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Individual Differences in the Representation of Sentences in Memory

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A cued recall procedure was used to assess the nature of the memory representation that underlies the ability of mentally retarded and nonretarded individuals to remember single sentences. Mentally retarded, equal-CA, and equal-MA subjects listened to a list of sentences after which their ability to recall the object noun of the sentence was assessed when they were provided recall cues that contained (a) only the subject noun of the original sentence, (b) only the verb of the sentence, or (c) both the subject and verb. As expected, performance for all groups was best when they were provided the subject plus verb cue relative to the single word cues. In addition, the groups differed in the magnitude of this two-word cue advantage, with the retarded subjects exhibiting the smallest and the equal-CA subjects exhibiting the largest advantage. This finding reflects a difference in the degree to which mentally retarded and nonretarded individuals construct sentence representations that more precisely specify the meaning of the sentence through the integration of its constituents.

Merrill and Mar (1987) reported data suggesting that mentally retarded and nonretarded individuals may construct different quality mental representations of sentences during language comprehension activities (Experiment 3). In that experiment, mentally retarded and nonretarded subjects were asked to determine whether an aurally presented sentence was semantically identical to a picture. In one condition the sentence and picture were presented simultaneously. In a second condition subjects were given time to encode the sentence before the picture was presented. Both groups of subjects easily comprehended the sentences in both conditions, but there was a difference in the degree to which they were able to use the time between the presentation of the sentence and the presentation of the picture to facilitate performance on the matching task. Having time to semantically encode the sentence in the second condition decreased sentence–picture comparison times for both groups. However, the size of this improvement was twice as great for the nonretarded relative to the retarded subjects. Because the sentence ended approximately one-half second before the picture was

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presented in this condition, Merrill and Mar assumed that all subjects were comparing the picture to a semantic representation of the sentence held in memory. Therefore, they suggested that the difference in comparison times may reflect a difference in the way that sentences are encoded and represented in memory by mentally retarded and nonretarded subjects. In the present experiment we examined the possibility that the quality of the mental representations that underlies the ability to remember simple sentences differs for retarded and nonretarded individuals.

Although there are many ways in which the mental representations of sentences may differ in quality, we chose to focus on the possibility that nonretarded individuals are better able than mentally retarded individuals to construct semantic representations of sentences in which the components of the sentence are well-integrated. This was done for two reasons. First, most current theories of discourse processing include establishing cohesive relations among constituents as an important component in their analysis of sentence-processing activities (see Kintsch, 1988; Rumelhart & McClelland, 1986; Waltz & Pollack, 1985). Initially, sentence processing results in the construction of a semantic representation of the sentence that includes all of the semantic information contained in the conceptual nodes accessed, most notably those concepts represented by the individual components of the sentence. Context-appropriate and context-inappropriate meanings of the individual words are included (Conrad, 1974; Kintsch & Mross, 1985; Swinney, 1979). In a sense, it is analogous to a string of words linked together by simple associations in that the activated semantic meanings of the individual words are not dependent upon context. It is only over time (approximately 1,000 msec) that context-appropriate meanings of the individual words dominate the semantic representation of the sentence and context-inappropriate meanings are lost (Till, Mross, & Kintsch, 1988). Presumably, this is accomplished through an integrative process in which the context supplied by the configuration of the sentence (and prior knowledge) more precisely specifies the sentence meaning (see Kintsch, 1988).

The second reason we chose to focus on the integration of constituents of a sentence during processing was because Merrill and Mar's (1987) results indicate that mentally retarded and nonretarded individuals may differ in this ability. Subjects in their experiment were required to compare a sentence to a picture representation. The greater ability of the nonretarded subjects to make this comparison after having time to encode the sentence may reflect a greater similarity between the picture and their semantic representation of the sentence relative to that constructed by the retarded subjects. If the picture is viewed as an integrated representation of the sentence, then this difference between mentally retarded and nonretarded individuals may reflect a difference in their ability to construct mental representation from the surface structure of the sentence in which the individual constituents of the sentence are well-integrated; in other words, the mental representation of sentences constructed by mentally retarded individuals may remain more like the surface structure of the sentence than does the mental representations constructed by nonretarded individuals.

