JOURNAL OF VERBAL LEARNING AND VERBAL BEHAVIOR **18**, 257–273 (1979)

Acquisition of Domain-Related Information in Relation to High and Low Domain Knowledge

HARRY L. CHIESI, GEORGE J. SPILICH, AND JAMES F. VOSS

University of Pittsburgh

This research was concerned with how knowledge of a given topic influences the acquisition of topic-related information. The knowledge domain studied was baseball, and a knowledge structure was postulated which included the goal structure as well as the states and actions of the game. In each of five experiments, passages of domain-related information were presented and performance was compared for individuals with high (HK) or low (LK) baseball knowledge. Experiment 1 indicated that HK recognition performance was superior to LK, and that this difference was greater for changes in "New" material that were more important in terms of the game. Experiment 2 showed that HK individuals need less information to make recognition judgments than LK individuals. Experiment 4 showed that HK individuals anticipated a greater percentage of high-level goal state outcomes than LK individuals. Experiments 3 and 5 indicated that HK individuals are superior at recalling event sequences, a finding attributed to the greater ability of HK individuals to relate successive segments of input information. The results are considered in relation to a conceptual framework and to related literature.

The present research was concerned with how knowledge of a particular domain influences the acquisition of new domain-related information. While it generally is thought that learning about a given topic is facilitated by prior knowledge of the topic, the problem has received little empirical attention (cf. Ausubel, 1960; Chase & Simon, 1973). Moreover, the issue is of special current interest because problems of knowledge representation and utilization are being studied intensively in artificial intelligence (Charniak, 1977; Schank & Abelson, 1977), discourse comprehension (e.g., Anderson, Reynolds, Schallert, & Goetz, 1977), and other research areas.

The question of how knowledge should be defined within any particular domain is essentially unanswered; while there have been attempts to classify knowledge, for example, tacit and explicit knowledge (Polanyi, 1966) and declarative and procedural knowledge (Anderson, 1976; Ryle, 1949), a system has not yet been developed for classifying knowledge within a particular domain or across domains. Therefore, for our present purposes, we view knowledge of a domain as an understanding of its basic concepts,[1] as well as its goals, rules, and/or principles.

The present research employed the contrastive method, that is, we delineated two groups of individuals as experts and nonexperts in a given knowledge domain and

The authors wish to thank Alan Lesgold, Chuck Perfetti, Jim Pellegrino, Gay Bisanz, and Gregg Vesonder for their comments on an earlier draft of this paper. The research of this paper was supported by the Learning Research and Development Center, supported in part as a research and development center by funds from the National Institute of Education (NIE), United States Department of Health, Education, and Welfare. The opinions expressed do not necessarily reflect the position or policy of NIE, and no official endorsement should be inferred. Requests for reprints should be sent to Dr. James F. Voss, Learning Research and Development Center, 3939 O'Hara Street, University of Pittsburgh, Pittsburgh, Pennsylvania 15260.

[1] We use the term concept here in a Wittgenstein-like sense, that is, the concept involves not simply the definition of the concept but its relations and usage.

0022-5371/79/030257-17$02.00/0

compared their acquisition of domain-related information. This method has been used effectively to study performance correlates of expert and nonexpert chess-playing ability (Chase & Simon, 1973; deGroot, 1966), "Go" playing ability (Reitman, 1976), reading comprehension (Perfetti & Lesgold, 1977), and verbal aptitude (e.g., Hunt, Frost, & Lunneborg, 1973). The particular knowledge domain we selected was baseball.[2] We now consider the conceptual framework for the present work.

Conceptual Framework

Goal structure. The knowledge domain we selected is a game, and the primary object of virtually any game is winning. The most important type of knowledge, therefore, consists of knowing the means by which a game is won, that is, the game's goal structure. The goal structure is typically hierarchical, consisting of the highest goal, winning the game, and of subgoals that permit an individual and/or a team to work toward the goal of winning. Moreover, the subgoals of the adversary individuals and/or teams are typically placed in opposition to each other. In baseball, the second level of the goal structure involves scoring runs (team at bat) and preventing runs from being scored (team in field). The third level consists of advancing runners, including getting batters on base (team at bat), and preventing runners from advancing and batters from reaching base by making them out (team in field). Finally, the fourth level consists of getting "balls" (team at bat) or getting "strikes" on the batter (team in field). Furthermore, at each level of the goal structure, there is at least one variable which may take on one of a finite set of values, for example, the position of runners, the number of outs, the number of balls, and so forth. (A more complete description of baseball's goal structure is given in Spilich, Vesonder, Chiesi, & Voss, 1979.)

Game states and game actions. The play of most games may be considered in terms of sequences of *game states* and *game actions.* A game state is defined in terms of the conditions existing at a given point in a game. In baseball such conditions are defined by the existing values of the variables of the goal structure as well as setting information (cf. Spilich et al., 1979); a game action is defined as an activity or sequence of activities occurring during the course of a game which typically produces a change in the game states. In baseball, the game action involves getting a hit, making an out, getting a strike on the batter, and so on. While in games such as chess, game states and game actions (moves) provide a virtually complete account of the activity of the game, other games such as baseball contain a considerable amount of activity that does not involve changes in game states. The role of such activity is considered elsewhere (Spilich et al., 1979).

There are two points to note about game actions. First, since game actions produce changes in game states, game actions vary in importance; an action which produces a change in the value of a variable that is high in the goal structure is more important than an action which produces a change in the value of a variable lower in the goal structure. Naturally, any activity not producing any change in the game state, for example, "the umpire dusts off home plate," is of minimal importance. Second, many game actions are state specific, that is, a given action may occur only when a game is in a specific state, for example, a double play can only occur when there is at least one runner on base. Also, for any given game state, only a particular set of actions may occur.

[2] Arguments could of course be given for and against the use of any given knowledge domain. We chose baseball because of its apparent intrinsic interest, the likelihood that we could get participants, and most importantly, the fact that we wanted high-knowledge and low-knowledge participants. We did not want no-knowledge participants because of difficulties that could arise in such matters as instructions and basic vocabulary.

