chaos and simplify at the same time."
2 Exploration	"Black threatened Nxc3; then Bb5 skewering Q&R; and if white plays Qxc3; Q is on same file as the Rc8; which is undesirable. I looked at Bh6 on principle (as there is a hole on g7); but after Re8; nothing much is happening. Also; white could start 1.Nxd5; and try to get Nd7 forking Q&R; but after 1....Nxd5; 2.Bxe7 Nxe7 the fork is unlikely."	"I felt like this would then be taken by the pawn; with bishop takes bishop takes following; allowing for a Knight fork of the queen and the f rook."
3 Investigation	"I hit on Qh3 to go Qh4 next move. I rejected Qg3; on the basis that black may be able to threaten Ne2+ in some lines winning the queen."	"By taking with the knight; it creates a direct threat against the queen."
4 Proof	"Q on h4 will produce nasty threats to the weak black kingside."	

Note. K-side: King side of the board, Q-side: Queen side of the board.

The order in which the phases were recorded by the participants were not considered in deciding the number of phases remembered by the participants. One experimenter and one independent assessor, who is a chess author and science project manager based in the Netherlands, independently coded six participants' data.

The experimenter was aware of each participant's group condition and memory questionnaire, whereas the independent assessor was blind to participants' group conditions and memory questionnaires. There was a 78% agreement between the experimenter and the

independent assessor. A discussion about the scores was carried out over Zoom, and an agreement on scores was reached.

Two weeks later, the experimenter's supervisor randomised all the participants' memory answers and emailed it to the experimenter to blind score. The blind scores for the six participants were compared with the agreed scores between the experimenter and the independent assessor. There was a 98.3% agreement between the blind and agreed scores.

Quantitative Analysis of the Differences Between Generic and Episodic Memory

Table 12 presents the results of the mean number of phases recalled in the generic protocols that capture the schema-like or prescriptive information about how a chess move is generally made. Presenting two generic protocols allows to see whether one group, or more groups, or no groups improved over time. If a group showed significant improvement, then the experimenter would need to uncover the reasons causing this. These checks evaluate the efficiency of the randomization process and also determine whether the rapid groups showed a significant difference.

All groups did not differ much between the two generic protocols. Direct comparison between the second generic protocol and the first episodic protocol showed, as expected, that the highly skilled chess players in the two-time conditions—rapid and blitz—produced longer, more detailed generic descriptions of their chess move and shorter, less detailed, episodic recollections of their chess move, —that is, greater chess skill was associated with longer generic descriptions and shorter episodic recollections.

Furthermore, as can be seen in Table 12, the highly skilled chess players under the blitz condition gave the longest generic descriptions based on how many phases they described, and the shortest episodic descriptions based on how many phases they described of any group. The competent rapid and blitz groups only had a difference of 0.4 between their generic descriptions and their episodic descriptions.

Table 12

Questionnaire Responses: Chess Move Thought Phases, Recalled out of Four

Groups	Questionnaire 1		Questionnaire 2	
	Highly skilled	Competent	Highly skilled	Competent
		Generic		
Rapid	2.8 (1.16)	2.8 (1.16)	3.2 (1.16)	2.0 (0.89)
Blitz	3.2 (0.4)	3.2 (0.4)	3.4 (0.8)	2.0 (0.89)
Random	1.8 (1.32)	1.8 (1.32)	2.6 (1.01)	1.8 (0.4)
		Episodic		
Rapid	1.8 (0.74)	1.6 (1.2)	1.8 (0.74)	1.8 (1.16)
Blitz	1.0 (0.8)	1.6 (0.8)	1.0 (0.89)	1.6 (0.8)
Random	2.6 (1.2)	1.8 (0.74)	1.8 (1.32)	0.8 (0.74

Note. Means and standard deviations, in parentheses, for De Groot's four phases.

In contrast, both random groups' generic and episodic protocols had the same mean number of phases. The highly skilled rapid group had the highest mean number of phases out of all the groups in the episodic protocol (see Table 12). Possibly paying increased attention to the novel random position speculatively, prompted these highly skilled chess players to allocate more attention to skill execution processes, which resulted in them encoding more detailed explicit episodic memory traces of the move they made.

If the highly skilled participants gave more elaborate episodic descriptions of their chess move in a random position because of their increased attention to the explicit processes involved in novel skill execution, then instructing these players to pay close attention to a particular chess move prior to filling out the second episodic questionnaire, should not significantly change their episodic descriptions in comparison to the first, unexpected questionnaire. That is, if a random chess position serves to increase attention to skill execution, instructing highly skilled chess players to explicitly monitor performance should not alter attention allocation and, thus, should not affect episodic

memory protocols. In contrast, if those highly skilled chess players, making a move in a standard position are asked to monitor their performance for a later recall test, their episodic descriptions should increase in comparison to their first episodic protocol. However, this was not observed as both the blitz and rapid groups of highly skilled players provided the same length of descriptions of De Groot's four phases for both of their episodic protocols.

As shown in Table 12, the only competent group to have an increased description in the second episodic memory protocol was the group of competent rapid chess players, who gave marginally longer chess move descriptions in the second episodic questionnaire than in the first episodic questionnaire. The competent blitz chess players did not differ in their description length of their best move from the first to second episodic memory protocol. The competent random chess players gave shorter chess move descriptions in the second episodic questionnaire than in the first episodic questionnaire. The highly skilled chess players making a move in the random position also gave a shorter description in the second episodic questionnaire than in the first episodic questionnaire. In comparison, the highly skilled players making a move in a standard chess position did not differ from the first to second episodic memory protocol in their move description lengths.

Qualitative Analysis of De Groot's Four Phases Recalled in Generic and Episodic Protocols

Since all the groups' mean of phases recalled did not differ much between their two generic protocols (see Table 12), they were combined for the qualitative analysis of De Groot's four phases recalled in the generic protocols. Likewise, the groups' mean of phases recalled did not differ much between their two episodic protocols, as is shown in Table 12. Therefore, they were also combined for the qualitative analysis of De Groot's four phases recalled in the episodic protocols.

Table 13 presents the relative frequencies of the four phases recalled in the generic protocols, episodic protocols, and the total percentage of the four phases recalled. De Groot's four phases were divided into types of phases (orientation, exploration, investigation, and proof) and the relative frequency of each phase is presented in the relevant sections of this qualitative analysis.

Table 13

Total Relative Frequency of the Four Phases Recalled

Groups	Generic	Episodic	Total
	%	%	%
Highly skilled			
Rapid	75.0	45.0	60.0
Blitz	82.5	25.0	53.75
Random	55.0	55.0	55.0
Competent			
Rapid	47.5	42.5	45.0
Blitz	47.5	35.0	41.25
Random	37.5	32.5	35.0

Orientation. For a description De Groot's orientation phase see Table 10. Orientation steps occurred more often in the generic protocols of the highly skilled blitz players than in any other group's protocols, as can be seen in Figure 1. In terms of the episodic protocols, the highly skilled rapid players recalled more orientation steps in their episodic recollections than any other group.

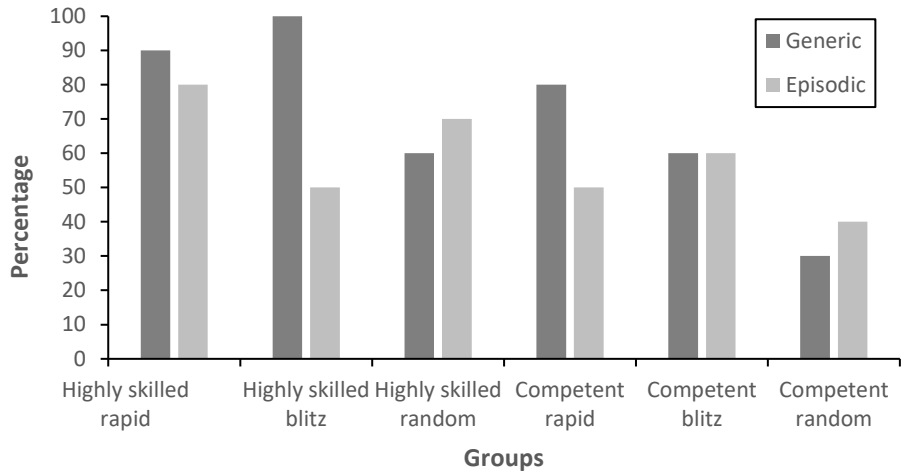
Highly skilled blitz players had a higher percentage of orientation steps in their generic protocols than in their episodic protocols, whereas the highly skilled rapid players had a slightly larger recall percentage of the orientation phase in their generic protocols than they did in their episodic protocols. The highly skilled random players had a slightly larger recall of the orientation phase in their episodic protocols than in their generic protocols.

In contrast, the competent blitz players did not differ in terms of the percentage of the orientation phase recalled in their generic and episodic protocols. In comparison, the competent rapid players' recall percentage of the orientation phase in their generic protocols was larger than in

their episodic protocols, and the competent random rapid players gave slightly more orientation steps in their episodic protocols than their generic protocols.

