The Use of Memory and Causal Chunking in the Game of Shogi

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Doing cognitive research in games can give new insights into the processes involved in human problem solving. By studying different games, it is possible to compare similar behavior in different domains. In this paper we present the results of cognitive experiments in *shogi*, a Japanese game similar to chess. We have conducted two memory tasks and one problem solving task in shogi. In general, we got similar results as in chess, but we also found evidence for a new type of chunking, which we call causal chunking.

INTRODUCTION

The cognitive processes involved in human problem solving have been the subject of numerous studies. Probably most famous is the work by Newell and Simon (1972), which has inspired many other researchers in the field.

From early on, games and game theory have played an important role in the study of human problem solving behavior. The advantage of using games for cognitive studies is that they provide an environment that can be easily defined and is almost noise-free. Most games have a simple set of rules and behavior within this set of rules is fixed. Yet games have all the complexity of other, more general, human problem solving tasks. Also, the behavior of experts can be studied and compared to the behavior of players that are less skilled, as in most games it is clear who the experts are.

Chess is being played all over the world, so it is not surprising that most of the cognitive studies in games have focused on this game (De Groot, 1965; Chase & Simon, 1973; Cooke, 1993). The game of Go has also been subject of cognitive study (Reitman, 1976; Burmeister, 1997; Saito & Yoshikawa, 2000).

Studying cognitive behavior in different games makes it possible to compare similar behavior in different domains. To this end, we have started to conduct a cognitive study into *shogi* (Japanese chess) as there have been only very few cognitive studies in shogi. Shogi is a game in which the goal of the game is the same as in chess: capture of the king of the opponent. The most important difference between chess and shogi is that in shogi the pieces that have been captured do not disappear from the game. The pieces a player has captured from the opponent become *pieces in hand* and when it is a player's turn to move, a choice can be made between playing a move with one of the pieces on the board or put one of the pieces that was previously captured on an empty square (this is called a *drop*).

In chess the most famous cognitive experiments are on memorizing positions and have been performed by De Groot (De Groot, 1965). As a follow-up to De Groot's work, Chase and Simon (1973) introduced the theory of *chunking* to explain why expert game players perform so well in memory tasks. Chunking is the process of dividing a chess position into smaller parts that have meaning. Chase and Simon showed that stronger players have bigger chunks of chess knowledge than weaker players.

As a first step in our cognitive study of shogi, we repeated some experiments that were conducted in chess. We felt that repeating these experiments is necessary, as there are some important differences between chess and shogi from a perception point of view. Both the pieces and the squares of a shogi board have the same color (one's pieces can be distinguished from those of the opponent by the shape of the pieces). Also, in shogi the pieces in hand have no relation to a square on the board, thus potentially complicating perception. Furthermore, there are more pieces in shogi than in chess, 40 instead of 32. Finally, it is unclear how the Kanji characters that are written on each shogi piece influence perception.

We will now present the experimental results of two memory tasks and one problem solving task in shogi.

MEMORY TASK 1

EXPERIMENTAL SET-UP

The first question we investigated was how much time it takes for shogi players of different playing strength to memorize shogi positions. We had nine subjects: three beginners, three club players (Japanese grade: amateur 3-dan) and three experts (professional 8-dan). Our experiment consisted of 10 positions from 10 professional games that were taken from the game collection of expert games on a Shogi Yearbook CD-ROM. We selected 2 positions each after 20, 30, 40, 50 and 60 moves played from the starting position in those games. From each game only one position was selected. To make sure that there are no simple opening positions, we started at move 20.

Each position was shown to the subject on a computer monitor. The subjects were given as much time as they thought they needed to remember the positions. When the subject decided that he had memorized a position, he would click an OK button. After clicking the button, an empty shogi board is displayed with the pieces next to the empty board. The position could now be reconstructed by dragging the pieces to the squares. Our system measures the time between the appearance of the position on the screen and clicking the OK button. The system also records the number of pieces that have been placed correctly during the reconstruction stage.

Finally, the eye movements of all subjects were tracked with an eye camera during both the memorizing stage and the reproduction stage.

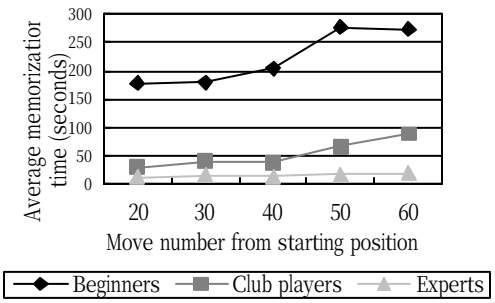

Figure 1. Average memorization time for 10 positions (no time limit)

RESULTS

In Figure 1 we can see that beginners use more time to remember the positions than the club players, who in turn use more time than the expert players. We can also see in the figure that the beginners slow down at positions that are later in the game. Even though this effect is less pronounced for the club players, in Figure 1 we can see that the club players also slow down a little for positions that are later in the game. In contrast, there is almost no difference between the different positions for the expert players. A final observation was that the beginners were often confused during the reproduction stage while the club players and the experts confidently put the pieces on the board.