The description provided thus far is reasonably straightforward, but it may be helpful, especially for the reader with low baseball knowledge, to consider a nonbaseball example. The game of chess has a goal structure with the highest goal consisting of winning the game. There also exist subgoals which vary in importance, for example, capturing a queen is typically more important than capturing a pawn, or occupying one particular square may be of greater importance than occupying some other square. The game state consists of the pieces remaining in the game at any given time and their relation to each other, and the game actions (moves) produce changes in the game state.[3]

Processing Information

As stated previously, for any given game state a set of actions may occur. Moreover, the actions differ in importance according to their relation to the goal structure. We assume that the processing of actions occurs differentially in relation to the importance of the action to the goal structure. While we cannot specify the processing mechanisms involved, we would suggest that for a given game state, a set of expectancies occurs within the individual which consists of the actions that may occur for that game state. When the action occurs, the information is mapped onto that expectancy and stored.

The second processing assumption is concerned with sequential information. A baseball game is divided into a number of reasonably well-defined units called innings (or half-innings). Each half-inning is defined by the occurrence of three outs, but during the inning there is a set of loosely defined "episodes" which primarily involve actions related to getting on base and scoring. In the course of an inning the game states change, and in order to keep track of the game, the spectator must monitor the parameter values of the goal structure variables. The monitoring consists of knowing how many outs have been made, the location of runners, the number of runs scored, the current ball–strike count on the batter, and so forth. Indeed, at baseball games the scoreboard provides an external memory system for such information, and on radio and television, broadcasters often repeat such information to keep the listener updated about the state of the game. We assume that the necessary monitoring takes place in a working memory system and that such monitoring involves keeping track of the game actions and related state changes.

The mechanisms of the monitoring process are not specified, but the following suggestion is made. The ability to monitor information accurately consists of relating sequences of game states and game actions. Since only a given set of actions may occur for any game state, it similarly is true that only particular state–action–state–action, and so on, sequences may occur subsequent to any game state. Moreover, when three outs occur, the episodes of that inning cease, although the score is carried over to the next inning. The sequences of events thus may be mapped onto the existing knowledge structure in the same way that specific actions were mapped onto the structure.

The account presented thus far suggests at least three loci of knowledge differences in high knowledge (HK) and low knowledge (LK) individuals which may influence acquisition. First, differences could exist in the knowledge of the game's basic goal structure. Such differences would be expected to produce relatively large processing differences in HK and LK individuals because a knowledge of the goal structure is requisite to an understanding of the states and actions of the game.

[3] The issue of strategy differences in baseball and chess could be considered at this point. However, the development and use of strategies is beyond the scope of the present paper, except to note that strategies in most games including chess and baseball are typically developed to accomplish particular subgoals. (For a particular game high-knowledge individuals would of course be expected to have a greater knowledge of strategies than low-knowledge individuals.)

Second, while both HK and LK individuals may know the game's goal structure, including the variables of the goal structure and their parameter values, HK and LK individuals may differ with respect to knowledge of how particular actions produce changes in game states. For example, the LK individual may not know how a given action, such as a "bunt," could produce a change in the parameter values of the goal structure variables. (Similarly, in chess an LK individual may not know the significance of a particular move in relation to a goal such as capturing a particular piece.) The failure to relate game actions to state changes in LK individuals would be expected to produce poorer performance because the LK individual would not process more significant and less significant information differentially; in other words, the actions would not be "understood." Third, HK and LK individuals may differ in their ability to interpret the successive actions of the game in a reasonably unified manner. The LK individuals would be poorer in this regard because they are less able to relate successive actions to each other and to the goal structure. The assumptions that are basic to these possible processing differences in HK and LK individuals are that information is processed in relation to a goal structure, more important information involves differential processing compared to the less important information, and that "understanding" the activity of the game consists of relating sequences of actions and state changes to the goal structure.

The above formulation leads to a number of implications regarding performance differences in HK and LK individuals. The experiments presented below, while not viewed as precise tests of the conceptual framework, provide for the study of the HK and LK differences in the context of the formulation.

Experiment 1

It was suggested that HK individuals have more knowledge than LK individuals regarding the relation of the actions of the game to the game's goal structure. If, therefore, a brief description of part of a baseball game is presented and subsequently a recognition test is given, HK individuals should be more sensitive than LK individuals to changes in the account when the "New" material involves a change in a variable related to the goal structure. But more importantly, the relative difference in sensitivity to change between HK and LK individuals should be directly related to the importance of the change. This hypothesis was tested in the present experiment.

Method

Subjects. Three populations of college students were obtained, one from each of three terms of the school year. From each population 48 qualifying students participated.

During Term 1, a 40-question baseball test and the first 40 questions of the Davis Reading Test (Form 1A) were administered to a group of approximately 100 college students. The former test consisted of completion questions which primarily tested one's knowledge of the terminology and principles of the game. There were no "trivia" questions, nor were there any questions pertaining to particular teams or players. Students were given 20 minutes to complete each test. Students who scored 35 points or more on the baseball test and those who scored 24 points or less were designated as HK and LK individuals, respectively. The 24 HK subjects had a mean correct score of 38.33, $SD = 1.51$, on the baseball test, while the 24 LK subjects had a mean score of 16.63, $SD = 4.44$. The LK subjects thus had some knowledge of baseball. The mean Davis Reading Test scores were 24.50, $SD = 5.70$, for the HK subjects and 21.33, $SD = 6.45$, for the LK subjects. The HK group contained 21 men and 3 women; the LK group contained 2 men and 22 women.

For Term 2 the same tests were administered to approximately 200 students. The 24 HK subjects scored a minimum of 38 points while the LK subjects scored a maximum of 25 points. The 24 HK subjects, 19 men and 5 women, had a mean score of 39.01, $SD=0.65$, on the baseball test, while the LK subjects, 7 men and 17 women, had a mean score of 17.33, $SD=4.05$. The mean Davis Test score of the former was 22.58, $SD=4.12$, and of the latter was 23.13, $SD=6.87$.

For Term 3, a revised version of the baseball test containing 65 questions was administered. The mean score for the HK group was 57.00, $SD=3.01$, and that for the LK group was 18.46, $SD=7.32$.[4] The respective mean Davis scores were 26.08, $SD=5.94$ and 24.50, $SD=6.55$. There were 24 men and 0 women in the HK group and 4 men and 20 women in the LK group.[5]

One-half of the subjects in each of the five experiments reported in this paper were HK individuals and the other half were LK individuals. The respective numbers of subjects serving in Experiments 1–5 were 48, 48, 42, 44, and 36. All subjects within one experiment were from one of the above populations.

