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ABSTRACT

The nature and development of semantic processing in chess was investigated in a study involving younger players from 6 through 18 years of age. Efforts were directed toward establishing the assertion that skilled players' memory for chess positions depends largely upon the availability of pre-stored schema (PSS) that are both abstract and semantically organized. Subjects were players at the 1985 Tennessee Scholastic Chess Championship who had ratings of 1100 or above. In the first experiment, a total of 46 subjects participated in a midgame task and 48 participated in an endgame task. Subjects were shown target boards for 10 seconds, read accompanying context descriptions when appropriate, and reconstructed from memory as much of the display as possible. Performance was measured by number of correctly placed pieces. In a second experiment, subjects were shown midgame positions they had viewed previously and were asked to reconstruct them, looking at the displayed model as often as necessary. Taken together, data from the memory and reconstruction tasks lend strong support to the general hypothesis that abstract, semantically organized PSSs are an important component of chess cognition, and to several special cases of that hypothesis. Data also disclosed age-related qualitative differences in the cognitive mechanisms for constructing representations of briefly presented chess positions. (RH)

ABSTRACT SCHEMAS IN CHILDREN'S CHESS COGNITION

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Abstract Schemas in Children's Chess Cognition

DeGroot (1946/1965) studied top level players (master through grandmaster) and found that after a 5-second exposure to a pictorial representation of an actual game in progress, top-level players typically can accurately reconstruct virtually the entire board from memory. Chase and Simon (Chase & Simon 1973; Simon & Chase, 1973; Simon & Gilmartin, 1973) hypothesized that during stimulus presentation, subjects recognize patterns of pieces on the board as corresponding to pre-stored chunks in long term memory. Labels for these patterns supposedly are placed into short term memory, up to the limit of 7 plus or minus 2 items. These labels are then supposedly used to search long term memory to recover the pre-stored chunks. According to this theory, highly skilled players have vast numbers of chunks stored in long term memory, whereas less skillful players have fewer and smaller chunks; hence the difference in chess recall. Also, many of the pre-stored chunks in long term memory have associated with them a list of "plausible moves." This theory was strengthened by results showing that the superior chess recall of skilled players disappeared when they were shown randomly generated chessboard scenes, rather than scenes from actual games in progress.

Charness (1976) challenged this view by showing that recall of briefly presented chess positions is hampered only slightly by a 30 second interpolated task, even though recall of nonsense trigrams is hampered very extensively by the same interpolation task. He concluded, therfore, that virtually all the information the subject encodes from

the chess position is stored directly into long term memory. Further evidence for this conclusion was provided by Frey and Adesman's (1976) finding that two middle game chess positions presented in sequential 8 second exposures can be remembered nearly as well as one. Yet Chase and Simon's model had suggested that one middle game position (i.e., about 24 pieces) virtually saturates short term memory.

Later research applied Craik and Lockhart's (1972) "levels of processing" hypothesis. Goldin (1978), for example, found that in forced-choice recognition involving chess positions, ratings were higher in recognition accuracy, confidence, and familiarity when the original task involved semantic processing (choosing a move) as opposed to a structural task (piece counting).

Although it is no doubt true that performance on the DeGroot memory task is a function of the level of processing, and that players' ability to engage in rapid semantic processing of chess positions increases as their chess skill increases, these facts alone provide little theoretical insight into chess cognition. What is the nature of semantic processing in chess, and how does it develop?

In the present study we address these questions, by focusing on younger players aged 6 through 18. We seek to further elaborate the "levels of processing" approach, by advancing and testing some relatively specific hypotheses about chess-related semantic structures and processes. Since chess skill is not an isolated curiosity, but rather a paradigm of highly sophisticated cognitive ability, the attempt to understand the development and operation of semantic processing in chess is likely to have important implications for cognitive and developmental psychology generally.

Our theoretical orientation will center around the concept of schema. We will use pre-stored schema to refer to the memory structure which one draws upon when examining a board. Semantically constructured representation (SCR) will refer to the items which then are deposited into memory and which code information about the presented material. Lane and Robertson (1979) suggest that better players are more adept than weaker players at constructing, and then placing into long term memory, rich and elaborate SCR's. The ability to construct better SCR's depends in turn upon access to richer, more elaborate, PSS's.

The most general and fundamental assertion we seek to establish is that skilled players' memory for chess positions depends largely upon the availability of PSS's that are both (i) abstract, and (ii) semantically organized. Abstractness here means that a given PSS can be instantiated in various ways by different configurations of pieces. (For example, the same relationships among pieces might be maintained if a queen were substituted for a bishop. The "meaning" of the position can be preserved even if actual pieces differ, as long as their roles stay constant.) In contrast, a non-abstract PSS is one that represents a specific configuration of pieces. In the early theorizing about chess memory (Chase & Simon, 1973; Simon & Chase, 1973; Simon & Gilmartin, 1973), the only PSS's posited were non-abstract ones depicting specific piece configurations. Semantic organization means that a given PSS is structured around certain features which have chess related meaningfulness. In general, these features will not be associated in any simple way with the specific placement of specific pieces.

