

# Chunks and Problem Solving Processes in an Expert's Play in a Card Game

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**Summary:** In this study, we have focused on chunks which are configurations of tableau cards in a card game. We performed experiments on subjects to clarify how experts deal with the incomplete information problem, and examined the results. Regarding this card game, we suggest that a key of problem solving is the knowledge which controls the cycle of composition and recognition of flexible chunks.

## 1. Introduction

Human problem solving has been one of important research topics for cognitive science, and has been studied for many years. In those researches, the objects are changing from the one which does not require domain-specific knowledge to the one which needs specialist knowledge, also, from the one which can be solved algorithmically to the one which does not have explicit procedure for problem solving, and the more realistic problems are coming to be treated. Moreover, the differences between novice and expert are focused on, relating to the research of learning process (Chi, Feltovich & Glaser, 1981).

The cognitive research on game

Calculation is a game in which incomplete information is treated. The player should move all cards of the shuffled deck onto the foundations which should be built up in a defined way. If he won't move a card onto the foundations, he can place it on any of the four tableaux. Therefore, the key of this game is how to use the tableaux. This game belongs to an ill-structured problem which has no explicit procedure for solving. The success rate differs among persons, experts can play successfully at 95% or more, but novices can do at almost 0%. It can be improved by learning greatly. Besides, there are some alternatives in the selection of moves at each situation even when succeeding.

In general, it is assumed that human decomposes the pattern into some partial patterns, recognizes, memorizes and recalls them as chunks. Chase and Simon show that the chess experts have structured knowledge concerning a lot of patterns of chess position in long-term memory, collate with the patterns, recognize chunks, and memorize them efficiently (Chase and Simon, 1973). The reason why the experts are strong is that they can recognize chess positions by using

playing has been done for a long time, in recent years a task of game is by no means recognized as a toy problem but as the more realistic problem which includes some important research topics such as perception, memory, problem solving, learning and so on. Though such researches mainly consider the non-probabilistic, open, two-person, turn-taking, zero-sum games such as chess, we have adopted a solitaire named Calculation as a task in this study (Kobori, Fujii & Nakamura, 1998).

chunks based on the huge knowledge, hit on good moves immediately and select the best move, searching moves ahead in their mind and memorizing them.

In contrast with it, in case of Calculation, the experts do not seem to maintain a lot of concrete patterns of card position in long-term memory, judging from the character of the game in which it is impossible to forecast the next cards. It would not be so effective to search moves ahead because there are a lot of numbers of situations. Not only in case of game, experts have different viewpoints from the ordinary people, and there are great differences concerning the selection and the following processing even if the same information is given. Hence, the features in problem solving of experts are not only abundant knowledge and efficiency of memory due to recognition of chunks using the knowledge.

Shingaki and Yoshikawa have investigated not only spatial chunks but also sequential chunks as regards the game of Go (Shingaki and Yoshikawa, 1994). Walczak and Dankel have introduced the idea of strategic and tactical chunks in chess (Walczak and Dankel, 1993). On the other hand, in Calculation, we suppose that experts recognize some configurations of tableau cards as significant chunks when moving a hand card onto tableaux or perceiving a position of tableau cards, consequently such chunks show procedures or strategies.

Then, in this paper we aim to examine how experts deal with the incomplete information problem by using chunks concretely, to clarify the features in problem solving processes and

## 2) Analysis by the verbal data

By using the data of videotapes, the compositions of chunks and the achievements of plans were analyzed, and the stages of decision making were classified.

## 3. Results

### 1) Analysis by the operation data

When detecting chunks from positions of tableau cards, more long chunks were counted than short chunks as regards the expert's data. This fact was especially remarkable for difficult hand data, compared with the novices.

Consequently, the expert appears to

strategies of experts in Calculation from viewpoint which we claim that composing chunks and recognizing them play important role.

## 2. Method

### 2.1 Experiment

The subjects were one person who was assumed to be an expert (the success rate is over 90%) and 12 persons (called novices here) who had had no experience in playing this game.

As regards the expert, 10 trials were performed (the results were eight success cases and two failure ones). The card operation data were recorded in a computer, while the behaviour data were recorded on videotapes by using the verbal protocol experiment method. The interview after each trial was also executed

As regards the novices, 30 trials were performed, and the operation data were recorded. As for the last 10 trials of the 30 trials, the same hand card data as the data for the expert were used. Regarding three trials of two novices, the behaviour data were recorded on videotapes and the interview after the trials was executed.

### 2.2 Analysis

In analysis, we define chunks as configurations of tableau cards which correspond to patterns of cards the players were presumed to perceive or recognize.

#### 1) Analysis by the operation data

The chunks were presumed from positions of tableau cards, and were detected and counted in each length.

have an ability which enables himself to compose longer chunks and deal with difficult hand data.

#### 2) Analysis by the verbal data

It was clarified that a lot of overlapping chunks over two or more tableaux were composed as regards chunks of the expert.

Accordingly, the expert understands the character of game, for instance, some cards can move onto which foundations, and so he can compose flexible chunks which does not qualify the possibility of use of tableau cards.

Regarding the achievement of plans of the expert, it was clarified that there were several cards put on tableaux at the early stage which did not move onto foundations so exactly as he had mentioned before and that in case of consistent moves he mentioned two or more possibilities. There were not so many examples of mention about changes of the plans.

Judging from these facts, the expert has not only judgment to enable to change plans but also design to enable to place cards in such ways.