Materials. Thirty-two descriptions of approximately equal length were constructed. One description contained three sentences and each of the remaining contained four sentences. Two different changes, either a major or a minor change, were made for each description. (Major and minor changes referred to importance to the goal structure.) An example of a major change was that the runner was on first base rather than third base, while an example of a minor change was that the ball was hit over the "420-foot mark" rather than "400-foot mark." Three high-knowledge raters agreed on the classification of the changes as major and minor. The 32 descriptions were divided randomly into two groups of 16. Within each group of 16, two groups of 8 descriptions were randomly delineated.

Procedure. The 32 situations were randomly presented on tape with 10 seconds intervening between each presentation. Subjects subsequently performed a 10-minute series completion task. For the recognition phase, one of the sets of 16 descriptions was designated as "Old" and the other was designated as "New" for one-half of the subjects. For one-half of these subjects (one-fourth of the total), one subset of 8 "New" descriptions was presented with the major change and the other set of 8 "New" descriptions was presented with the minor change. The set of 16 "Old" descriptions was not changed during the recognition task. For the other one-fourth of the subjects having the same set of "Old" and "New" descriptions, the "New" situations were counterbalanced with respect to major and minor change. For the remainder of the subjects, the two sets of 16 descriptions were reversed with respect to which descriptions were "Old" and "New." Within the "New" descriptions, the same counterbalancing occurred during the recognition testing with respect to major and minor changes as that of the other one-half of the subjects.

Subjects were instructed to listen carefully to each description and were told they would be tested on the materials. During recognition testing, which was presented via a booklet with one description per page, they were instructed to read the description carefully and respond. Subjects recorded their judgments by circling one of the following phrases printed on each page of their test booklet: certainly is the same; probably is the same; undecided; probably is not the same; certainly is not the same. A tape paced the subjects through the recognition phase; 30 seconds were allowed for reading and making the recognition judgment for each description.

Results and Discussion

The judgments were coded on a 1 (certainly same) to 5 (certainly different) scale. For Old

[4] On the Term 3 test 15 questions were of baseball "trivia." Low-knowledge individuals typically got few if any items correct, but high-knowledge performance was considerably better.

[5] For the second and third terms we expended considerable effort to obtain high-knowledge female subjects, including advertisements, signs in the women's physical education department, and contact with sororities. However, we were not successful.

descriptions the mean HK and LK recognition ratings were 1.86 and 2.02, respectively, $F(1,46)=1.59$, $p>.05$, $MS_e=3.35$. For New descriptions, the mean HK rating, 3.37, was significantly greater than the mean LK rating, 2.58, $F(1,46)=29.13$, $p<.001$, $MS_e=4.08$, thus indicating that HK individuals were more sensitive to changes in "New" descriptions than LK individuals.

Figure 1 presents the major results of the study. While the HK group was more sensitive than the LK group in detecting both major changes, $F(1,46)=42.73$, $p<.001$, and minor changes, $F(1,46)=6.74$, $p<.05$, the significant interaction of Knowledge × Type of Change, $F(1,46)=12.10$, $p<.001$, $MS_e=1.71$, indicates that HK individuals were relatively more sensitive to changes that were more important to the game.

An alternative way to examine the data is to view all "4" and "5" judgments as correct and all "1" and "2" judgments as incorrect when the description presented is "New." Such a tabulation was done, with "3" (undecided) judgments considered as incorrect responses. Table 1 presents the proportion of correct responses, along with the obtained d' and β values. Major and minor conditions are differentiated. As shown, the HK group was more sensitive in detecting changes than the LK group, and was especially sensitive in detecting changes in major details. (The HK group had a mean of 1.3 "3" responses to New descriptions while the LK group had a mean of 1.7.)

TABLE 1

PROPORTION OF CORRECT RESPONSES FOR KNOWLEDGE GROUPS (EXPERIMENT 1)

Situation	High-knowledge group response		Low-knowledge group response	
	4–5	1–2–3	4–5	1–2–3
Major	.66	.34	.34	.66
Old	.14	.86	.16	.84
	$d'=1.49$		$d'=0.58$	
	$\beta=1.65$		$\beta=1.51$	
Minor	.41	.59	.28	.72
Old	.14	.86	.16	.84
	$d'=0.85$		$d'=0.41$	
	$\beta=1.74$		$\beta=1.39$	

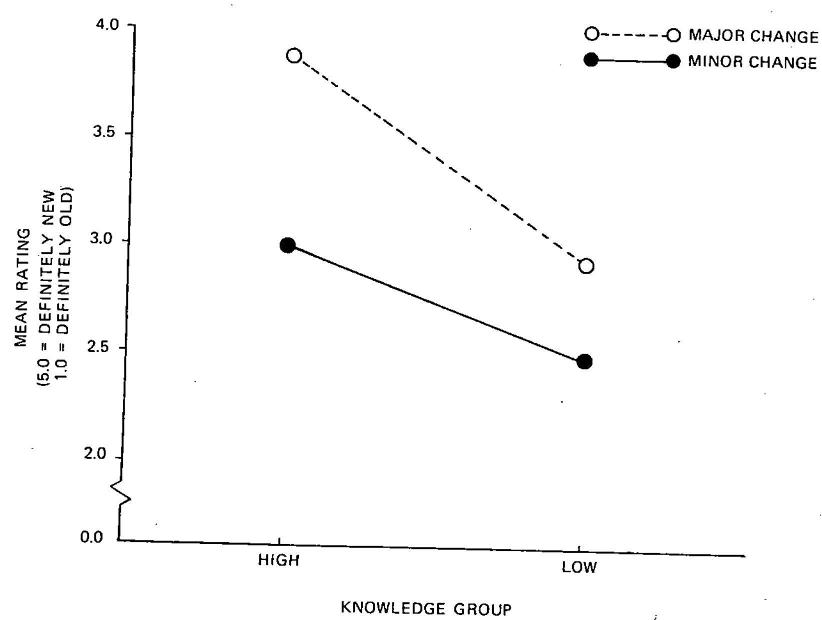

FIG. 1. Certainty judgments on passages with major versus minor changes (Experiment 1).

The results of Experiment 1 thus indicate that HK individuals were more readily able to detect changes in baseball descriptions than LK individuals and that the differences in HK and LK sensitivity increased with the importance of the change.

EXPERIMENT 2

This study was concerned with the question of how much information is required to recognize a game description as "Old" or "New." It was previously suggested that HK individuals process domain-related information in terms of the goal structure more readily than LK individuals and that such processing enabled the HK individuals to be superior to LK individuals in relating game events sequentially. If such is the case, then, input information should be more "unitized" for HK individuals than for LK individuals, and the former should be able to recognize a given description as "Old" or "New" sooner (in terms of information presented) than the latter. Since the information is processed more as a "whole" by HK individuals, they should be able to judge the "whole" on the basis of less "part" information more readily than LK individuals.