CONCLUSIONS

We have shown that the expert players can do this memory task very quickly. In Figure 2 we can see how the eyes of an expert moved during the 6 seconds it took to remember this position. The subject focuses on the center of the board and the only time he focuses outside the board is when he considers several times to push the OK button (positioned outside of the board on the right). This indicates that the expert player can memorize the position faster than the 6 seconds he actually took, but that he just checked the position a couple of times to make sure. The difference with Figure 3 is clear. Figure 3 gives an example of the eye camera data of a beginner. The beginner needs to look at every piece of the board and tries to remember them individually.

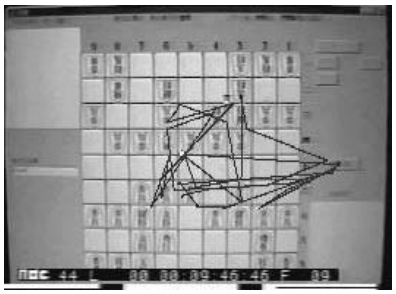

Figure 2. Eye tracking diagram of an expert

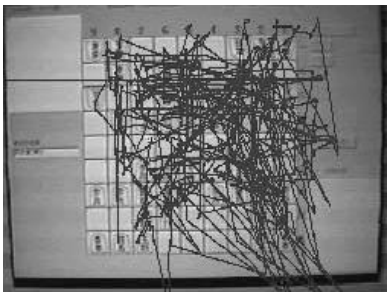

Figure 3. Eye tracking diagram of a beginner

MEMORY TASK 2

EXPERIMENTAL SET-UP

In this experiment we will show the connection between shogi playing strength and memorizing ability. The set-up is similar to the previous experiment, but this time there is a time limit of 3 seconds. Of course, different positions from the ones used in the previous experiment are presented to the subjects. After showing the position for 3 seconds, the position is removed from the display automatically and an empty board is displayed onto which the subjects must move the pieces with the mouse. We also wanted to analyze the connection between memorizing abilities and shogi knowledge. To this end, we also presented a number of random positions to the subject in the same way as the "meaningful" positions. In this experiment, the eye movements of the subjects were also tracked with an eye camera.

RESULTS

In Figure 4 the accuracy results by playing strength are given. The average score of the beginners is very low and gets lower as the number of moves played to reach a position increases. The scores of the club players and the expert players are almost equally high at the start. However, as the number of moves increases, the club players accuracy rates decline, while the expert players are still capable of scoring close to 90% in the positions after 60 moves (advanced middle game positions).

In Figure 5, the results by playing strength are given on the random positions. From these results we can see that there is almost no difference between the subjects. In all cases the average accuracy is very low.

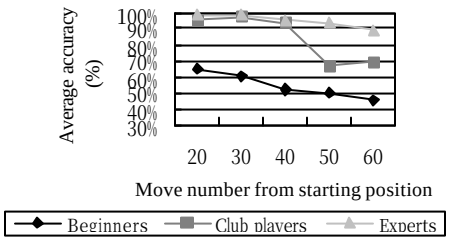

Figure 4. Accuracy rates for memorizing 10 positions with 3 seconds time limit.

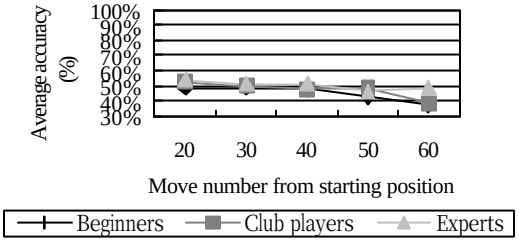

Figure 5. Accuracy rates for memorizing 10 random positions with 3 seconds time limit

CONCLUSIONS

Like in the first experiment, we can see from the eye camera data in Figure 6 that the beginner tries to memorize each piece individually. However, soon time runs out and the beginner is only able to put a few pieces on the right squares. On the other hand, the club player is able to get the same accuracy results as the expert player in the early stages of the game, but in positions that are more advanced in the game, the accuracy goes down rapidly. Unlike the club player, the expert player is still able to achieve a 90% accuracy rate in middle game positions, so it can be concluded that even for difficult middle game positions, the expert has chunks to help memorize positions.