By analyzing the processes of decision making, it was clarified that the expert's statements included ones by intuitive judgments and logical analyses, that the processes can be classified into several stages, that each stage in decision making related to recognition of chunks, that statements concerning chunks include procedural information, and so on. On the other hand, it was indicated that the novices did not consider the cards which had not appeared yet, and that they tried to fix plans of tableau cards as early as possible, and so on.

The chunks which had overlapping composition were also detected and counted.

From comprehensive analyses, we guess that the differences between expert and novice are at the stage of decision making, that recognition of chunks and strategies are related strongly as for experts, that experts can deal with intuitive judgments and logical analyses according to the situations, and so on.

#### 4. Discussion

##### 1) Composition of chunks

From the results mentioned above, experts appeared to be excellent in the ability of composing complex chunks and recognizing them. This can be explained by not only the fact that having many structured knowledge is essential in order to become an expert but also the fact that the appropriate interactive mapping between the external world and the inner world is necessary. Namely, while constructing tableau cards for the externalization of internal chunks, experts consider not only the present hand card and tableau cards but also the cards which have not appeared yet. Since configurations of tableau cards have reflected experts' intention of moves till then, they can understand the intention when recognizing the chunks.

We can say that experts do not only accept situations of tableaux passively but also operate them actively. In a word, experts can cope with situations flexibly because they construct the position of tableau cards as an external environment that can be operated directly. This would be common in some respects as regards the effect

According to Dreyfus, the intuition means judgment by recognizing the similarity with experiences of the past (Dreyfus & Dreyfus, 1986). In case of chess, not only is a situation, when seen as similar to a prior one, understood, but also the associated decision, action, or tactic simultaneously comes to mind. Experts depend almost entirely on intuition.

In case of our expert of Calculation, intuitive judgements are not so many and logical analyses are much more at a glance, so his stage seems to belong to the previous stage of expert (stage 4: proficiency) in the distinction by Dreyfus.

However, since the most important decision for selection of moves is made by intuition and logical analyses are used in the other auxiliary processes, his stage would show the feature of expert which Dreyfus mentions. The experimental condition in which the subject was instructed to think aloud would have caused a lot of analytical statements.

Moreover, when the problem is actually processed (for instance, the game between experts), logical analysis would play an important role. The ratio of intuitive judgements and logical analyses depends on the character of the task. Especially, in case of Calculation, judging from the character of the game, deliberate selection for concrete moves is required frequently.

##### 3) Strategies and problem solving

Since the statements referred to the

which drawing and memo give problem solving (Ito, Ohnishi & Sugie, 1992). Experts appear to cope with incompleteness of information by knowing well about the character of the game, by utilizing it, and by devising the arrangements of tableau cards which enable themselves to change plans.

## 2) Processes of decision making

By analyzing verbal data mainly, we guess that intuitive judgments are empirical and based on visual image, and that logical analyses are deliberate and based on verbal representation.

Although this may be true, intuition and logic also are no more than the classification from the verbal data. Some intuitive expressions may be based on logical analyses, and some logical expressions may be explanation for intuitive judgments.

chunks include information about procedures, we guess that the problem solving, namely, playing the game, is ongoing while repeating the following cycle: The recognized chunk relates to the strategy in long-term memory, and is developed as sequence of concrete moves in short-term memory. The result reflects the selection of moves, if the card is put on tableau, new chunk is composed, and then the new situation is recognized with the following hand card.

In such an interactive cycle, chunks change dynamically in connection with strategies, and are utilized for decision making. Consequently, chunks do not only play a role of assistance of human memory which Chase and Simon show but also chunks lie in the centre of information processing for problem solving.

From the verbal data, it is clear that experts use visual images, we suppose that strategies are associated with the visual images as well as in chess. However, judging from the character of this game and the verbal data of the expert, we guess that experts do not search moves ahead so deeply as in chess, that experts regard the interaction which makes use of chunks, and that the interaction is controlled by strategies in long-term memory.

## 4) Comparison with novices

As for novices, selection of moves by intuitive judgments is sometimes incorrect, and also some processes in logical analyses which experts use are lacking. However, novices are capable of recognizing chunks, enumerating plans of cards, moving cards according

It is difficult to consider the knowledge in long-term memory and its internal representation directly from the results of experiments here. After all, since experts play the game with controlling the complex position of tableau cards flexibly, the system does not seem to have a simple mechanism which collates recognized chunk with concrete pattern in long-term memory, but seems to utilize the abstract knowledge mainly. In future research we will reveal how the chunks experts use are associated with their strategies and how they are represented internally. It is also important to model them and verify the model by simulation.

For further information as regards our study, including the rule of Calculation, refer to the following web site:

to plans, and changing plans. These would indicate that the ability to combine some effective chunks and recognize them is very important in practice but novices do not have such ability adequately.

Novices not only ignore some remarkable points but also do not have appropriate viewpoints in each situation. Besides, novices try to fix plans of tableau card as early as possible, which seems to be for reducing their cognitive load. On the other hand, experts do not utilize so much information, but pay attention only to necessary information when it is necessary. If only experts put a hand card to tableau according to chunks in their mind, they can understand the meaning when seeing the chunk again, so they need not to memorize it. We suppose that experts usually process tasks by intuition based on experiences and try to think logically only when it is necessary, which would really reduce their cognitive load.

## 5. Conclusion

We suggest that problem solving processes of experts involve the cycle of composition and recognition of flexible chunks, and that the strategies derive from the knowledge which controls such a cycle. Further, we guess that experts solve the problem by making use of the character of the game, in spite of the limitation of capacity of information processing. In a word, we can say that a key to deal with the incomplete information problem and solve the problem is the knowledge which controls the cycle.

<http://milan.elec.ryukoku.ac.jp/>

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