Method

Materials. Sixteen four-sentence descriptions of logical baseball sequences were constructed.

Procedure. The 16 descriptions were randomly presented via tape with a 5-second interval between descriptions. Subjects were instructed to listen carefully and try to remember the contents of the descriptions. Subsequently, the 16 previous, that is, "Old," descriptions were presented with an equal number of distractors, that is, 16 "New" descriptions. There were two randomizations of presentation order of "Old" and "New" descriptions, which were counterbalanced within each knowledge group.

In the recognition phase, subjects were instructed that a number of baseball descriptions would be presented and that some would be those previously heard while others would be new. They also were told that each situation would be presented *one sentence at a time*, and that sentences from different descriptions would never be mixed. As each sentence of each situation was presented, subjects judged whether the description they were hearing was one of those previously presented. Three responses were possible: "Yes" (an "Old" description), "No" (a "New" description), and "I need more information."

Results and Discussion

The data indicate that while recognition performance was not significantly different for the HK and LK groups, the HK group required less information (fewer sentences) to make the judgment.

Mean correct recognitions (of 16) as Old and New were 13.3 and 13.9, respectively, for HK subjects, and 12.5 and 13.3, respectively, for LK subjects, $F(1,40)=1.38$, $p>.05$, $MS_e=7.26$. Type of situation also was not a significant variable, $F(1,40)=1.50$, $p>.05$, $MS_e=6.69$. The interaction of the variables yielded $F<1$.

Figure 2 presents the mean sentences needed to make the Old and New judgments. The HK subjects required less information to make a correct judgment than the LK subjects, $F(1,40)=8.63$, $p<.01$, $MS_e=0.30$. In addition, Old descriptions were correctly recognized with less information than New descriptions, $F(1,40)=69.49$, $p<.001$, $MS_e=0.13$. The interaction of Knowledge and Old vs New situation was not significant, $F<1$. The results thus support the hypothesis that HK individuals recognize descriptions on the basis of less information than that required by LK individuals.

The findings thus suggest that HK individuals integrate domain-related information more readily than the latter. Because of such integration, HK individuals are more

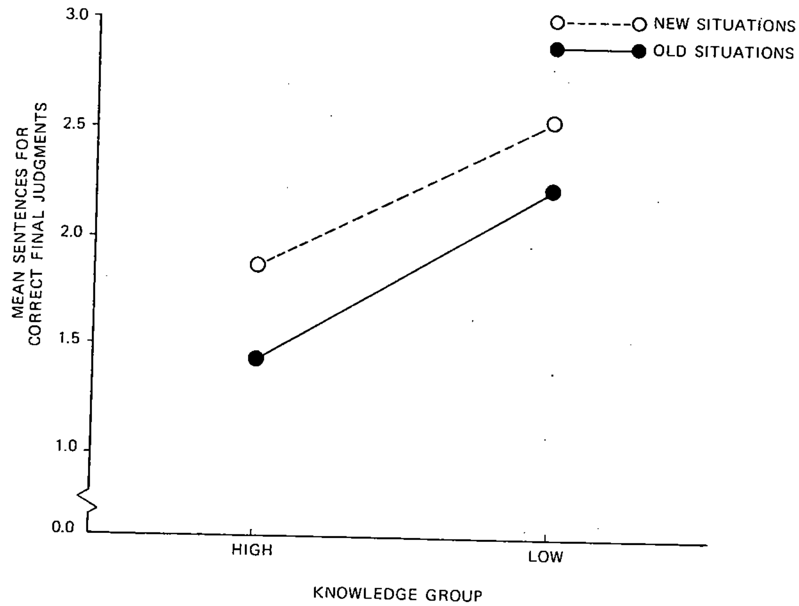

FIG. 2. Number of sentences required for correct Old–New judgments on passages. (Experiment 2).

readily able to make judgments pertaining to the whole on the basis of fewer parts. Two alternative explanations are possible, however. First, HK and LK individuals may have been using different criteria for responding; the HK individuals may have been more confident and judged quickly whereas the LK individuals may have wanted to be "more sure." While this is a possibility, the relatively small differences in the values of Experiment 1 at least suggest that the criterion of responding employed by HK and LK individuals is not appreciably different when making recognition judgments. The second alternative explanation is that HK individuals are sensitive to more domain-related cues than LK individuals (cf. Experiment 1) and, when tested, HK individuals are more likely to detect a given cue (as same or different) than LK individuals. We reviewed the materials of Experiment 2 to determine whether the passages could be differentiated in terms of the significance of the contents, but such differentiation was not possible. However, in view of the results of Experiment 5, which strongly suggest substantially greater integration of information by HK than by LK individuals, we favor the integration explanation for Experiment 2 findings rather than the interpretation based upon differentiated sensitivity to cues.

EXPERIMENT 3

It was suggested that the hypothesized superior knowledge of game states and actions of HK individuals would enable them to understand event sequences more readily than LK individuals. It was therefore expected that the immediate memory for sequences of baseball events should be greater for HK individuals than LK individuals and that this difference should increase with the length of the sequence. In addition, it was expected that scrambling event sequences should produce poorer recall for both HK and LK individuals, but such scrambling should have a greater effect upon HK recall. As a control procedure, the present experiment included the description of nonbaseball visual scenes, for which HK and LK performance differences were not expected.

Method

Design and procedure. The normally ordered baseball passages consisted of brief sequences of baseball events that typically occur in actual games. In the scrambled passages the sentence presentation order within each passage was random. The third condition consisted of descriptions of visual scenes, such as an area of a particular city. Passage length was 1, 3, 5, 7, or 9 sentences, and was orthogonal to the three material conditions. The mean sentence length was 7.18 words, $SD = 1.66$.

Each subject received two passages at each length in each of the three material conditions, or a total of 30 presentations (5 lengths × 3 materials × 2 passages). One passage of each length was randomly presented within each block of 5 presentations. The three passage types and two passages of each type were varied randomly over the trial blocks.

The subjects were instructed to listen to each passage and were told they would be asked to recall the information of each passage immediately after the presentation of that respective passage. The passages were presented on tape and immediately after each presentation subjects were asked to write down the passage. The time allotted for recall was 10 seconds for each sentence of the passage.