Figure 1

Relative Frequency of the Orientation Phase by Questionnaire Type



Exploration. For a description of De Groot's exploration phase refer to Table 10. The two highly skilled groups recall of their moves in a standard position produced a larger percentage of the exploration phase in the generic protocols than in the episodic protocols regardless of time control, which is observed in Figure 2.

Exploration phase recall differences for the two skill groups (competent and highly skilled) depended on the type of recall task (generic or episodic). The highly skilled blitz players had a larger recall percentage of the exploration phase in their generic protocol than the competent blitz players, whereas the opposite occurred when comparing the highly skilled blitz players' recall of the exploration phase to the competent blitz players recall of the exploration phase in the episodic protocols.

The standard chess positions produced a larger percentage of the exploration phase for the two highly skilled groups (rapid and blitz) in their generic protocols than in their episodic protocols

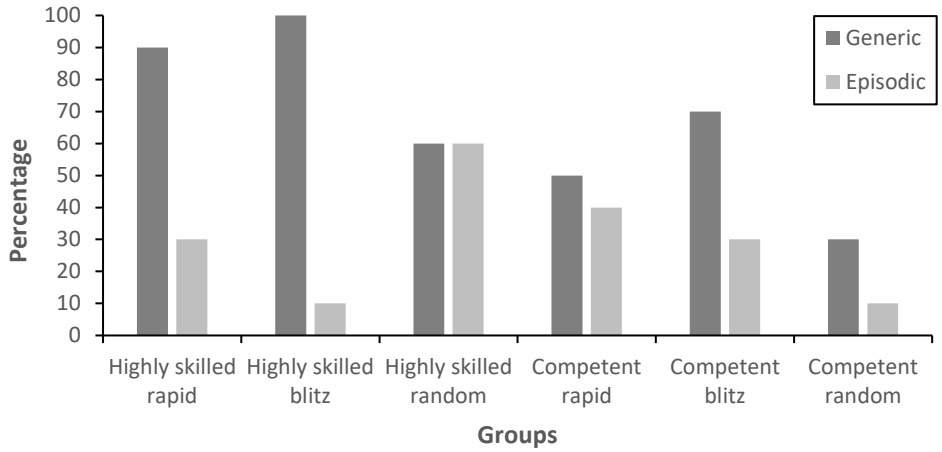
regardless of time control, which is observed in Figure 2. The highly skilled rapid players had a larger recall percentage of the exploration phase in their generic protocols than in their episodic protocols, whereas the competent rapid players did not differ in the terms of the percentage of the exploration phase recalled in their generic and episodic protocols.

The highly skilled rapid players had a larger percentage of the exploration phase recalled in their generic protocol than the competent rapid players, whereas the competent rapid players had a larger recall percentage of the exploration phase in their episodic protocols than the highly skilled rapid players.

The highly skilled random players did not differ in terms of the exploration phase recalled in their generic and episodic protocols, whereas the competent random players recalled a larger percentage of the exploration phase in their generic protocols than their episodic protocols. The highly skilled random players had a larger recall percentage of the exploration phase than the competent random players regardless of the protocol, as can be observed in Figure 2.

Figure 2

Relative Frequency of the Exploration Phase by Questionnaire Type



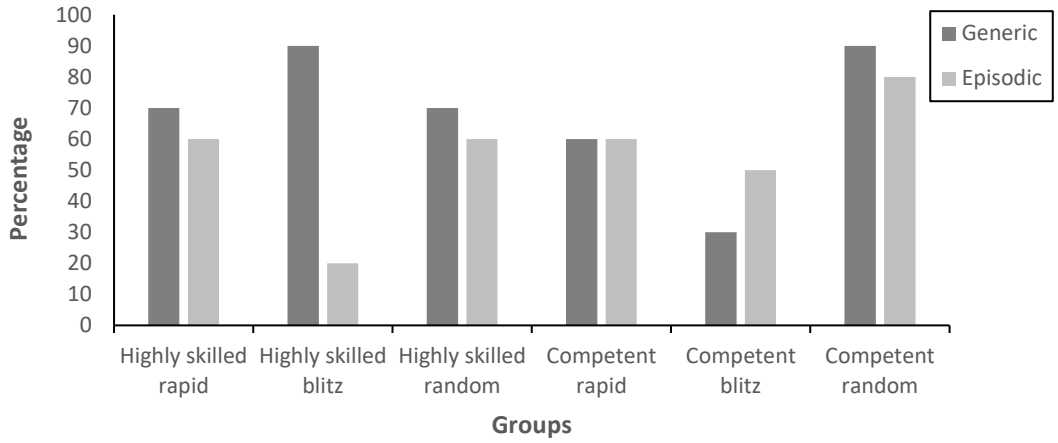
Investigation. Refer to Table 10 for a description of De Groot's investigation phase. The highest percentage of the investigation phase occurred in the generic protocols of the competent rapid random players, as can be seen in Figure 3. The random chess position produced a larger percentage of the investigation phase in the generic protocols than the episodic protocols regardless of skill (competent and highly skilled), which is observed in Figure 3. The competent random players had slightly higher percentage of recalling the investigation phase in their generic protocols than in their episodic protocols, as had the highly skilled rapid random players.

The standard chess positions produced a larger percentage of the investigation phase for the two highly skilled groups (rapid and blitz) in their generic protocols than the episodic protocols regardless of time control (see Figure 3). The highly skilled blitz players had a larger recall percentage of the investigation phase in their generic protocols than in their episodic protocols, as had the highly skilled rapid players.

In contrast, the standard chess positions produced a larger percentage of the investigation phase for the two competent groups in their episodic protocols than in their generic protocols regardless of the time control (see Figure 3). The competent rapid players had slightly more investigation steps in their episodic protocols than their generic protocols. The competent blitz players had a larger recall percentage of the investigation phase in their episodic protocols than in their generic protocols.

Figure 3

Relative Frequency of the Investigation Phase by Questionnaire Type



Proof. To view a description of De Groot's proof phase, refer to Table 10. The standard chess positions produced a larger percentage of the proof phase for the highly skilled rapid and blitz groups in their generic protocols than their episodic protocols regardless of time control, which is observed in Table 14.

The highly skilled rapid players had a larger percentage of the proof phase in their generic protocols than their episodic protocols as did the highly skilled blitz players, whereas the highly skilled random players did not differ in the terms of the percentage of the proof phase recalled in their generic and episodic protocols (see Table 14).

The competent blitz players only had a small recall percentage of the proof phase in their generic protocol and no recall in their episodic protocol. The opposite was observed with the competent rapid players only having a small recall percentage of the proof phase in their episodic protocols and no recall of the proof phase in their generic protocols. As can be seen in Table 14, the competent random players did not have any proof steps and therefore did not differ in terms of the number of proof steps given in their generic and episodic protocols.

Table 14

Relative Frequency of the Proof Phase by Questionnaire Type

Group	Generic	Episodic
	%	%
Highly skilled		
Rapid	50	10
Blitz	50	20
Random	30	30
Competent		
Rapid	0	10
Blitz	20	0
Random	0	0

Note. Rapid and random groups have a 4 min time control, blitz groups have a 4 s time control.

Discussion

This study examined whether expertise-induced amnesia (EIA) occurs in the cognitive sport of chess and if attending to a proceduralised skill, diminishes memory of the performance. This was done by assessing the declarative accessibility of the knowledge representations governing real time performance of making a chess move at different Elo levels of chess skill. Highly skilled and competent chess players made four chess moves in a standard configured chess position with either a 4 min time control if they were in the rapid condition or a 40 s time control if in the blitz condition; or if in the random condition, they made a move in a randomly configured chess position with a 4 min time control. All participants in all three conditions answered a generic question about their moves after they had made their first move and again after they had made their second move. They answered an episodic question about their move after making their third move and again after their fourth move.

Performance of Highly Skilled Chess Players in Blitz vs Rapid Time Conditions

The results tentatively supported the hypothesis that highly skilled chess players making a move in a standard position will perform as well in the two-time conditions. The highly skilled players in the rapid condition had a slightly higher percentage of best Stockfish moves and Stockfish centipawn-valued moves than the highly skilled players in the blitz condition, whereas the highly skilled players in the blitz condition were the only group that made an accurate Stockfish evaluated best move in each of the four positions. This correlation between performance in the blitz condition and a player's overall skill level is expected if high-level chess skill becomes proceduralised or automatic by use of fast processes (Beilock, Bertenthal et al., 2004; Burns, 2004).

Standard Position Move Description In Two-Time Controls: Highly Skilled vs Competent

The prediction that highly skilled chess players would give longer, more generic descriptions of the move they made in a standard chess position compared with accounts given by competent chess players in a standard position was supported. It was predicted that in comparison to the generic descriptions of their chess move in a standard position, highly skilled chess players would have shorter, less detailed episodic recollections than competent players in the two-time conditions. This prediction was well-supported in the blitz condition. In fact, the highly skilled blitz chess players gave more detailed generic descriptions and had the most diminished episodic memories than all the other groups. The highly skilled blitz players' time constraint of making a move in under 40 s most likely prompted the participants' use of procedural knowledge and, possibly, their longer generic descriptions reflect the rich semantic knowledge links assumed to characterise templates (Gobet & Simon, 1996b).