Figure 6. Eye tracking diagram for the beginner in memory task 2

Furthermore, the expert players scored just as low as the beginners in the random positions generated for 20 to 60 moves from the starting position. Therefore, we can conclude that the outstanding memory performance of the experts is not a result of exceptional memorizing ability, but is caused by the availability of superior shogi knowledge (chunks) to memorize positions.

PROBLEM SOLVING TASK

EXPERIMENTAL SET-UP

We have presented 15 shogi problems that were constructed with the help of an advanced player to the nine subjects. During the problem solving stage of each problem, we asked the subjects to think aloud and also used the eye camera to track the eye movements.

RESULTS

Here are three typical examples of the think-aloud protocols by the subjects.

Problem 6 (Beginner)

*Last move: R7d. It seems like the defense of the opponent is quite weak. If we play Rx3b+ next, isn't it immediately finished…Maybe it is not finished…Rx3b+ Sx3b. Not good. Hey, but I want to do something like that. How about P*2b?*

Problem 6 (Club player)

*Next, after Bx7g+ there is a fork on king and rook and that is the end. So we should play R3f, but then P*2h loses the knight, so we should move R2d and then after Bx7g+ Sx7g Rx2d, we have the fork on rook and king B*1e, after which P*2c Bx2d Px2d stops the drop of the pawn on 2h, so black seems to be better.. If we just play B*8c, then…*

Problem 6 (Expert)

*This does not look like a position I have seen before. But then again, it looks familiar. It is black to move, right? This position resulted from P*3h Sx3h B*4d, isn't it? P*3h Sx3h B*4d, pawn drop, pawn drop, pulling back the rook. R2d is my first impression. Then Bx7g+ Sx7g Rx2d B*1e R*2e…*

CONCLUSIONS

The beginner analyzes the position in parts, realizing on the way that certain moves are possible ("How about P*2b?") and changes the evaluation of the position accordingly, ending up with the best looking move.The club player seems to analyze the position as a single chunk, and bases his move selection upon certain typical features of the position ("After Bx7g+ there is a fork on king and rook"). The expert player is able to analyze not only the position as it is, but also has chunk knowledge of how it came about ("This position resulted from P*3h Sx3h B*4d, isn't it?"), what plan should be pursued and how the position should be evaluated. As can be seen in the think-aloud protocol example, the expert talks about which move sequence lead to the position, and combines this with the evaluation of the position.

DISCUSSION

In the three experiments that we have conducted, it has been shown that in shogi, chunks similar to the ones observed in chess are being used. In the experiments it was shown that the perceptual differences between shogi and chess do not have an important effect and lead to similar results as those observed in chess. Especially expert shogi players are able to include pieces in hand into their full board chunks and can reproduce a position from memory with about 90% accuracy even when the memorization time is limited to only 3 seconds.

In the first experiment we saw that the beginners tried to memorize pieces one by one. Therefore, the beginners seem to have only chunks that are the size of a single piece and memorizing a complete board position takes a very long time. In contrast, from the eye camera data of the club players, we can conclude that they are able to divide the position into several areas. A position is divided into several chunks, each containing several pieces. This is further evidenced by the think-aloud protocol of the third experiment, where the club players talked about common piece configurations like *Yagura* and *S3g-formation*.

Finally, the expert players are capable of recognizing large chunks, sometimes even complete board positions as a single chunk. From the eye camera data we can see that in some positions the expert players only focus on the center of the board, so it is quite likely that the full board position is recognized as a single chunk. In the think-aloud protocol for these positions, the expert players do not say anything about the position as it currently is, but immediately start talking about the possible move sequences, about how this position came about and how the position should be evaluated. This also seems to indicate that not only the position is recognized as a single chunk, but also that it is part of a logical flow of positions or dynamical chunks. The reasoning from the position at hand to the evaluation and the next best move seems to be part of a causal chain.

Table 1.
Playing Strength and Chunk Structure

	Board level	Sequence level	Evaluation level
Beginner	Individual piece		
Club player	From individual piece to full board	Simple combinations, Standard opening moves	
Expert	Full board	Applying combinations, Subtle opening play	Correct search supporting correct evaluation

Our results are summarized in Table 1. The expert player not only relies on board level recognition, but also uses dynamic sequence level and evaluation level knowledge to support the problem solving. Therefore, we believe that chunking is not only done on the level of pieces and their positions, but that also dynamic chunks like move combinations and opening sequences are being used. Furthermore, these *causal chunks* also are used to evaluate the position.

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