Results and Discussion

Percentage correct recall. The data were scored in terms of gist units, with each sentence containing three such units consisting of the actor, action, and recipient of action. The number of units recalled for each sentence was obtained for each passage. Because of passage length differences, percentage recall was employed. The two findings of greatest interest are shown in Figures 3 and 4. Figure 3 presents the data for the significant interaction of Passage Type × Knowledge, $F(2,80) = 24.31$, $p < .001$, $MS_e = 0.115$. The HK group demonstrated significantly greater recall for normally ordered baseball information than the LK group, $F(1,80) = 53.17$, $p < .001$, $MS_e = 0.115$, as well as for scrambled baseball information, $F(1,80) = 14.84$, $p < .01$, $MS_e = 0.115$. Omitting the visual scene data, the Knowledge × Passage Type interaction yielded an F value of 3.35, $p < .07$. These data thus support the hypothesis of HK recall superiority, and the hypothesized interaction in HK and LK recall for normal and scrambled materials also was obtained, although of borderline statistical significance. For visual scenes, LK subjects performed better than HK subjects, $F(1,80) = 5.93$, $p < .05$, $MS_e = 0.115$. Figure 4 presents data of the significant interaction of Passage Type × Length × Knowledge, $F(8,320) = 4.21$, $p < .001$, $MS_e = 0.047$. As the figure indicates, performance diverges over passage length for the knowledge groups for the normally ordered baseball information, although the difference seems to be equivalent at the two longest lengths.

Percentage consecutive recall. The data were also tabulated in terms of recall order. Starting with the first sentence of each passage, the number of consecutive sentences from which at least one gist unit was recalled by a given individual was tabulated. This number was divided by the total number of sentences from

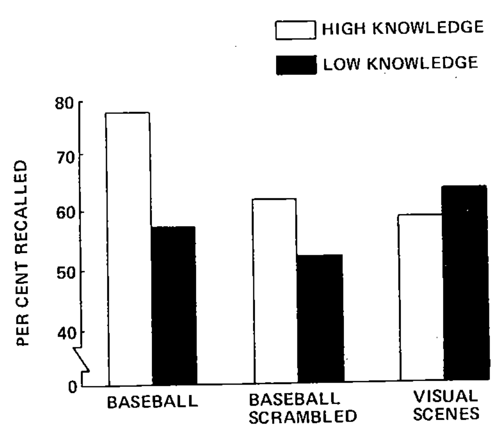

FIG. 3. Recall for three passage types (Experiment 3).

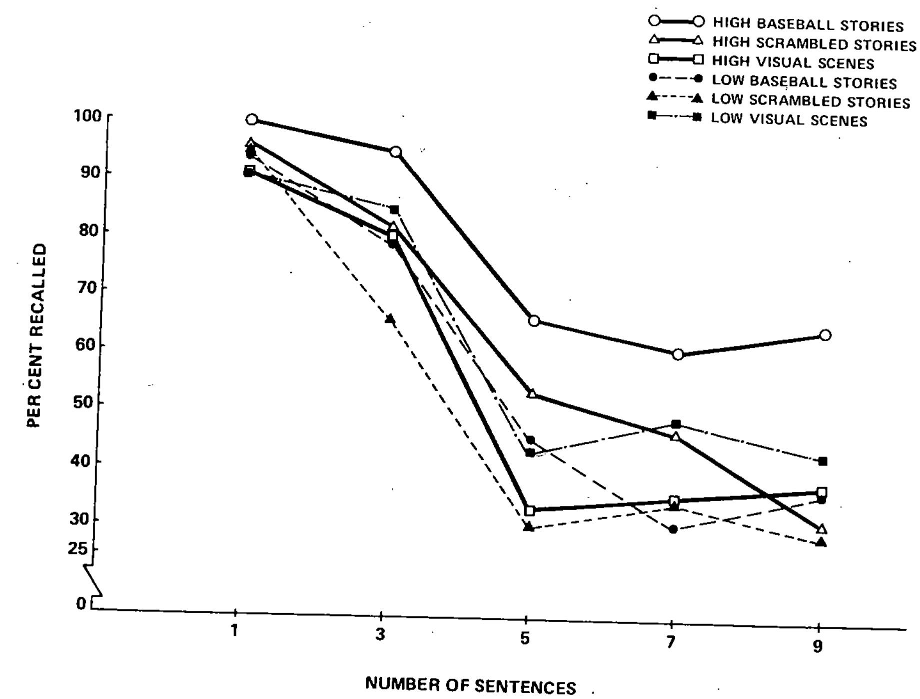

FIG. 4. Recall for passage types of various lengths (Experiment 3).

which at least one gist unit had been recalled for that passage. Essentially, the score provided a measure of correct order of recall for the material that was correctly recalled. Recall of at least one unit from the first sentence was necessary for inclusion in the analysis. The single sentence condition was deleted from the analysis as was the scrambled condition because of discrepancy between logical order and the input (scrambled) order by which the subjects were instructed to recall.

The interaction of Knowledge × Passage Type, $F(1, 40) = 7.14$, $p < .05$, $MS_e = 0.154$, was significant for the percentage ordered recall measure. Ordered recall was greater for the HK group than the LK group for the baseball materials, 74.4 and 55.7%, respectively, but there was little difference in performance for the visual scene condition, HK = 57.8%, LK = 54.8%. The Knowledge × Type × Length interaction was not significant, $F(3, 129) = 1.52$, $p > .05$, $MS_e = 0.093$.

The data support the notion that for normally ordered baseball information, HK recall is superior to LK recall on an immediate memory task. The fact that this difference was due to differential knowledge is strongly supported by the results for the visual scene passages. Thus, these results generally support the idea that HK individuals encode and retrieve sequences of baseball-related information more readily than LK individuals because of their hypothesized greater facility in processing sequential information. With respect to the superiority of HK recall in the scrambled condition, it must be remembered that the scrambling was at the level of sentences, and the HK individuals may have been able to provide some order to the scrambled materials (cf. Kintsch, Mandel, & Kozminsky, 1977). Indeed, although not included in the percentage consecutive recall analysis, the percentage ordered recall in terms of input order with scrambled materials was 62.8 for the HK group and 47.6 for the LK group, a result which supports this suggestion.

EXPERIMENT 4

This experiment was conducted to test the hypothesis that HK individuals are more likely than LK individuals to generate actions for a given baseball game state that are oriented toward the goals of the game. While it was expected that HK individuals would generate more potential actions to any given state than LK individuals, the primary interest was in the nature of actions generated.