In the rapid condition, the highly skilled chess players also had more detailed generic representations and diminished episodic memories. However, in the rapid condition, the highly skilled participants had slightly longer episodic recollections than the competent participants, and, therefore, this did not support the hypothesis that highly skilled chess players would have shorter, less detailed episodic recollections than competent chess players.

On the one hand, this result likely stemmed from a sense of familiarity facilitated by pattern recognition, an automatic function of deliberate practice (Anderson, 1982; Chassy & Gobet, 2011; Craik et al., 1996; De Groot & Gobet, 1996; Gobet & Chassy, 2008; Kiesel et al., 2009; Lane & Chang, 2018; Reingold et al., 2001; Saariluoma, 1984, 1985, 1990). Accordingly, competent chess players may execute certain chess moves without consciously attending to their skills, attributed to their greater chess experience compared to novice players (Anderson, 1982). Consequently, they may have decreased declaratively accessible episodic memories of a chess move (Beilock, 2007; Craik et al., 1996; Naveh-Benjamin et al., 1998). The level of skill is further explored later in this discussion, in which the important skill difference between this chess study's participants and Beilcock and Carr's (2001) golf putting participants is highlighted.

On the other hand, the result could indicate an increase in the highly skilled rapid players' process of conscious evaluation, such as looking ahead to the outcome of a sequence of chess moves as well as strategizing (Bilalić et al., 2008b; Charness, 1981; De Groot, 1946/1978; Gobet, 1986, 1998a; Montero, 2019; Saariluoma, 1995). If this was the case, conscious evaluation did not play an important role in selecting good chess moves in Position 3 and Position 4, as the combined percentage of the best Stockfish moves for both the highly skilled rapid and highly skilled blitz groups was only 20%.

Highly skilled blitz players' generic descriptions had considerably more orientation phases that dealt with assessing and planning a chess move than competent blitz players' generic descriptions. This finding aligns with expertise literature on skilled performers in a variety of task domains (Beilock & Carr, 2001; Voss & Post, 1998). In the domain of physics, it has been shown that experts spend more time evaluating a physics problem and planning a method to solve or formulate a problem before they even start the task (Voss & Post, 1998).

In the two-time controls, highly skilled players had fewer orientation steps in their episodic recollections than in their generic descriptions. They also made fewer references to the workings of

their chess moves in the exploration and investigation phases of De Groot's four phases in their episodic recollections compared to their generic descriptions.

These findings are consistent with the prediction of EIA from theories of skill acquisition and automaticity (Beilock & Carr, 2001). In line with this idea, highly skilled players' extensive generic knowledge of a chess move in a standard chess position is declaratively accessible in reflection after the move was made, but it is not used when the move is made in real-time, in which fast cognitive processes are controlled by procedural knowledge and episodic recollection of each phase of the thinking process of the real-time move is impoverished (Anderson, 1987, 1993; Beilock & Carr, 2001; Chassy & Gobet, 2011; Fitts & Posner, 1967; Krivec et al., 2021; Proctor & Dutta, 1995; Toner et al., 2015). It is noted that the highly skilled rapid players (90%) described only slightly more orientation phases that delt with assessing and planning a chess move in their generic protocols compared to the competent rapid players (80%).

Nevertheless, the data leave no doubt that the quality of moves chosen by the two rapid skill groups—highly skilled and competent—is independent of the level of the chess players' memory protocols. For example, in Position 2, the highly skilled rapid players' evaluation (orientation phase) of the position was 80% correct in comparison to the competent rapid players' evaluation, which was 40% correct. All De Groot's four stages of the thinking process of a chess player appear to be influenced by prior knowledge of previous chess positions. However, the orientation phase is specifically critical to skill at chess since seeing ahead is pointless if the player does not know if the projected position is favourable or not (Holding & Reynolds, 1982). The complexity of the current chess study's positions made efficiency in evaluation challenging for the players, resulting in differences between the two skill groups. These differences may stem from variations in memory for generic information about the positions.

However, there was no relationship observed between the details of the generic or episodic protocol and quality of chess moves by the chess players in the current study. Beilock and Carr (2001) observed a significant relationship in their study between the length of the novice golfers'

generic descriptions and their pretest putting accuracy as in the more detailed the generic descriptions supplied by the undergraduate novices early in practice, the better they performed.

Besides the complexity of the chess task, in comparison to Beilock and Carr's putting task and differences in the design of the tasks, there is also an important skill difference between the respective participants of each study. Skill difference is an important factor when contrasting this finding and the two above findings that occurred in the blitz group but not in the rapid group. The novice golfers had no prior golf experience, whereas the competent chess players in this study where required to have played at least 15 competitive chess matches to qualify. Indications from email correspondence between participants and the researcher suggested that each participant had played a higher number of competitive chess matches. Therefore, even if the chess positions were easier for participants to find a best move in this study, it is highly unlikely that a significant relationship between the length of competent chess players' generic descriptions and the quality of their moves would be observed for the simple fact that all participants in this experiment had competitive chess experience.

This difference in skill level is likely to have contributed, firstly, to the highly skilled rapid players having slightly longer episodic recollections than the competent rapid players and, secondly, to the highly skilled rapid players having the same length of orientation phases that delt with assessing and planning a chess move as the competent rapid players.

These findings suggest that competent chess players benefit from more attention in the longer time control of the rapid condition for the execution of the chess move in comparison with the blitz condition time control, which takes such attention away from the competent players, whereas highly skilled players execution of the chess move is not affected by limited attention in the blitz condition. Hence, fast processes are accessible in both time controls as highly skilled chess players played at a similar level in the two-time controls. Therefore, the results support the argument that the variance in the effectiveness of fast processes, such as recognition, explains most of the variance in chess skill (Burns, 2004).

However, these findings have not demonstrated that slow mechanisms, such as depth and breadth of serial search of possible moves and responses, are inconsequential. Nonetheless, these findings support experiments that demonstrated that search does not get a lot better as chess players' skill levels increase (Charness, 1981, 1991; De Groot, 1946/1978), which suggests that search should not explain much of the variance between the blitz and rapid groups in this study.

Beilock and Carr's (2001) putting experiment had a very low-rate inclusion of outcome information, such as goals achieved, effectiveness, impact, and any other relevant outcomes associated with the task or environment, even among experts. In contrast, the current chess study had a moderate rate inclusion of outcome information by highly skilled players in their memory protocols. The difference in skill between Beilock and Carr's experts and the highly skilled participants in this chess study is likely to have contributed to the observed increase in the inclusion of outcome information or the proof phase observed in this study.

College golf is currently more competitive than it was when Beilock and Carr completed their study[11]. The odds for a player in the top division of a university golf team of making a PGA tour are about 1 player every 24 years (Canadian, 2007). In comparison, this chess study's highly skilled players contained two international masters—the second most difficult title to attain in chess, and there are only 3,800 out of millions of chess players[12]; three candidate masters—as of 2020, there are roughly 1,700 active Candidate Masters[13], which is a small percentage of the millions of chess players worldwide; and one U.S. National Master—less than one per cent of rated players hold this title[14]. Forty percent of the highly skilled players were masters in this chess study, and besides the higher ratings of masters over experts in the first three years, experts have been shown not to improve much despite the same amount of deliberate practice as masters, who do improve (Campitelli & Gobet, 2008).

[11] https://www.ncsasports.org/mens-golf
[12] https://maroonchess.com/chess-titles-in-order/
[13] https://maroonchess.com/chess-titles-in-order/
[14] https://www.uschess.org/index.php/Learn-About-Chess/FAQ-Starting-Out.html

The finding that highly skilled players gave more extensive recollections of the proof phase (outcome information) than competent players in this study suggests that performance outcomes are more salient to more skilled chess players. This finding is consistent with another cognitive domain in which it was shown that expert physicists allocate more attentional resources to assessing and monitoring specific goal outcomes during problem solving than do less experienced physicists (Voss & Post, 1988). Also, it is worth noting that the players' attempts to prove the move found is the best available to meet their objectives would increase in chess players' thinking when making a move in a competitive chess match where the consequences of success and failure are greater (Beilock & Carr, 2001).

Comparison of highly skilled chess players' and competent chess players' generic protocols' recall of moves made in a standard chess position shows that there are differences in the percentage of exploration and investigation phases in their thinking processes. To explain the difference in the perceptual encoding advantage of highly skilled players, Chase and Simon (1973a, 1973b) suggested that skill in chess develops due to considerable practice with domain-related visual-configurations. For the duration of considerable practice, higher skilled chess players store memories for configurations of chess pieces in LTM in the pattern of chunks (Chase and Simon, 1973a, 1973b), which are enhanced by greater memory structures called templates (Gobet & Simon, 1996, 2000). The advantage of these memory structures is a perceptual encoding superiority for highly skilled chess players, who are able to recall chess stimuli in terms of larger configurations of pieces rather than individual features.