We also seek to establish several somewhat more specific hypotheses. Each can be regarded as a special case of the general

hypothesis of abstract semantic organization.

1. Diachronic organization. This is the assertion that many of the relevant PSS's are instantiated not by any single position but rather by sequences of positions. This is because, as one of our subjects said, "A chess game is a story; you have to know the players and the plot."
2. Global tactical/strategic organization. This is the assertion that many of the relevant PSS's are instantiated in ways whose salient common characteristics involve tactical or strategic considerations, rather than involving superficial similarity of pieces or piece positions. For example, a player may not organize the board in terms of pieces but rather in terms of opportunities (a back row check mate), obstacles (a strong pawn chain), or temporal concerns (lost tempo).
3. Overlapping instantiation. This is the assertion that when several PSS's are present, there is often a significant overlap in the piece configurations that instantiate the different PSS's. This hypothesis contrasts with the view that PSS's are used to segment a position into "chunks" which are largely discrete and non-overlapping. This discreteness hypothesis, as we shall call it, was tacitly made in much of the early literature on chess memory. Indeed, it was largely implicit in the early use of the term 'chunk.' If the important PSS's are often abstract, global, and semantically structured, as we maintain, then one would expect overlap of instantiations to be common.

Experiment 1: The Memory Task

Stimulus Items

This experiment employed a memory task of the kind used originally by DeGroot and more recently by various other investigators, but with certain variations. A scene depicting a chess game in progress was briefly presented, and the subject was then asked to reconstruct it from memory. The boards varied in three ways yielding eight types of board.

Context. For half of the trials, a context statement preceded the presentation of the board. Typically this description said which side (black or white) was on move, and then added a brief general comment mentioning strategic/tactical considerations without mentioning specific pieces on specific squares.

Board Types. We also used a variety of different board types:

1. Loud versus Quiet. DeGroot's original positions were all "quiet" rather than "loud"; i.e., all were positions in which a piece exchange was not in progress. Our loud positions came from the same games as the corresponding quiet ones, but at a slightly earlier (or later) stage; thus, there were minimal extraneous differences within pairs of corresponding quiet and loud midgame positions. Figure 1 gives an example of a loud and a quiet stimulus item.

Insert Figure 1 about here

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2. Endgames and Fischer puzzle boards. We chose quiet endgame positions from grandmaster games described in Chess Life, and realistic later-game positions used for instructional purposes in Fischer et al. (1966). (The latter all involve actual or potential attacking situations--often situations where forced checkmate is

possible in a series of moves.) Figure 2 gives an example of each type.

Insert Figure 2 about here

Predictions

1. Performance and chess skill will be related. This result is fully to be expected, in light of prior findings of such correlations among adult players.
2. Overall performance on loud midgame positions will be inferior to performance on quiet midgame positions. Further, this result will be more pronounced in the no-context condition. Quiet positions more often represent the initial stage in a multi-move sequence while loud positions always represent a move in the middle of a sequence. This would make the quiet positions less ambiguous and hence easier to reconstruct. If PSS's are not abstract, then it is difficult to see why loud boards would be more difficult since piece exchanges represent very common configurations.
3. Context descriptions focusing on tactical/strategic features will improve performance.
4. Context descriptions will have a stronger positive effect, overall, on performance with the Fischer positions than on performance with either the endgame positions or the quiet midgame positions. This is because Fischer positions, too, involve an important diachronic element.

Method

Subjects. Players at the 1985 Tennessee Scholastic Chess

Championship, with USCF ratings of 1100 or above, were invited to be subjects. A rating of 1100 is two standard deviations below the mean for all tournament players in this country. An 1100 player can beat most adult recreational players. Fifty-nine players between the ages of 6 and 18 participated in one or more activities. Table 1 gives the breakdown of subjects by grade level and skill level.

Insert Table 1 about here

Procedure. Forty-six subjects participated in the midgame task and 48 in the endgame task. Subjects were shown the target boards for 10 seconds. When a given item had an accompanying context description, that description was read to the subject immediately before seeing the presentation. After each presentation the subject was asked to reconstruct from memory as much of the board as possible.

Results and Discussion

Performance was measured by the number of correctly placed pieces. Performance of subjects at all ages and skill levels was affected by the type of board and by the presence or absence of context descriptions. Overall performance in the context conditions was significantly better than in the no context conditions ($t(47)=2.04$, $p<.05$). Context helped most in loud games and in Fischer boards. Overall, performance on quiet midgames was better than on loud midgames ($t(45)=-1.25$, $p=.1$, one-tailed test.)

Age and skill. As expected, age and skill level were highly

correlated, r=.48. In general, performance was more highly correlated with skill than with age. The last column in Table 2 shows the partial correlations with the effects of age partialled out. With the exception of end games, performance was more highly correlated with rating in the no context conditions, suggesting that the context acts as an equalizer.