To examine this possibility, we used a cued recall paradigm patterned after that used by Foss and Harwood (1975). Subjects were presented a series of agent–action–object sentences, after which memory for these sentences was assessed using three types of cues: cues containing (a) only the subject noun of the original sentence, (b) only the verb of the original sentence, and (c) both the subject noun and verb of the original sentence. We were interested in the degree to which the subjects' recall of the object noun of the sentence was greater when they were presented with the double-word cues relative to the single-word cues. Our reasoning was that an integrated representation of the sentence would very likely incorporate semantic information that is provided by the overall configuration of the

sentence and not by the individual constituents of the sentence. In contrast, less integrated semantic representations would be expected to more closely resemble the surface structure of the sentence and not incorporate as much of this additional semantic information. Because the double-word cue provides more configural information than either of the single-word cues, we assumed that the quality of subjects' semantic representations would be reflected in the degree to which performance to the double-word cue was greater than what would be predicted by performance to the single-word cues. A higher degree of semantic integration would lead to a larger advantage of the double-word cues relative to the single-word cues.

Subjects' predicted double-word cue performance was based on the formula $P(O/SV) \leq P(O/S) + P(O/V) - P(O/S) \times P(O/V)$, where P(O/S), P(O/V), and P(O/SV) refer to the probability that the object nouns of the sentences will be recalled from the subject only, verb only, and subject plus verb cues, respectively (see Foss & Harwood, 1975). This formula assumes an associative network representation of the sentence in memory that does not incorporate semantic information provided by the overall configuration of the sentence (cf. J. Anderson & Bower, 1971, 1972). To the extent that our subjects construct integrated semantic representations of the sentences, the actual number of object nouns recalled when they were presented a double-word cue should exceed the number predicted by this formula. Further, if nonretarded individuals exhibit a greater facility for this than do mentally retarded individuals, then this difference should be greater for the nonretarded relative to the mentally retarded subjects.

Method

Subjects

Subjects were 33 mildly retarded adolescents, 33 nonretarded 4th grade children, and 33 nonretarded 10th grade students selected from schools in the Norwalk, Connecticut Public School System. The mentally retarded sample had a mean chronological age (CA) of 181.9 months (standard deviation [*SD*] = 13.0) and a mean IQ of 62.9 (*SD* = 18.2). All IQs were based on recent administrations of the Stanford-Binet Intelligence Scale or the Wechsler Intelligence Scale for Children. Mean mental age (MA) for the retarded sample, estimated by the formula MA = CA × IQ/10, was 122.9 months (*SD* = 18.2). Mean CA for the 4th graders was 179.2 months (*SD* = 6.1). Although no IQ information was available for the nonretarded children, their MAs were estimated to be roughly equivalent to their CAs on the basis of their placement in the appropriate school grade and the absence of any learning problems as indicated by teachers. Mean estimated MAs for the retarded and 4th grade samples did not differ.

Design

The variables were group (mentally retarded, equal-MA, equal-CA) and type of cue (subject only, verb only, subject plus verb). Type of cue was manipulated between subjects. The dependent variable was the number of object nouns recalled for each type of cue.

Materials

Study materials were 48 agent–action–object sentences generated by the experimenter, who was careful to ensure that preexperimental associations among the constituents of each sentence were minimal (e.g., "The girl found the gate"). Because pilot work revealed that the full 48-sentence list was too long to elicit adequate remembering from all of our subjects, sentences were randomly divided into two 24-sentence lists. The presentation order of sentences within each list was randomized. Each list was both tape recorded and typed one sentence per page in a test booklet.

Test materials were three equivalent forms of a 24-item cued recall test con-

structed for each study list. Each cue, typed on a separate page of a test booklet, consisted of one or two words. Examples of the format of the test items are as follows: subject only cue: "____ girl ____; verb only cue: ____ found ____; subject plus verb cue: ____ girl found ____. One third of the cues provided only the object noun of the original sentence, one third provided only the verbs from these sentences, and one third provided both the subject nouns and verbs from the original sentences. The three test booklets were constructed such that in each test booklet each sentence was tested only once, and across all test booklets, each sentence was tested three times, once with each type of cue. An equal number of subjects in each group received each form of the test.

Procedure

Subjects were tested individually in a single session. All subjects received both study lists. The order of presentation of study lists was counterbalanced across subjects within groups.

During the experimental session, subjects were seated at a desk and supplied with the written study materials corresponding to the first study list to be received. They were informed that they would be hearing a list of sentences and were instructed to listen to each sentence carefully while silently reading that sentence in the study booklet. They were told that a memory test would follow the presentation of the list of sentences. Sentences were presented at the rate of one sentence per 5 seconds.