Consequently, highly skilled chess players are able to use their memory for chess configurations to guide their exploration and investigation for the best move on the board. This theoretical account is consistent with the present study's finding that the highly skilled chess players had a superior recall percentage of the generic information that was relevant to their best move on the board. This study's finding is consistent with the results of heightened memory research about

the recall of generic knowledge of domain-relevant information (Chase & Simon, 1973a, 1973b; Ericsson & Lehmann, 1996; Høffding & Montero, 2019).

Comparing Episodic Accounts of Moves: Highly Skilled Random Chess Players vs. Highly skilled Standard and Competent Players

The hypothesis that highly skilled chess players making a move in a randomly configured chess position would give more elaborated episodic accounts of their move than highly skilled chess players making a move under the two-time conditions in a standard position and the competent chess players in all three conditions was supported. Those highly skilled participants that were asked to make a move in a random position also gave more detailed generic representations than did competent players in any of the three conditions—rapid, blitz and random.

In contrast to highly skilled players using a standard position, highly skilled players using a random position did not show diminished episodic memories for specific performances as would be expected if proceduralisation decreases the requirement to attend to the processes by which the execution of the chess move unfolds. In fact, highly skilled random players gave more elaborate episodic descriptions of the skill execution of a chess move than highly skilled players using a standard position and all the competent groups. The result suggests that making a chess move in real time is supported by proceduralised knowledge for experienced players who may be disrupted by novel task constraints.

When this disruption occurs, more skilled chess players are forced to attend to the step-by-step performance in the same way as less skilled players—their expertise allows them to remember more of what they have attended to than less skilled players. This finding mirrors the one of Chase and Simon (1973b), in the way it was demonstrated that expert chess players had superior episodic memory of chess stimuli to which they have applied their knowledge.

Furthermore, regardless of the time control or type of position, competent chess players in the current study produced marginally different generic and episodic chess move descriptions, thus

suggesting that in contrast to more skilled chess players, competent skill performance in competent chess players is less based on a proceduralised, practice specific skill representation.

Competent Players' Episodic Accounts: Random vs Standard Positions

The finding, that competent skill performance in competent chess players is less based on a proceduralised, practice-specific skill representation, was further demonstrated by the result supporting the hypothesis that there would be no difference in the detail of the episodic accounts of a chess move made by competent chess players in a random position and competent chess players in a standard position. Although competent chess players in this current chess study demonstrated some ability to use pattern recognition, this finding still shares similarities with Bilalić et al.'s (2010) study. In their research, novice chess players were unable to use pattern recognition processes in either a standard or randomly configured chess position because they did not have previously stored knowledge that is essential to the knowledge structures for pattern recognition.

Highly Skilled vs Competent Players: Stockfish Evaluated Best Moves

Finally, the hypothesis that highly skilled chess players in each of the three conditions should make more Stockfish evaluated best moves in each of the positions than the competent players in their respective groups was supported. The level of skill was determined by the valid and reliable Elo rating system, and the result supports the Elo rating's high level of reliability as it captured the general chess ability of the two skill groups in this chess study accurately (Blanch et al., 2017; Elo, 1978; Glickman, 1995; Gobet, 2001; Rasskin-Gutman, 2009; Thurstone, 1994; Van der Maas & Wagenmakers, 2005).

Automaticity and Skill Acquisition in Chess performance

The finding that EIA occurs in the cognitive sport of chess is consistent with previous research, demonstrating an association between skill acquisition and automaticity (Beilock & Carr, 2001; Fitts & Posner, 1967; Lewandowsky & Thomas, 2009; Speelman & Maybery, 2013, pp. 93–98; Toner et al., 2015; Williams & Fords, 2008). The results of this chess study show skill representations at various Elo rating levels. Regarding the cognitive skill of chess, it would appear that intensely

practiced, well-learned task elements are encoded in a procedural form that aids real time performance without engaging attentional control of the steps to make a chess move (Beilock & Carr, 2001). Diminished attention leads to a lessening in declaratively available episodic memory for accounts of the performance (Beilock & Carr, 2001). However, if task constraints (e.g., a randomised position) are established that enforce experienced chess players to change execution processes in order to adapt to the novel environment, the proceduralised skill knowledge that formerly controlled regular execution is disrupted (Beilock & Carr, 2001).

The effect is a more explicit memory trace for a particular chess move. The suggestion that well-learned cognitive skill performance is structured by a proceduralised representation affects how this sort of skill will act under pressure (e.g., speed constraints) or in attention demanding situations (e.g., dual task). Specifically, the two main theories—self-focus and distraction—that were outlined in the introduction of this study make different predictions about the sorts of skills that will be susceptible to performance decrements under pressure (Beilock & Carr, 2001; Beilock, Kulp et al., 2004; Lewis & Linder, 1997; Masters, 1992).

Examining Pressure Effects on Chess Skill Acquisition: A Controlled Training Study

The finding of this chess study suggests that pressure-induced attention to the well-learned structure of chess skill should disrupt execution. Testing this hypothesis should be done by examining the distraction and explicit monitoring theories in a controlled chess training environment at different chess skill levels. Participants at different skill levels could learn a chess task to a high level of skill under dual-task or self-consciousness training conditions and be subjected to identical single-task, low- and high-pressure situations both near the start and end of the training. At the beginning of the training, participants with lower chess skill levels are likely to be more affected by a distracting environment, while highly skilled chess players may also be impacted if the chess task is unfamiliar to them. Near the end of the training, those trained in a dual-task environment with different skill levels should not be affected by pressure. In contrast, those trained in the self-consciousness-raising condition should improve under the pressure at the beginning of the training,

and the participants with the lower chess rating may perform better under pressure. Near the end of the chess training, only those trained in the self-consciousness-raising condition should improve under pressure.

Impact of Time Pressure on Highly Skilled Chess Players: Insights from Memory Protocols and Participant Feedback

Observations from highly skilled players in the blitz condition, as evidenced by remarks in their memory protocols such as "40 seconds was way too quick!" and "I was rushed for time...", indicate heightened perceptions of performance pressure and anxiety. This contrasts with their counterparts in the rapid condition who did not express concerns about time pressure.

The researcher followed up with some participants whom he thought might appreciate additional details about the time allocation, and participants further confirmed experiencing performance pressure and anxiety. For instance, one participant responded, "Thanks for the follow-up. Apologies for the frustration but it felt authentic to voice it in the moment! I'm over 60 years old which doesn't exactly help when given next to no time. I'm sure I could have provided you with a much more elaborate and appropriately balanced answer with more time.". The pressure scenario of making a move in 40 s created conditions that prevented explicit attentional control of skill execution (e.g., distraction theory). Performing in under 40 s did not harm highly skilled chess players' quality of chess moves in comparison to highly skilled chess players performing in under 4 min as was expected if well-learned cognitive chess skill is proceduralized. The result supports Burns's (2004) finding that the higher the level of chess skill a player possesses, the more likely they will make a good move under time pressure. Perhaps only players in this study who possessed excellent fast processes were able to choose good moves. Therefore, the result may suggest that high chess skill is not solely determined by how fast and effectively a player can access chunks from their chess knowledge, but rather, it could be one of the important factors (Burns 2004; Chase & Simon, 1973a).

Nevertheless, it is common for chess players to play blitz, and it is considered part of highly skilled players' training because it sharpens their ability to make fast evaluations and assessments of a chess move (Burns, 2004; Hooper & Whyld, 1984). Further, prior training in a blitz environment should enable chess players to adapt to the time pressure of the blitz condition and the associated allocation of attention to something other than choosing the best move, reducing the adversities of pressure (Beilock & Carr, 2001). Therefore, the sample of chess players at different levels of skill who made good moves was unlikely to have included only blitz specialists, and the presence of such specialists would be inconsistent with the correlation between Elo ratings and blitz performance in this study.

Analysis of Chess Move Quality in Standard Positions and Unexpected Findings with the De Groot A Position

The number of quality chess moves made in the standard positions aligned with expectations in this current chess study. Firstly, players had to orientate themselves to these complex positions without prior knowledge of the previous moves made. Secondly, if they did not recognise patterns or themes within the configurations of the positions, they would be required to engage in the cognitive slow processes of considerable look-ahead search and evaluation when choosing a move. However, it was unexpected that the De Groot A position yielded the same low number of Stockfish evaluated best moves as was anticipated with the De Groot C position (see Table 4 for a description of both positions). It was assumed that the De Groot A position would be easily recognised by the chess players in this study due to its extensive availability in the chess literature (Campitelli & Gobet, 2004).

An explanation as to why more highly skilled players did not play better moves when presented with the De Groot A comes from the principal finding of Bilalić et al.'s (2009) research, which demonstrated that chess players made significantly better moves in positions stemming from within than outside their chess opening of specialization. Recognition of positions was shown to override skill in that less skilful players in the research who were presented with a position that

stemmed from within their area of opening specialization performed as well as the more skilful chess players when the position was not stemming from within their area of opening specialization (Bilalić et al., 2009).

The position stemming from the Sicilian Defence used in the Bilalić et al.'s (2009) study has the same number of chess pieces on the board as the De Groot A position. Further, it is noted in the chess literature that it is unrealistic to expect all middle game positions to fit a chess player's known schemata, and therefore it is best for them to study typical positions stemming from their opening specialization (Bilalić et al., 2009; Gobet & Jansen, 2006).