Insert Table 2 about here.

Developmental results. The results can be summarized as follows:

1. For the positions that are easier to analyze semantically (the endgame and quiet midgame positions), context descriptions are helpful mainly to primary players and junior high players; yet they actually somewhat hinder the overall performance of elementary players and high school players.
2. For the positions that are harder to analyze semantically (the Fischer positions and loud midgame positions), context descriptions are again most helpful to junior high players, but they no longer strongly benefit primary players. Their overall effects for non-junior-high players are sometimes somewhat positive and sometimes somewhat negative.
3. There are no discernible patterns of skill-related context effects for any of the four kinds of position.

This rather striking pattern may have to do with qualitative differences in cognition as suggested by Piaget and how those differences might affect SCR formation. At certain ages (primary school age and junior high age for the easier positions; only junior high age for the more difficult ones), players are able to make very effective

use of context descriptions in their SCR formation processes, thereby substantially improving their performance in the memory task over the corresponding no-context performance. But at other ages, they are much less able to use context descriptions effectively as a way of improving SCR formation. In fact, in some instances the context descriptions actually seem to interfere with the SCR formation mechanisms, causing performance in the context condition to be weaker than in the corresponding no-context performance. It is possible that children in the beginning of a stage (concrete operations and formal operations) tend to be more receptive to new ways of categorizing and conceptualizing their environment. This greater receptiveness might manifest itself in a greater tendency to form new kinds of SCR's.

Experiment 2: The Reconstruction Task

Method Subjects were shown midgame positions that they had viewed previously in the memory task. The boards were placed in the bottom of a box, and subjects were asked to reconstruct the position using pieces and a board outside the box, looking back into the box as often as desired. Chase and Simon interpreted the successive piece groupings, constructed from each successive glance back to the reference position, as separate "chunks" of the kind which they claimed were also identifiable as units in the memory task.

The positions used were midgame positions (either loud or quiet) which the subject had already seen in the memory task. (Two other tasks had been interpolated between the midgame memory task and this one.)

Results and Discussion

General results. We found, as did Chase and Simon (1973), that the

size of the average perceptual unit increased as the skill rating increased (r=.25, pr=.10). (Our master level subject correctly placed all pieces without looking back.) Perceptual units also increased in size as age increased (r=.38, pr=.31).

The average size of a subject's first perceptual unit is correlated more strongly with age than with skill. This suggests that the size of perceptual units is more a matter of increased memory capacity due to maturation, and is not a crucial factor in chess skill. Such a result is entirely consistent with our position, but is damaging to the contention that the crucial PSS's in DeGroot-style memory tasks and in lookback reconstructon tasks are non-abstract representations of specific piece configurations. For, those who maintain the latter position have consistently claimed that the difference between stronger and weaker performance is a function of the size of the configurations allegedly represented by the relevant PSS's. If this were true, then presumably the average size of perceptual units in the reconstruction task would have been correlated more strongly with skill than with age, and not the other way around.

Skill and age, loud and quiet. We examined the size of the first perceptual unit in relation to skill, age, and the loud/quiet distinction. The first perceptual unit in a quiet position is correlated more with rating (r=.46, pr=.40) than with age (r=.26, pr=.08). Interestingly, the quiet positions did not produce larger perceptual units until skill was above 1300. For loud positions the opposite is true: there is no relationship (or a negative one with age partialled out) with rating (r=.004, pr=-.18), but there is one with age (r=.36, pr=.40).

If one supposes that subjects in this task are responding primarily to local piece configurations that instantiate non-abstract PSS's, then loud and quiet results ought to be very similar since on a perceptual level the boards are almost identical. On the other hand, if perception of a position is governed largely by PSS's that are abstract, global, and semantically structured, then this loudness effect becomes much more understandable. Subjects perceive the position not merely as a collection of familiar piece configurations, but also as a semantically significant whole. Loud positions are substantially harder to analyze semantically. Thus, the loudness effect is further evidence for the abstactness of the relevant PSS's.

Look-backs. On the average, it took 9.5 glances at the target position for subjects to reconstruct the position. Loud and quiet positions did not differ significantly in average number of glances used. Younger children and lower rated ones needed more perceptual units to complete the task. Skill level is closely related to the number of perceptual units used to complete the reconstruction, with more advanced players needing fewer glances ($r=-.36$, $pr=-.27$). Age is also related to the number of perceptual units ($r=-.25$).

General Discussion

Taken altogether, the data from the memory task and the reconstruction task lend strong support to the general hypothesis that abstract, semantically organized PSS's are an important component of chess cognition, and to several special cases of this hypothesis. First, many of those PSS's are organized around global tactical/strategic features. Second, many of them have diachronic

structure. Third, many of them are instantiated in overlapping ways in specific positions, rather than dividing the board into discrete segments. In addition, the data about context effects in the memory task support the hypothesis that there are important age-related qualitative differences in the cognitive mechanisms for constructing SCR's of briefly presented chess positions.

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