After all the sentences in the study list had been presented, the study booklet was collected and the test booklet passed out. Subjects were informed that each item in the booklet was part of one of the sentences that they had just heard and that they were to fill in all of the missing parts of the sentence that they could remember. Subjects went through the booklet in order, one page at a time. Responses were made verbally and recorded verbatim by the experimenter. Fifteen seconds were allowed for each response. Once a test item was passed, returning to that item was not allowed.

Presentation of the second study list immediately followed subjects' recall attempts to the first list.

Results

The proportion of words recalled correctly to each type of cue and the predicted value of P(O/SV) are reported in Table 1. Protocols were scored for both verbatim and substance recall. Verbatim scoring allowed only abbreviations and changes in number or tense. Substance scoring allowed both synonyms and close superordinates (e.g., "food" for "dinner") of the original words to be scored as correct. Two independent raters scored each protocol. There were no disagreements in scoring. Because analyses of the two scoring methods yielded identical results, only the analysis of substance recall is reported.

Our preliminary analysis was a 3 (mentally retarded, equal-MA, equal CA) × 3 (subject only, verb only, subject plus verb) mixed analysis of variance conducted on the number of object nouns recalled. This analysis revealed a significant main effect of groups, $F\ (2,\ 90) = 9.06$, $p < .01$, and a significant main effect of type of cue, $F\ (2, 90)$

Table 1
Mean Proportion of Object Nouns Recalled as a Function of Type of Cue

	Type of cue			Predicted
Group	Subject only	Verb only	Subject + verb	recall[a]
Mentally retarded	.289	.179	.459	.397
Equal MA	.357	.198	.516	.474
Equal CA	.446	.225	.615	.560

[a] Calculated for each subject and then averaged.

= 14.97, $p < .01$. Analysis of the main effect of groups revealed that all three groups were significantly different from each other, all $ps < .05$, using Newman-Keuls, with the equal-CA subjects recalling the most, the equal-MA subjects second, and the mentally retarded subjects recalling least. The main effect of type of cue revealed that all groups of subjects recalled most when given subject plus verb cues and least when given the verb only cue, with recall to the subject only cue falling in between the two extremes, all $ps < .05$, using Newman-Keuls. These variables did not interact.

Predicted Versus Observed Object Noun Recall

As reported in the preliminary analysis, the overall amount recalled was different for the three groups of subjects. These differences reduced the ability to accurately compare group performance using overall mean data; that is, as the amount recalled to the subject only and verb only cues increases, the potential advantage of the two-word cue is logically smaller because subjects are approaching the performance ceiling. To ensure that the results would not be biased by this inherent relation between the measures, we chose to conduct our analyses on regression lines relating predicted to observed object noun recall. Least squares regression equations computed for each group of subjects are shown in Figure 1. The Pearson product-moment correlation coefficient for each group was high and positive (.74 for the mentally retarded, .78 for the equal-MA, and .87 for the equal-CA subjects), suggesting a highly consistent linear relation between predicted and observed object noun recall for all three groups of subjects. We therefore concluded that a direct comparison of the linear regression equations was justified. Support for the hypothesis that the three groups differed in the degree to which they constructed integrated representations of the sentences would obtain if we observed a significant difference among the intercepts of the regression lines in the absence of a

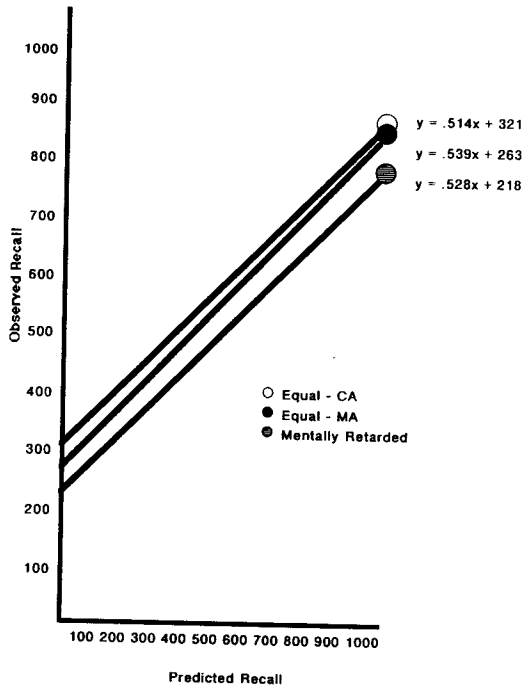

Figure 1. Least squares regression equations relating observed and predicted recall for each group of subjects.

significant difference among the slopes. This would indicate that the size of the two-word cue advantage (relative to the predicted level) was different for the various groups but that the size of this group difference was independent of the actual amount recalled. Hence, we would conclude that our groups were using similar encoding processes but at different levels of efficiency. In contrast, a significant difference in the slopes of the regression lines would be indicative of the use of different encoding processes by our three groups.