On this basis, it is possible to say the chess players in this study had not previously encountered the De Groot A position because it was not part of their acquired chess knowledge. Further, it can be argued that Campitelli and Gobet's (2004) claim that the De Groot A position "is now widely available in the chess literature" (p. 211) is somewhat ambiguous as this finding would suggest that the De Groot A position is widely available in the cognitive chess literature but not common in the popular chess literature.

Investigation of Performance in Randomly Configured Chess Positions

A widely cited result in the cognitive chess literature argues that chess skill is relinquished when an expert and above (see Table 1 for expert and above) is presented with a randomly configured chess position (Gobet & Simon, 1996a). In this study, we examined chess moves in randomly configured chess positions as a function of level of expertise. Compelling evidence indicated that participants engaged with the four random positions presented in this chess study without being aware of any imposed constraints. Evidence for this claim included:

1. Emails from participants to the researcher. An example of an email that was similar in content to the many others that the researcher received that questions the legitimacy of the random positions in this study: "I have now completed the study but did find that White/Black were switched around at the start and also the naming of the squares was not right. If needed - I can repeat the study."

2. Evidence for the claim also came from some examples of the participants' generic and episodic memory protocols that highlight the general experience of all the participants in the random condition: "The position was too disorientated to think properly", "It took me 3 minutes to orient to the position as the pieces were upside down!", "To me the position was weird and I found it difficult to orientate things", and "The black and white pawns are on the wrong side of the board. This position could not possibly occur in a real game. That made it virtually impossible to analyze."

Even though the highly skilled players were as disorientated as the competent players by the random positions in this chess study, they did have a higher percentage of best Stockfish moves and Stockfish centipawn valued moves than the competent players in the random condition. Nevertheless, the competent group did make the only accurate Stockfish evaluated best move in random Position 3, which could suggest that highly skilled players could not access their superior complex pattern recognition processes in Position 3 (Bilalić et al., 2010). Yet, the data of this study makes it clear that the performance of the highly skilled players was superior to the competent players' performance as they had more than double the number of Stockfish evaluated best moves.

What kind of process allowed the more skilled players to perform better than the competent players in the random positions? Gobet and Simon (1996a) suggested the association between skill acquisition and automaticity in the form of a large database of chunks stored in LTM that sometimes support more skilled chess players to recognise stored patterns that appear incidentally in random positions. The better performance of the highly skilled players in the random positions of this chess study appears to be best explained by the theory that human memory mechanisms are somewhat based on small memory structures, known as chunks (Gobet & Simon, 1996a).

Comparing the best Stockfish moves made by highly skilled players in the standard position under the two different time conditions with the best Stockfish move made in the random position may not yield meaningful results because the standard and random positions represent different experimental conditions in this chess study's design. Conducting such comparisons can be useful in

an exploratory sense of performance in random positions, while keeping in mind that any comparisons between the standard and random moves made should be interpreted cautiously due to the inherent differences in the experimental conditions. For example, in this current chess study, both Standard Position 2 and Random Position 2 each had two Stockfish evaluated best moves (see Table 5). The highly skilled random group (60%) exhibited a higher percentage of best Stockfish moves than the highly skilled blitz group (40%), but not the rapid group (80%).

Moreover, the highly skilled random group had the same overall percentage of best moves (21%) as the highly skilled blitz group. However, the highly skilled blitz group made a move in every position, whereas the highly skilled random group did not (see Table 9). Additionally, the highly skilled random group had a lower percentage of best Stockfish moves than the highly skilled rapid group (25%), but both groups only made best Stockfish moves in two of the positions. Even though the material count of the chess pieces was the same in the standard and random configurations, to reiterate any comparisons between the moves executed by highly skilled players in standard and random positions should be approached with caution, considering the inherent disparities in the experimental conditions.

The performance of the highly skilled players in random positions could tentatively support Holding and Reynolds's (1982) findings that skilled participants, even when pattern recognition is disrupted, still choose the best move. Holding and Reynolds's results suggest that memory about generic chess knowledge plays a key role in skill differences rather than pattern recognition. However, as stated earlier, the notion of chunking appears the most plausible explanation for the highly skilled players' performance in random positions. Theories hypothesising the existence of small memory structures predict the presence of some chunks still being present by chance in random positions (Sala & Gobet's, 2017).

Limitations and Future Research

This study has several potential weaknesses. Considering the anticipated discrepancies between the highly skilled chess players and the competent chess players because of the high level

of reliability of the Elo chess rating (Ross, 2006), the sample size of five participants per group was consistent with a long tradition of using a small number of participants in expertise research (e.g., Campitelli & Gobet, 2004; Chase & Simon, 1973a; De Groot, 1948, 1978) and corresponds to the size of samples used in research on expertise in behaviour (e.g., Bilalić et al., 2010; Bilalić et al., 2008b, 2009; Kiesel et al., 2009).

Most importantly, our highly skilled players were exceptionally skilled. The international chess Elo scale is an interval scale with a theoretical mean of 1,500 and standard deviation of 200 (Elo, 1978). For example, the difference in Elo points between the theoretical mean and our highly skilled random players (M = 2,147.2, SD = 65.2) was 647.2. Our players had a 3.08 standard deviation above the average player, and therefore, the difference in Elo points corresponding to a deviation of 3.08 standard deviations between the two means is approximately 200.816 Elo points.

Nonetheless, the size of the sample is not large enough to make quantitative inferences about the procedural memory variables under study, such as fast processes. Yet the results of the rapid and blitz task appear to be almost consistent with the hypothesis that highly skilled chess players can solve complex chess problems without extensive search. However, it must be highlighted that in the standard Position 2 of this study (Fisher/Karpov endgame, refer to Appendix D to view Position 2), highly skilled chess players were unlikely to employ extensive search when making a move. During the endgame phase, players will use procedural algorithms, using memorised move patterns that are fast processed as a single chunk of information to find the best move (Holding, 1992; Krivec et al., 2021; Sigman et al., 2010). Moreover, Position 2 had the highest number of best moves for the highly skilled players out of all the standard positions.

Furthermore, the time controls in the rapid and blitz conditions may have affected the search behaviour of chess players in this study even though Van Harreveld et al.'s (2007) results showed that a chess player's Elo rating in a standard time control chess game is predictive of their performance under a rapid time control chess game.

Under this chess study's rapid time control, there were some additional features that a chess player would not have to address in a rapid time control chess game, such as orientating oneself to the presented position and being blind to the moves played previously. Also, a chess player during a game of chess that is under a rapid or blitz time control may allocate more time to a chess move in some of the complex positions in this chess study than the time they were constrained to in the rapid and blitz conditions of this study.

In addition, it remains uncertain whether slow processes might be more important in each of these positions under a standard time control, while fast processes might be more important under a blitz or rapid time control, as this aspect was not determined from the collected data. And in a way, this consideration is not dissimilar to the discussion between Gobet and Simon (1996c, 2000) and Lassiter (2000) about why computers are much stronger than humans under blitz time controls than standard time controls. Lassiter argued his case that humans are most likely unable to engage in slow process due to the limited time available, and Gobet and Simon countered that humans are disadvantaged because they have less time for pattern recognition when limited time is available.

Depending on one's emphasis on the statistical power problem, these shortcomings should not invalidate the primary finding of this study, namely, that EIA occurs in the cognitive sport of chess. Nonetheless, it is acknowledged that these limitations may potentially influence a participant's use of deeper or more selective slow processes and strategies. Further clarification could address these limitations by implementing a procedure where chess players, under varied time controls, compete against a computer online, and at designated intervals, the clock would pause, allowing players to complete generic and episodic questionnaires regarding their recent moves. The statistical power problem can be addressed by replicating this study with a larger sample size. Omitting the random or blitz condition from the study would increase the sample size, provided it aligns with the future research question.

It remains a question for future research whether the differences between the highly skilled players and the competent players in the random position, are genuine or due to the low power of

the experiment design used in this current chess study. The random studies reviewed, which had similar sample sizes to the current chess study, indicate that the relationship between expertise and random configurations in the domain of chess expertise may be somewhat more complex than previously thought (Gobet & Simon, 1996a; Holding & Reynolds, 1982). For future research, exploring the complexity of comparing moves made by highly skilled chess players, a repeated measures design could be considered. This design would involve analysing moves made by these players in standard chess positions and comparing them with moves made in the randomised versions.

It is possible to question the conclusiveness of the current chess study based on its use of De Groot's defined four phases of a chess player's thought process as a measure of generic and episodic recall. There is inherent uncertainty about the completeness and validity of a model of thought process to precisely determine the best possible move (Avni, 2004; Heisman, 2009). Even if there was a systematic process based on De Groot's model, implying a structured or methodical approach for selecting chess moves, it is unlikely that strong players would strictly adhere to it because they often shape and clarify their own style (Avni, 2004; Heisman, 2009). Furthermore, a chess player strictly adhering to a systematic process under one time control would need to alter it for a faster or slower time control (Heisman, 2009).