Method

Materials. A three-sentence description was written for six different game states, for example "The Pirates trail the Brewers 1–0 in the bottom of the eighth. With nobody out, the Pirates have two fast runners on first and second base. Their left handed hitting shortstop comes to bat."

Procedure. Subjects received a booklet containing the six game situations and were asked to read each description and write as many possible actions (things which could happen on the next play) as they could think of, up to a maximum of 15. They were specifically instructed to generate different outcomes, and were told *not* to state a narrative continuation. Twenty minutes were given for the task.

Results and Discussion

Scoring. Each outcome was placed in one of five categories: high probability, appropriate; low probability, appropriate; marginally appropriate; not appropriate; and, a "link" in a narrative chain following one of the above response types. The first category consisted of events such as hits, outs, or pitches that were probable and reasonable events. The second category consisted of events which, although reasonable, were not highly likely, such as a "balk." The remaining categories are self-explanatory. Two investigators classified the responses in 12 of the 44 protocols and had an interrater reliability coefficient of .91. The remaining protocols were classified by one investigator.

The HK subjects generated more actions per item, 7.19, than LK subjects, 4.66, $F(1,42)=5.70$, $p<.05$, $MS_e=24.73$. The percentage of responses per category for the HK and LK groups is shown in Table 2. The HK individuals produced a greater percentage of appropriate, high probability outcomes than LK individuals, $F(1,42)=7.25$, $p<.01$, $MS_e=732.28$.

The responses given by HK individuals to the situation presented as an example in the Materials section were placed into 34 categories that were based upon specific plays, for example, single, bunt, pitchout, and so on. An additional miscellaneous category was created for low-frequency responses of LK individuals which did not appear in the 34 categories. Approximately 19% of LK responses fell in the miscellaneous category.

These tabulations revealed three results of interest. First, LK responses represented only about one-half, 16 of 34, of the categories derived from the HK protocols. Second, despite the variety of responses among the HK individuals, there was a high degree of commonality on responses involving strategic, goal-related plays. For example, among the HK responses, there were 18 double steals, 15 bunts, 7 drag bunts, and 10

TABLE 2

PERCENTAGES OF RESPONSES OF VARIOUS TYPES (EXPERIMENT 4)

Knowledge condition	Appropriate high probability	Appropriate low probability	Marginally appropriate	Not appropriate	Chaining
High	85.13	2.91	1.42	1.67	8.86
Low	69.60	3.53	2.25	7.55	17.07

hit-and-run plays. The corresponding LK frequencies were 1, 8, 0, and 0. Finally, 45.0% of HK responses represented plays designed to advance the runners (bunt, hit-and-run) or defensive plays to prevent such advances (pitchout, pickoff), while only 12.5% of LK responses fell into these categories.

The results support the idea that for a given game state, HK individuals are more likely than LK individuals to generate actions that are important to the game's goal structure. In addition, HK individuals have knowledge of, or have available, a wider variety of potential actions for a given game state that are important to the goal structure.

Experiment 5

The conceptual framework suggested that sequential baseball information should be recalled better by HK individuals than LK individuals because of the greater ability of the former to relate sequences of states and actions of baseball-related information. This suggests that HK and LK individuals should yield performance differences in their ability to use context. Specifically, if a sequence of baseball-related sentences is presented with the final sentence defined as the target sentence and the preliminary sentences defined as context sentences, then cueing by the context sentences should produce better target sentence recall in HK individuals than in LK individuals. This hypothesis is based upon the idea that the HK individuals process the information at input as a unified sequence of related information to a greater extent than LK individuals.

Method

Design and procedure. A total of 24 three-sentence passages was constructed. The contents of each passage consisted of a logical sequence of baseball-related information. The last sentence in each passage was designated as the target sentence, and it always appeared in capital letters. Eight of the target sentences were presented without any context sentences, eight target sentences were presented with only the second sentence of the passage (one context sentence), and eight target sentences were presented with the first two sentences of the passage (two context sentences). The three sets of eight sentences were counterbalanced over the three context conditions via use of a 3 × 3 Latin Square. During presentation of the passages, one passage occurred randomly from each of the three context conditions within each set of three passages.

Materials were presented via a booklet and subjects were informed that a passage appeared on each page and the passages varied in length. The instructions specified that while the entire passage was to be read, particular attention should be given to the sentences in capital letters because testing would subsequently take place on those sentences. Reading time was controlled by a tape which instructed participants to turn the booklet pages. Presentation time was at a rate of 8 seconds/sentence, that is one-, two-, and three-sentence passages were presented for 8, 16, and 24 seconds, respectively. After presentation of all 24 passages, a 3-minute letter cancellation task was given.

In the first test, a free recall task, 10 minutes were given to recall as many target sentences as possible. This condition was included to determine the extent of target sentence recall with no cueing. Cued recall followed by presenting subjects with the context sentences which had appeared with the respective 16 target sentences. Ten minutes was also given for cued recall.

Results and Discussion

Free recall. Responses were scored on a 3-point scale for each sentence with 1 point given for recall for the actor, action, and recipient of the action.

Figure 5 presents the proportion of gist units recalled by the HK and LK groups for the three context conditions. Although the HK group exhibited better performance than the LK group, $F(1,30)=10.17$, $p<.01$, $MS_e=2.22$, the most interesting result is the significant interaction of Knowledge × Context, $F(2,60)=9.92$, $p<.001$, $MS_e=1.92$. As shown, having the context sentences present *at input* aided the HK subjects in recalling the target sentences even though the context sentences were not present at recall, $F(1,60)=8.92$, $p<.01$. However, the presence of the context sentences at input significantly reduced recall effectiveness for the LK subjects, $F(1,60)=11.30$, $p<.01$. For target sentences presented without any preceding sentences, free recall performance was not significantly different for the HK and LK groups, $F(1,60)=1.40$, $p>.05$, $MS_e=1.92$.

One interpretation of the HK data is that the individual may generate a context sentence at recall and because the context sentence(s) and the target sentence have been encoded in a unified manner, the individual is able to use the context sentence as a cue to recall the target sentence. The specific probability of generating a context sentence and the probability of recalling a target sentence, given recall of one or both of the context sentences, are of course not known, but our interpretation suggests the latter probability is substantial.