The primary analysis was a hierarchical regression analysis (see Cohen & Cohen, 1975) in which the observed object noun recall to the subject plus verb cue was entered into the analysis as our criterion variable, the predicted object noun recall was entered as our first predictor variable (X1), information about group membership (i.e., the main effect of groups as indexed by a difference in intercepts) was entered next

through the use of dummy variable coding (X2 and X3), and information about the interaction (i.e., a difference in slope values) was entered last as the product of X1 and X2 (X4) and X1 and X3 (X5). The results of this analysis are presented in Table 2. As can be seen, knowledge about subjects' performance in the subject only and verb only cue conditions accounted for a significant portion of the variance in object noun recall to the subject plus verb condition, $p < .01$, as did knowledge about group membership, $p < .05$. However, there was no interaction of these variables. Subsequent analyses revealed that the intercept values of the three groups were all significantly different from each other, all ps $< .05$. It appears that all three groups were essentially using the same acquisition process to semantically represent the sentences in memory because the slopes of the regression lines relating these variables were similar. In addition, this process must have included some degree of semantic integration because the object noun recall performance of all three groups in the subject plus verb cue condition exceeded that predicted by performance in the single word cue conditions. However, the magnitude of semantic integration appears to have differed for the three groups. The equal-CA group exhibited the greatest degree of semantic integration, the equal-MA group was second, and the mentally retarded subjects exhibited the least.

Comprehensibility

After completing the experiment, we decided that it was necessary to ensure that the sentences we used could be easily understood by all of our subjects. We therefore selected 15 additional mentally retarded subjects and 15 additional equal-MA subjects to test their comprehension of our sentence stimuli. This was done by presenting sentences to subjects one at a time and asking them to determine which of two pictures accurately represented the meaning of the sentence. Incorrect depictions differed from correct ones by a single feature; we changed either the subject, object, or action from the original sentence. The results were straightforward. Performance was essentially at ceiling. No subject missed more than one sentence, and no sentence was missed more than twice across all subjects. Hence, the results of the analysis of recall performance cannot be attributed to a difference in the ability to comprehend the sentences by the different groups.

Discussion

When differences in overall recall levels were considered, the three groups of subjects differed from each other in the magnitude of the recall advantage exhibited for two-word relative to one-word cues. The mentally retarded subjects exhibited the smallest two-word cue advantage and the equal CA subjects exhibited the largest two-word cue advantage, with the performance of the equal-MA subjects falling between that of the two extreme groups. These differences suggest that the ability to construct and utilize holistic, integrated memory representations of sentences, at least within the context of our cued recall procedure, increases as a function of both age and intelligence.

Table 2
Results of Hierarchical Regression Analysis

	Beta coefficient table		
Parameter	Value	Standard error	t (97)
Predicted recall (X1)[a]	.608	.047	12.883*
Groups (X2 & X3)[b]	−45.22	19.30	2.343*
Groups × Predicted Recall (X4 & X5)[c]	.025	.114	.216

[a] First predictor variable. [b] Second predictor variable. [c] Third predictor variable.
* $p < .05$.

It is important to recognize that the group differences we observed do not indicate that our groups relied on fundamentally different ways to process the sentences. All of our groups exhibited some recall advantage of the two-word relative to the one-word cues. We would therefore suggest that the memory representations of most subjects contained some emergent, configural information about the constituents of the sentences (e.g., R. Anderson, 1974; Goetz, Anderson, & Shallert, 1981). Despite the general similarities in the performance of our subjects, however, the data seem to indicate differences in the amount or kind of configural information that was accessed and included in the memory representations constructed by subjects in the different groups. This difference may be extremely important. Sentence representations that include more in the way of emergent and configural properties are likely to specify the meaning of the sentence more exactly and uniquely (see, e.g., Barclay, Bransford, Franks, McCarrell, Nitsch, 1974; Merrill, Sperber, & McCauley, 1981; Till, 1977). One of the positive consequences of constructing a unique and well-integrated semantic representation for each sentence is likely to be a more enduring memory trace; and as we observed in this experiment, the groups exhibiting the more integrated memory trace also remembered more overall.