Additionally, any specific thought process, such as a cognitive strategy or mental approach, would, at minimum, involve a superior selection of subprocesses compared to other strategies. Moreover, the superior subprocesses within this particular thought process are considered to be better suited or more optimal for analysing chess positions and decision-making. These subprocesses could be applied to a position that was analytical or purely positional/judgemental, or a mixture of both (Heisman, 2009). For example, even if a chess player adhered to Kotov's *Think Like a Grandmaster* (2012) tree process—in short, it is a process to calculate correctly by using candidate moves to create an "analysis tree", they would apply it to analytical positions (most of the standard positions in this chess study) but not when deciding where to develop a knight on move six.

However, there are fundamental elements to an efficient thought process in chess (Avni, 2004; Heisman, 2009). These elements represent the basis of De Groot's four phases of the thought process—orientation, exploration, investigation, and proof. Many models of a thought process for making a chess move share the common elements of De Groot's thought process, such as Avni's (2004) system for problem solving (pp. 144–149) or Heisman's (2009) simplified thought process (pp. 31–32).

The phases of De Groot's thought process were chosen for this study over other thought process models because the criteria for each phase are broad. This broadness increases the likelihood of coding most statements of a player's chess move thought processes associated with a phase. For comparison, Heisman's (2009) second process of his five-step process "What are all the positive things I want to do?" (p. 31) is contained within De Groot's orientation phase.

In this study, six statements made by chess players were not coded with one of De Groot's four phases. Instead, these statements seemed to involve mental imagery, wherein the players imagined a phase of a chess move and visualised how it should look or feel before executing the move. For example, "I moved my Queen to b6 - diagonally one square to the right and upwards." This mental image involves recalling the visual movement of the Queen on the chessboard, imaging its position after the move (Qb6), and the direction of its movement (diagonally one square and upwards). Another example is, "I moved my light squared bishop one square diagonally to the left." Recalling the mental imagery of the physical execution of the move on the chessboard demonstrates the players' ability to visualize and plan their actions before making them (Saariluoma et al., 2004; Vasyukova & Mitina, 2013). Additionally, it is important to emphasize that there were numerous other instances of mental imagery in participants' protocols that were coded with one of De Groot's four phases.

The addition of six mental imagery descriptions, which were not coded within De Groot's four phases, would not have notably changed the outcomes. Only the highly skilled blitz group and the competent rapid group had episodic recollections of a mental imagery of a chess move that did

not meet the criteria of one of De Groot's four phases. This is apparent in the comparison of participants' episodic recollections of chess move thought phases, recalled out of four (refer to Table 12), with mental imagery included in recollections, recalled out of five (refer to Table 15). Table 15 contrasts highly skilled blitz players' recollections with and without mental imagery, as well as competent rapid players' recollections with and without mental imagery.

Table 15

Comparison of Episodic Recollections with and without the Inclusion of Mental Imagery

Groups	Episodic		Episodic with mental imagery	
	Position 3	Position 4	Position 3	Position 4
Highly skilled blitz	1.0 (0.8)	1.0 (0.89)	1.4 (0.48)	1.4 (0.48)
Competent rapid	1.6 (1.2)	1.8 (1.16)	1.8 (0.97)	2.0 (0.89)

Note. Means and standard deviations out of De Groot's four phases.

Mental imagery is a subject of considerable interest in chess, extending beyond the game itself to provide insights into skilled imagery—the ability of players to mentally visualize the board, pieces, and potential moves with accuracy and detail (Saariluoma et al., 2004). The ability to construct skilled images increases with skill, which helps highly skilled chess players with the memorization of moves and piece locations (Saariluoma et al., 2004; Vasyukova & Mitina, 2013). The significance of this type of imagery spans across various practical domains, as skilled visualization can be an essential part of expertise in numerous professions (Saariluoma et al., 2004). Nevertheless, we have rather limited information about the exact aspects of skilled images (Saariluoma et al., 2004). Future research could attempt to expand the operationalization of mental imagery to avoid including a questionnaire and/or material that is overly abstract, as this may result in narrow stimuli and inadvertently exclude some vital aspects of crucial theoretical concepts (Saariluoma et al., 2004).

Future studies could include chess players who are expert or above (see Table 1) to establish criteria for the steps, processes, or phases involved in making a successful chess move for each position, which would be used in future EIA research. Experts or above should cross-reference their analysis with a thinking process model, such as the De Groot four phases, and descriptions of the positions from published authors, as seen in Table 4's descriptions of Position 2 (the Fisher/Karpov endgame) and Position 3 (the R. Rozanky—S. Kagan game position, Tel-Aviv 1973). This comparison helps ensure consistency and validity in the experts' or above established criteria. The coding of the data should be done independently by two experimenters, or by one experimenter and a chess player who is expert and above, or by two chess players who are expert and above, to improve the validity of the measure.

Implications and Applications

The practical chess training recommendations for a strongly motivated competitive chess player (Elo 1800), proposed by Gobet and Jansen (2006), align with the implicit, or nonconscious, fast processes observed in highly skilled chess players (Elo 1900-2300) in this chess study. Gobet and Jansen proposed that a player (Elo 1800) should focus on a limited repertoire of chess openings. Additionally, they should incorporate middlegames, endgames, and entire games stemming from their chosen opening into their training. By mastering the general principles and rules of thumb for patterns of play within the chosen opening and its subsequent positions—referring to the various board configurations that arise as a result of the moves made in the chosen opening—a player develops an extensive knowledge of chess configurations that are stored in their memory (Bilalić et al., 2009; Holding, 1992). This approach enhances implicit cognitive fast processes, allowing a player to quickly recognize familiar patterns within their chosen opening and its subsequent positions without conscious effort. Through repeated exposure and practice, these patterns become encoded in a player's memory, facilitating automatic retrieval through pattern recognition during gameplay (Bilalić et al., 2009; Chase & Simon, 1973; Gobet & Chassy, 2009; Gobet & Jansen, 2006; Kiesel et al., 2009; Montero, 2019; Newell & Simon, 1972).

The recommendations emphasize the importance of repetition-based memorization of the strategies and tactics of the positions and/or games a player (Elo 1800) is learning. This method promotes the acquisition of procedural knowledge, where information is absorbed and stored through repeated practice without conscious awareness (Bilalić et al., 2009; Gobet & Jansen, 2006; Kiesel et al., 2009). By consistently studying and reviewing the strategic and tactical elements of the configuration patterns on the board, a player (Elo 1800) reinforces implicit memory traces, facilitating easier recall and application during gameplay (Gobet & Jansen, 2006; Kiesel et al., 2009) This enables a player to execute complex chess moves quickly and efficiently, drawing upon their stored knowledge and intuition.

Gobet and Jansen (2006) recommended that a player with an Elo rating of 1800 engage in cross-referencing and rote learning of deeper strategic and tactical considerations from resources such as opening textbooks, chess software, and chess databases. These materials discuss or exemplify recurring patterns or themes present in the player's chosen opening and subsequent positions. This learning approach strengthens the stored memories of chess piece configurations in LTM in the form of chunks, organized within larger memory structures known as templates (Gobet & Simon, 1996, 2000). When evaluating positions and making strategic decisions, players instinctively rely on these stored templates. Ultimately, Gobet and Jansen's chess training recommendations support a player's (Elo 1800) well-practiced chess moves with procedural knowledge, thereby enhancing their cognitive fast processes. The aim is to increase the player's skill level to Elo 1900 and above, consequently improving their performance in competitive chess matches.

While the strong influence of chess training on cognitive abilities and academic performance has been well-established (Blanch et al., 2017; Easvaradoss et al., 2018; Grabner, 2014), further research is needed to explore its influence on fast processes. Easvaradoss et al. (2018) demonstrated in their study that children of both genders studying in Indian city schools, spanning grades 3-9, after undergoing a chess training program had significantly improved fast processes. This suggests that chess training can effectively enhance fast processes, a crucial cognitive skill.

In the current chess study, fast processes were highlighted as a key factor differentiating highly skilled chess players from competent ones. This correlation underscores the importance of fast processes across various domains. For instance, in medical decision-making, rapid processing speed is vital for healthcare professionals to swiftly interpret patient symptoms, diagnose conditions, and administer timely treatments (Ericsson & Staszewski, 1989; Van Harreveld et al., 2007). Similarly, in engineering, quick processing speed is essential for analysing complex data sets, designing efficient systems, and troubleshooting technical issues in real-time (Ericsson & Staszewski, 1989; Van Harreveld et al., 2007).

Conclusion

In conclusion, comparing this chess study with that of Beilock and Carr's (2001) Experiments 1 and 2, there are overall similarities between the findings as the finding of this study aligns in salient detail to predictions attained from theories of automaticity and proceduralisation of chess performance as a function of practice (Campitelli & Gobet, 2004; Chase & Simon, 1973a; Gobet & Simon, 1996b; Lassiter, 2000; Saariluoma, 1995). The principal finding that EIA occurs in the cognitive sport of chess and that attending to a proceduralised skill diminishes performance is comparable to Beilock and Carr's (2001) principal finding for the sport of golf.