We attempted to provide support for the above interpretation by doing a propositional analysis of the 24 passages and relating the propositional analysis to recall. The idea was that the passages in which the context sentences had more connections with the target sentence should yield better recall in the HK group with an increasing number of sentences at input than should passages with fewer connections. "Connectedness" was measured by argument repetition (Kintsch, 1974). The mean number of connections for passages in which recall increased from zero context sentences to one context sentence was 1.74, while the mean number of connections for passages in which such recall did not increase was 1.11. This difference is in agreement with our hypothesis. With two context sentences, the mean connections from the first sentence of the

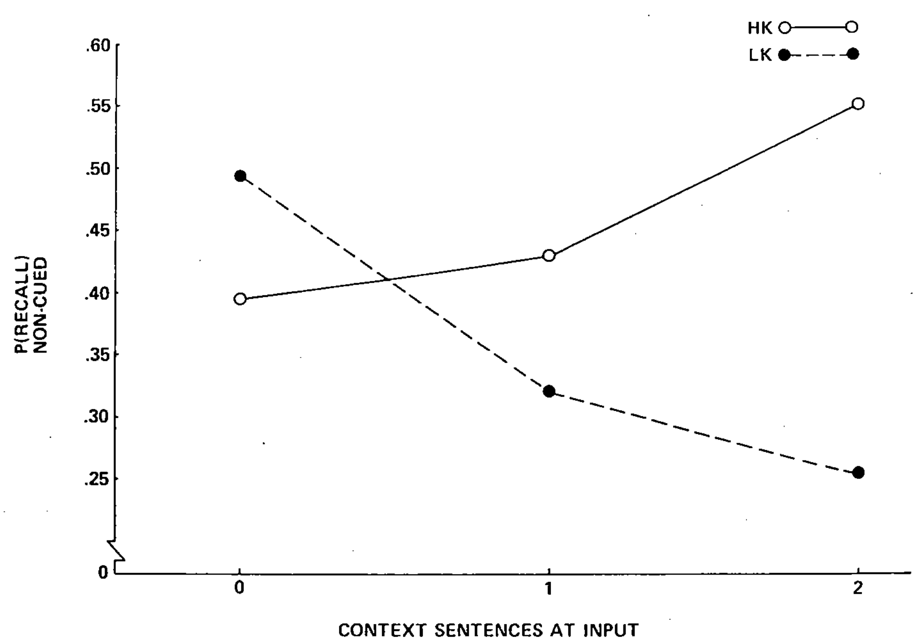

FIG. 5. Target free recall as a function of number of context sentences at input (Experiment 5).

passage to the target did not distinguish among the 24 passages with respect to better or poorer recall, nor was there sufficient differentation in number of connections between the first and second context sentences in order to consider this factor.

One interpretation of the LK data is that at input each sentence, whether context or target, is encoded as a discrete unit because of the inability of the LK individuals to unify the contents of the sentences. The information load, therefore, was greater when there were more context sentences, and despite the equivalent time allowed for processing each sentence, recall was affected detrimentally with the increasing information load at input. Moreover, if a context sentence was generated, the LK individual may not have been able to recall the target sentence because the passage had not been encoded in a unified manner.

Finally, the failure to obtain a significant difference between HK and LK performance when no context sentences were present at input coupled with the facilitative effects of context for HK individuals suggests that HK individuals not only may be able to make better use of context than LK individuals, but that HK individuals may *require* context in order to produce recall superior to that of the LK individuals.

Cued recall. Analysis revealed that even though the HK individuals were superior to LK individuals in free recall, HK recall was facilitated more than LK recall by cueing with the context sentences. The measure employed to determine cueing effectiveness was the percentage of target sentences for which cued recall was greater than free recall (percentage of 16 target sentences for which more gist units were recalled in cued recall than in free recall). The HK group showed a significantly greater increase in recall with cueing, 54.0%, than the LK group, 29.4%, $F(1,30)=37.23$, $p<.001$, $MS_e=584.58$.

The data were also separated into two categories: when free recall was zero, that is, no part of the target sentence was recalled in free recall, and when free recall was greater than zero. Analysis revealed that the interaction of Knowledge and the None-versus-Some previous recall was significant, $F(1,30)=4.34.$, $p<.05$, $MS_e=681.48$. Both the LK and HK groups showed greater recall facilitation with cueing when no target sentence information had been previously recalled, but the facilitation was less in the LK group, 12.8 (some recall) to 46.0% (zero recall), than in the HK group, 28.4 to 79.7%, respectively. Thus, the HK individuals were able to make more effective use of the context sentences when they served as cues, and this effect was of greater magnitude when no information from the sentence was previously recalled. The cueing results thus support the hypothesis that HK individuals would yield superior recall when the target was cued by the context sentences (cf. Tulving & Pearlstone, 1966).

Finally, we would note that the findings of Experiment 5 have some distinct implications for instruction. The results suggest that effective learning may be a function of the extent to which relations can be understood, an idea that is not new. The results also suggest, however, that if successively presented information is not understood, learning may be detrimentally affected.

Discussion

Taken as a whole, the results indicate that knowledge in a given domain indeed facilitates the acquisition of new domain-related information. In addition, the findings provide general support for the principles of the conceptual framework presented in the introduction. Essentially, the position assumes that acquisition of domain-related information (of the type studied in the present experiments) involves a mapping process by which input information is mapped onto an existing knowledge structure. Differential acquisition in HK and LK individuals is then attributed to the differences in the knowledge structures of the HK and LK individuals. The question of HK and LK acquisition differences thus becomes one of determining the knowledge structure differences of HK and LK individuals. Three possible loci of differences were mentioned in the introduction, and two aspects of the data are now examined in relation to these loci. [The three possible HK–LK differences were in knowledge of goal structure, relating actions (and states) to the goal structure, and relating successive action to each and to the goal structure.]

First, the results of Experiment 1 and 4 indicate that HK individuals are indeed more knowledgeable about how actions of the game are related to the game's goal structure. While these results would be expected if there were substantial differences between HK and LK individuals with respect to their knowledge of the game's goal structure, the results of the baseball test and the findings of Spilich et al. (1979) indicate that the LK individuals had a reasonable knowledge of the game's goals. We would therefore attribute the results of Experiments 1 and 4 to the relatively poor ability of LK individuals to interpret the actions of the game in terms of the goal structure.