On the basis of this single study, we cannot specify the nature of the cognitive-processing characteristics that enable some individuals, relative to others, to construct better integrated representations of single sentences. One factor that may be involved is the speed with which verbal coding processes can be executed. We know that mentally retarded adolescents process verbal information more slowly than do their equal-MA counterparts (Merrill & Mar, 1987). It may be necessary to process the constituents of a sentence and access the individual word meanings at an extremely rapid pace in order for the sentence to be perceived and encoded as an integrated unit. Perhaps the time required by the retarded subjects exceeded the limits within which this was possible. Another possibility is that differences in knowledge influenced the manner in which the sentences were processed. Although care was taken to ensure that the individual constituents of the sentences used in the experiment were not associatively related, we did not assess the extent to which the sentence as a whole could be thought of as more meaningful by the older nonretarded relative to the younger nonretarded and mentally retarded subjects. The older nonretarded subjects would have had a clear processing advantage if the meanings of the sentences overlapped more closely with their knowledge base.

We would ultimately like to draw conclusions concerning the processing of sentences during normal comprehension activities. If we have assessed differences in the ability to construct integrated representations of sentences, then such conclusions are warranted. Further, we would expect differences in this ability to profoundly influence general prose comprehension. The integration of sentence constituents with each other, and with prior knowledge, specifies the meaning of a sentence more precisely (Till, Mross, & Kintsch, 1988), thereby providing the individual with a somewhat different meaning that is achieved when this integration activity does not take place. Because subsequent processing is influenced by factors such as prior knowledge and previously given information (e.g., Haviland & Clark, 1974; Kintsch, 1988), differences in the results of these integrative processes would be expected to cause the comprehension of subsequent prose to be more difficult and less exact. To the extent that mentally retarded individuals exhibit a deficiency in this ability, we can expect that their ability to comprehend connected discourse would be seriously affected.

Nevertheless, it is necessary to be cautious about generalizing the results of a sentence-memory study to conditions that do not require that the sentences be committed to memory. We are encouraged by the fact that these results are consistent with those

reported by Merrill and Mar (1987), who asked subjects to semantically match the sentence to a picture rather than to memorize the sentence. Our future goals are to examine the extent to which differences in the way sentences are represented in memory correspond to differences in the amount or kind of information accessed during processing and to determine whether there are important consequences of these differences in sentence processing when individuals are faced with the comprehension of multiple sentence passages.

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APPENDIX A

Experimental Sentences

1. The monkey broke the stick.
2. The butcher carried the table.
3. The gambler laughed in court.
4. The shoe fell in a hole.
5. My brother sold the fruit.
6. The child received a quarter.
7. The janitor read the sign.
8. The cat sat in the corner.
9. The girl found the gate.
10. The sailor jumped over the stream.
11. The police listened through the wall.
12. The nurse dropped the plant.
13. Her husband built a well.
14. The cowboy paid for the painting.
15. The judge heard the band.
16. The horse walked to the river.

17. The rabbit hurt its leg.
18. The scientist picked up the papers.
19. His uncle ran into the lake.
20. The ducks lived on the island.
21. The train left last week.
22. The artist smelled the coffee.
23. His daughter studied in her room.
24. The boy lost his gold.
25. The king shouted for his dinner.
26. The soldier tasted the apple.
27. The baker stood under the tree.
28. The fire spread through the forest.
29. The clown stopped the car.
30. The dog discovered a mouse.
31. The Indian ate the ice cream.
32. My mother caught the flowers.
33. The senator asked for a favor.
34. The barber opened the door.
35. The dishwasher held the candle.
36. The bear slid in the grass.
37. The queen reached for the bread.
38. The woman looked at the ladder.
39. The baby grabbed the hat.
40. The goat chewed the shirt.
41. The captain played the song.
42. The oil was traded for salt.
43. The chickens saw the corn.
44. The bird hid in the barn.
45. The teacher threw the ball.
46. The hunters fixed the truck.
47. The animals slept under the chair.
48. The pilot pulled the rope.