The results of this chess study support De Groot's (1946/1978) and Chase and Simon's (1973a) conclusion that selective search and the role of pattern recognition are more important to the skill of chess. The robustness of pattern-recognition theories, which stress that pattern recognition is a source of look-ahead search, is that they specify structures for both fast and slow processes (Campitelli & Gobet, 2004; Gobet & Simon, 1996b; Saariluoma, 1995). In contrast, search theories, such as Holding's (1985), do not describe how skill effects remain when the time control of making a chess move is reduced to 40 s (blitz condition), and the chess player has almost no time to use search. The current chess study's findings predict that pressure-induced attention to the well-learned structure of chess skill should disrupt execution of chess moves.

Research in this area is needed to test this suggestion and to explain the specific features of the control structures that lead to decrements in chess performance under pressure. The small sample size in the current study is in the tradition of expertise research but is not large enough to make precise quantitative estimates of the procedural memory variables under study. Most importantly, our highly skilled players were exceptionally skilled. Further clarification is needed to address these limitations and a procedure in which a chess player under varied time controls, compete against a computer online is suggested. The statistical power problem can be addressed by replicating this study with a larger sample size. Omitting the random or blitz condition from the study would increase the sample size, provided it aligns with the future research question. Further research into the relationship between expertise and random configurations is needed due to the inherent complexities involved (Gobet & Simon, 1996a).

It was found that De Groot's four phases of the thinking process had limitations, such as coding matches with descriptions of skilled imagery, but the inclusion of skilled imagery in the scoring would not have made a difference to the overall scoring, as can be seen in Table 14. Future research could include mental imagery in the scoring of questionnaires to provide more information about skilled imagery.

The practical implications of this study, informed by Gobet and Jansen's (2006) scientific approach, for a strongly motivated competitive chess player with a skill level of Elo 1800 aiming to reach Elo 1900 and above, suggest focusing on training methods that enhance implicit cognitive fast processes. While the strong influence of chess training on cognitive abilities and academic performance has been well-established (Blanch et al., 2017; Easvaradoss et al., 2018; Grabner, 2014), further research is needed to explore its influence on fast processes. The primary finding indicated that expertise-induced amnesia occurs in the cognitive sport of chess, suggesting an association between skill acquisition and automaticity. These findings align with previous research by De Groot (1946/1978) and Chase and Simon (1973a), emphasizing the importance of fast processes in chess skill.

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Appendix A

New Zealand Recruitment Webpage

Chess Study

School of Psychology, MASSEY UNIVERSITY

My name is Nicholas Barr and I have participated infrequently in chess tournaments around New Zealand and Australia. An online chess study is part of my Master of Science degree at Massey University, Palmerston North, New Zealand. My supervisor is Dr Stephen Hill https://www.massey.ac.nz/massey/expertise/profile.cfm?stref=908630

I would like to invite chess club participants to take part in an online chess study that is looking at the process of finding a chess move. Participants must be over 16 years of age and be able to read and type in English. Currently, I require participants that have played 15 fully rated games, and who either have a FIDE rating of 1900 and above or a National Chess Federation rating of 1400 and under. Please do email any further rating questions to herrbarr@yahoo.com

The purpose of this study is to examine all the possible moves that can be made in a chess position. This study aims to build on cognitive skill studies that examine the thought process for finding a chess move. Direct benefits of participating in this study include an increased awareness and knowledge of the processes involved in research by actively participating in it and a satisfaction in knowing that you are contributing to cognitive skill studies and chess. Foreseeable risks, adverse effects, and discomforts that may be encountered by taking part in this study are minimal.

The time to complete this study will vary between approximately 20-40 minutes. In recognition of the time and participation in this study, participants will be given a Giftpay voucher worth NZ $15.

As a Participant you have the right to access the information collected about you as part of this study. It is important to us that we maintain privacy throughout this study. The names and contact information will be held electronically and stored on the principal investigator's computer only for data recording purposes. Each participant in the study will be allocated a number. Staff involved in analysis will have access to participants' numbers only. All data from test sessions will be recorded against the participant's ID number and their name will never be used in any report, correspondence or publication.

Please email - herrbarr@yahoo.com - for a link to the experiment and a code to access it.

SCHOOL OF PSYCHOLOGY
TE KURA HINENGARO TANGATA

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Appendix B

International Recruitment Webpage

Chess Study

School of Psychology, MASSEY UNIVERSITY

My name is Nicholas Barr and I have participated infrequently in chess tournaments around New Zealand and Australia. An online chess study is part of my Master of Science degree at Massey University, Palmerston North, New Zealand. My supervisor is Dr Stephen Hill https://www.massey.ac.nz/massey/expertise/profile.cfm?stref=908630

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Please email - herrbarr@yahoo.com - for a link to the experiment and a code to access it.

SCHOOL OF PSYCHOLOGY
TE KURA HINENGARO TANGATA

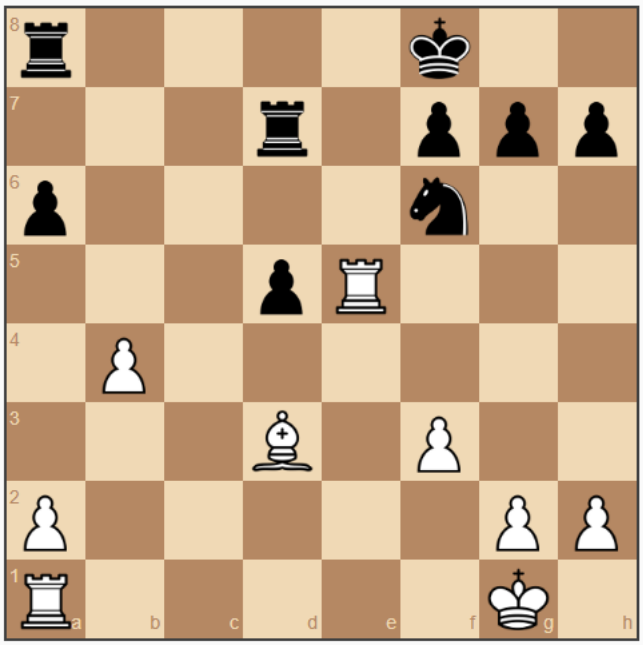
MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Appendix C