Second, the results of Experiments 2, 3, and 5 indicate that HK and LK performance differences were due to the superior ability of the HK individuals to relate successive game actions and changes in game state to the game's goal structure. Indeed, the results of Experiments 3 and 5 suggest that there is little difference between HK and LK performance with respect to the recall of single sentences of domain-related information; the primary difference lies in the ability to relate the information presented in a sequence of baseball-related sentences. In other words, the HK individuals are better able to use "context" in processing the input information (cf. Frey & Adesman, 1976).

As mentioned earlier, the superior ability of HK individuals to relate sequentially presented domain-related events is attributed to the operation of a working memory system which enables the HK individuals to keep track of the states of goal-related variables better than LK individuals. The successive actions constituting a game "episode" are interpreted in terms of the goal structure and related to each other as part of the "episode." The HK individuals thus have a better knowledge than the LK individuals of the different action sequences that are related to the goal structure, a knowledge comparable to that of the chess expert's knowledge of patterns of chess positions (Chase & Simon, 1973). The results thus suggest that the knowledge differences existing in HK and LK individuals that most likely produced the acquisition differences obtained in the present experiments are those involving relating specific game actions to the goal structure and integrating action sequences in terms of the goal structure.

The results of Experiments 3 and 5 also provide a basis for speculating about how knowledge influences encoding and retrieval. As noted, the encoding of input information is assumed to be a mapping process that is dependent upon the existence of a sufficiently developed knowledge structure. Furthermore, as previously stated, the input information is assumed to be processed differentially in relation to the goal structure. Similarly, knowledge of the goal structure would also be expected to influence retrieval. The goal structure may provide a hierarchical retrieval system, with information pertaining to higher-level goals retrieved more readily than information pertaining to lower goal levels, a result obtained by Spilich et al. (1979).

The present results are similar to other findings in that they place emphasis upon two processes, pattern recognition and rapid access to long-term memory information. While Chase and Simon (1973) argued that the chess expert has many more game-related patterns of chess positions in long-term memory than the novice, we argue that baseball knowledge involves the existence in long-term memory of patterns (or rules for generating patterns) of actions which produce changes in game states. Also, in comparing the present work to the chess studies as well as the research on "Go" (Reitman, 1976), it is clear that the chess and "Go" research, using interresponse times to denote chunks of information, placed strong emphasis upon an understanding of the chunking process. Our work, on the other hand, while acknowledging the importance of a working memory system, places emphasis upon the continual monitoring and selective processing of input information, with such processing related to goal structure information. Indeed, the emphasis upon the interpretation of actions in relation to the goal structure suggests that the interpretation of the events of a baseball game may be viewed as a type of problem-solving activity and that HK individuals are better able to interpret the game actions in a manner conducive to "solving" the problem (cf. Greeno, 1976).

Finally, while the present work did not pertain to the question of how the knowledge structures develop, the relation of the present framework to the problem solving literature does suggest some factors that are important to becoming an HK individual. First, such development is probably most effective if the goal structure is understood initially. Then, with exposure to a large number of games (in the present context) the individual learns to interpret the game actions in terms of the game's goal structure (cf. Loftus & Loftus, 1974). It seems that only through such exposure, coupled with explanations of how the actions relate to the goals, could a person become an HK individual. Furthermore, exposure in itself may not necessarily be conducive to the development of an HK structure because knowledge of the relation of actions to goals may be lacking; indeed, the individual would probably require instruction and/or the ability to induce the relation of actions to the goal structure, possibly by applying a set of rules from another knowledge domain.

References

Anderson, J. R. *Language, memory, and thought.* Hillsdale, N.J.: Lawrence Erlbaum Associates, 1976.

Anderson, R. C., Reynolds, R. E., Schallert, D. L., & Goetz, E. T. Frameworks for comprehending discourse. *American Educational Research Journal,* 1977, **14,** 367–381.

Ausubel, D. P. The use of advance organizers in the learning and retention of meaningful verbal material. *Journal of Educational Psychology,* 1960, **51,** 267–272.

Charniak, E. A framed PAINTING: The representation of a common sense knowledge fragment. *Cognitive Science,* 1977, **1,** 355–394.

Chase, W. G., & Simon, H. A. Perception in chess. *Cognitive Psychology,* 1973, **4,** 55–81.

deGroot, A. D. Perception and memory versus thought: Some old ideas and recent findings. In B. Kleinmuntz (Ed.), *Problem solving: Research, method and theory.* New York: Wiley, 1966.

Frey, P. W., & Adesman, P. Recall memory for visually-presented chess materials. *Memory & Cognition,* 1976, **4,** 541–547.

Greeno, J. G. Indefinite goals in well-structured problems. *Psychological Review,* 1976, **83,** 479–491.

Hunt, E., Frost, N., & Lunneborg, C. Individual differences in cognition: A new approach to intelligence. In G. H. Bower (Ed.), *The psychology of learning and motivation.* New York: Academic, 1973. Vol. 7.

Kintsch, W. *The representation of meaning in memory.* Hillsdale, N.J.: Lawrence Erlbaum Associates, 1974.

Kintsch, W., Mandel, T. S., & Kozminsky, E. Summarizing scrambled stories. *Memory & Cognition,* 1977, **5,** 547–552.

Loftus, E. F., & Loftus, G. R. Changes in memory structure and retention over the course of instruction. *Journal of Educational Psychology,* 1974, **66,** 315–318.

Perfetti, C. A., & Lesgold, A. M. Discourse comprehension and sources of individual differences. In M. Just & P. Carpenter (Eds.), *Cognitive processes in comprehension.* Hillsdale, N.J.: Lawrence Erlbaum Associates, 1977.

Polanyi, M. *The tacit dimension.* Garden City, N.Y.: Doubleday, 1966.

Reitman, J. S. Skilled perception in Go: Deducing memory structures from inter-response times. *Cognitive Psychology,* 1976, **8,** 336–356.

Ryle, G. *The concept of mind.* London: Hutchinson, 1949.

Schank, R., & Abelson, R. *Scripts, plans, goals, and understanding.* Hillsdale, N.J.: Lawrence Erlbaum Associates, 1977.

Spilich, G., Vesonder, G. T., Chiesi, H., & Voss, J. F. Text processing of domain-related information for individuals with high and low domain knowledge. *Journal of Verbal Learning and Verbal Behavior*, 1979, **18**, 275–290.

Tulving, E., & Pearlstone, Z. Availability versus accessibility of information in memory for words. *Journal of Verbal Learning and Verbal Behavior*, 1966, **5**, 381–391.

(Received June 30, 1978)