Standard Position 1 – De Groot Position A

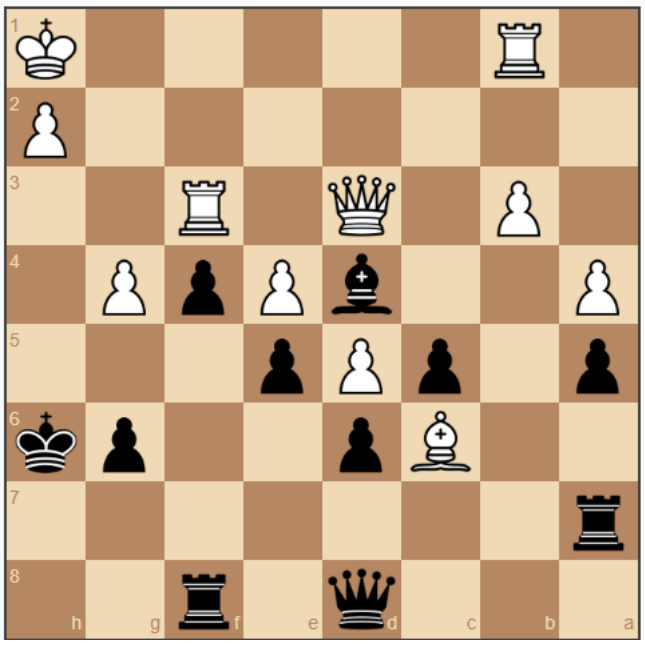
Appendix D

Standard Position 2 – Fisher/Karpov Endgame



Appendix E

Standard Position 3 – R. Rozanky—S. Kagan, Tel-Aviv 1973

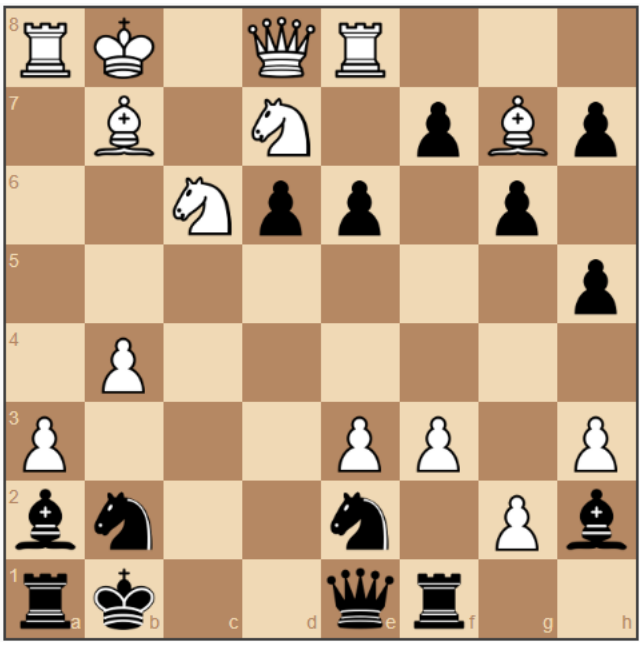


Appendix F

Standard Position 4 – De Groot C

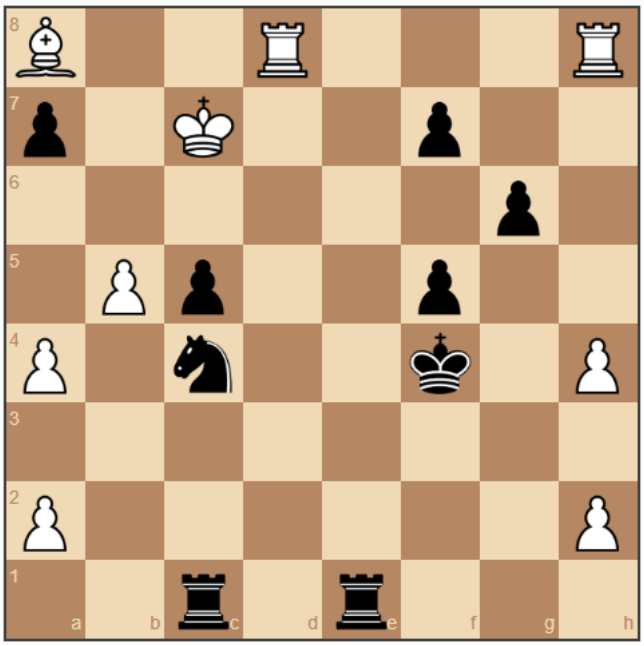
Appendix G

Random Position 1



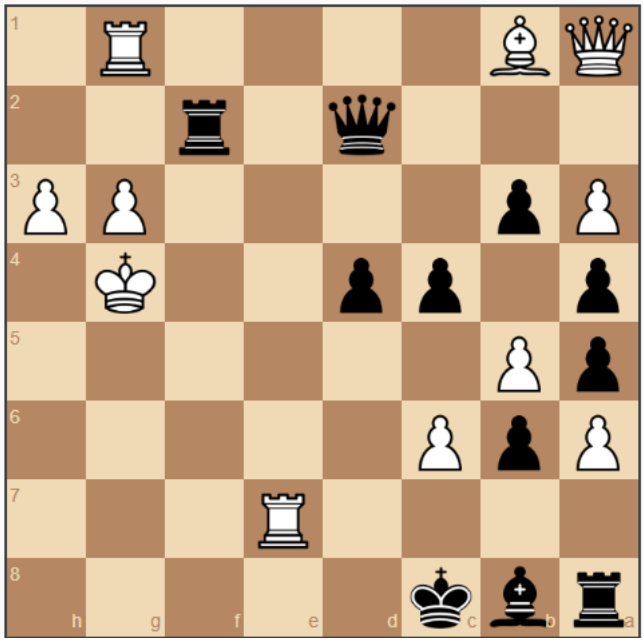
Appendix H

Random Position 2



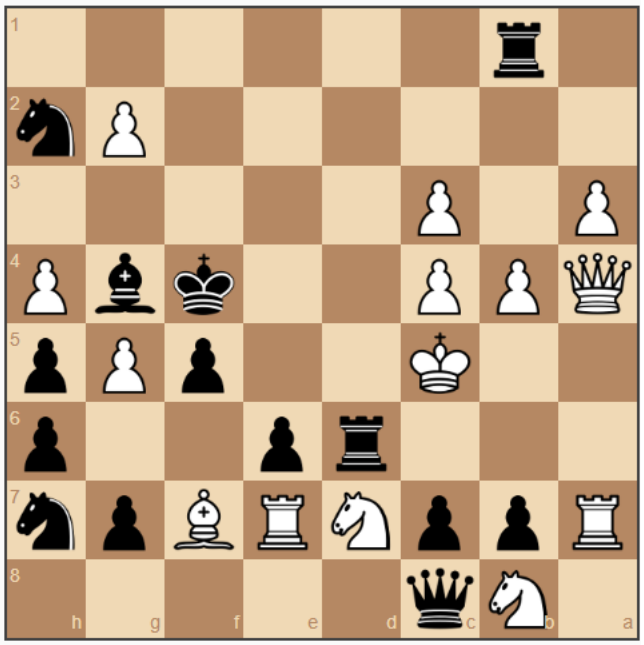
Appendix I

Random Position 3



Appendix J

Random Position 4



Appendix K

Full Instructions for the Rapid and Random Conditions Before Making a Move in Position 1 and 3

You will have a maximum of **four minutes** to make a move in the position presented, but you may find that you can complete the move in less time. A timer will appear on the screen, displaying the time counting down.

Pretend you are playing at The World Chess Championship.

Your game is important but not necessarily the final round when you are playing for big money.

You have decided that you can allow four minutes for making your move in order to still have sufficient time on your clock for the remainder of the game.

Do not do more or less analysis than you would in the above situation, i.e., don't "show off" for the exercise. This is not a "play and win" problem. It is supposed to be an interesting position from a real game and so to look for a "winning" - as opposed to a "best" - move may be a futile effort

Start

Appendix L

Full Instructions for the Blitz Condition Before Making a Move in Position 1 and 3

You will have a maximum of **40 seconds** to make a move in the position presented, but you may find that you can complete the move in less time. A timer will appear on the screen, displaying the time counting down.

Pretend you are playing at The World Chess Championship.

Your game is important but not necessarily the final round when you are playing for big money.

You have decided that you can allow 40 seconds for making your move in order to still have sufficient time on your clock for the remainder of the game.

Do not do more or less analysis than you would in the above situation, i.e., don't "show off" for the exercise. This is not a "play and win" problem. It is supposed to be an interesting position from a real game and so to look for a "winning" - as opposed to a "best" - move may be a futile effort

Start

Appendix M

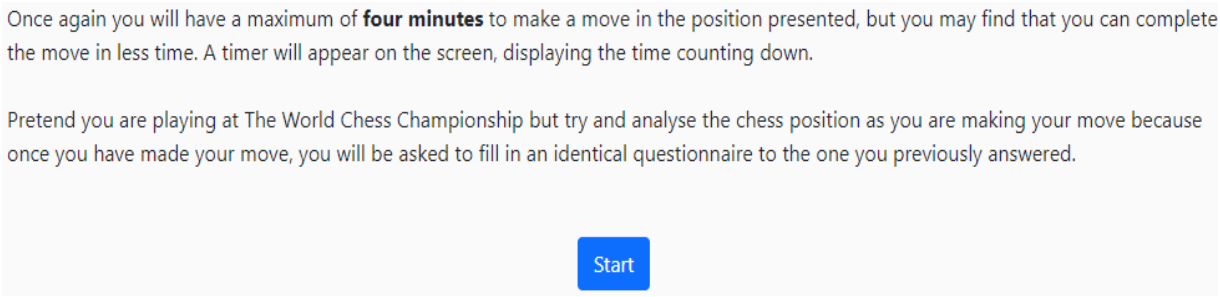
Generic Questionnaire

Write down your analysis of the position you just saw.

Examples could include - the opponent's threats, both sides tactics, what you are trying to do, any of your plans and/or goals, moves you rejected, any other candidate moves you had for best move, and general principles for playing this position.

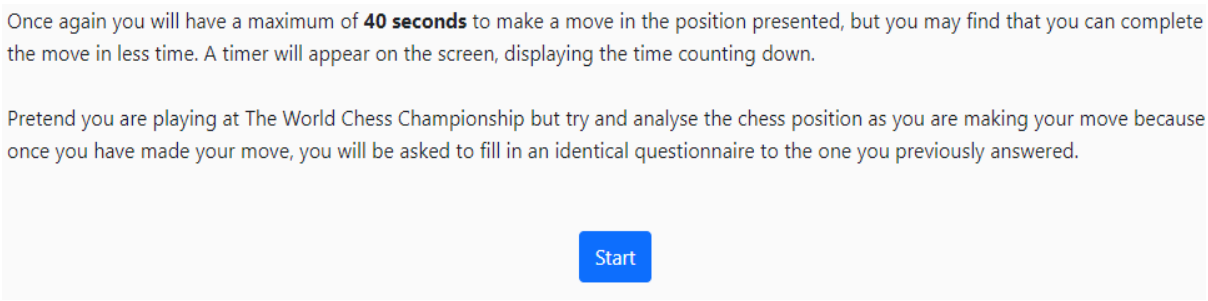
Appendix N

Summarised Instructions for the Rapid and Random Conditions Before Making a Move in Position 2 and 4



Appendix O

Summarised Instructions for the Blitz Condition Before Making a Move in Position 2 and 4



Appendix P

Episodic Questionnaire

Pretend that your friend just walked in the room. Describe the move you just made in enough detail so that your friend could duplicate the move by doing it just like you did.

Additional information - the friend has a basic understanding of chess, and therefore your instructions or recipe need to be written in plain language to allow the move to be duplicated in all its details by the friend who has not seen you making the move.