Rehearsal and Organizational Processes in Children's Memory

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Source: *Child Development*, Dec., 1975, Vol. 46, No. 4 (Dec., 1975), pp. 818-830

Published by: Wiley on behalf of the Society for Research in Child Development

Stable URL: https://www.jstor.org/stable/1128385

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ORNSTEIN, PETER A.; NAUS, MARY J.; and LIBERTY, CHARLES. *Rehearsal and Organizational Processes in Children's Memory.* CHILD DEVELOPMENT, 1975, **46**, 818–830. An overt rehearsal procedure was used to study the relationship between children's rehearsal strategies and recall performance in a free recall task. 2 experiments were conducted, 1 employing unrelated words and the other taxonomically related materials, so that rehearsal could be examined under different conditions of list organization. In both experiments, developmental changes in rehearsal content were observed. Third graders tended to rehearse the item currently being presented either alone or in minimal combination with other words. In contrast, sixth graders (and older subjects) rehearsed several different items together. These changes in rehearsal technique were related to developmental differences in the magnitude of the primacy effect. However, the role of rehearsal seemed to vary as a function of list structure. When categorical items were employed, ninth graders were better able than younger subjects to use taxonomic information to rehearse related words together. This rehearsal of category items was related to improved recall, but blocked presentation of the taxonomic materials facilitated the recall of the third graders, without corresponding changes in rehearsal being observed.

Rehearsal processes have assumed an important position in current views of memory and its development. Recent models of memory (e.g., Atkinson & Shiffrin 1968, 1971) view rehearsal techniques as subject-modifiable control processes which influence the flow of information within the memory system. Studies manipulating rehearsal instructions given to adult subjects (e.g., Palmer & Ornstein 1971), as well as those observing subjects rehearse aloud (e.g., Rundus 1971; Rundus & Atkinson 1970), have provided evidence consistent with the view that rehearsal affects (1) the maintenance of information in short-term memory store (STS) and (2) the recall of information from long-term store (LTS). Actually, while there is much evidence to suggest that rehearsal affects recall from

This work was supported by grant MH 22042 from the National Institute of Mental Health. Preparation of this report was facilitated by grant HD 08459 from the National Institute of Child Health and Human Development. Much appreciation is expressed to school officials in Franklin Township, New Jersey, and Wellesley, Massachusetts, for their assistance in obtaining subjects for experiments 1 and 2, respectively. Thanks are also due Kathy Keefe and Barbara J. Prince for their assistance in the collection and analysis of data. Portions of the data of experiment 1 were presented at the meetings of the Society for Research in Child Development, 1973; a shortened version of the findings of experiment 2 was presented at the meetings of the Psychonomic Society, 1973. Requests for reprints should be sent to Peter A. Ornstein, Department of Psychology, Davie Hall, University of North Carolina, Chapel Hill, North Carolina 27514.

[*Child Development*, 1975, **46**, 818–830.

LTS, it remains unclear as to whether this influence is in terms of transfer from STS to LTS, retrieval from LTS, or both.

Developmental studies of free recall clearly suggest the importance of rehearsal in understanding memory in children. When probability of recall is plotted as a function of serial position of the stimulus words, the major developmental differences in performance are observed over the beginning and middle sections of the curve, with older children recalling more at these positions than younger ones (e.g., Cole, Frankel, & Sharp 1971). Since recall from the beginning, and to some extent the middle, serial positions has been viewed as representing recall from LTS, while recall from the terminal positions is assumed to be from STS (Glanzer & Cunitz 1966), there appear to be developmental changes in children's abilities in transferring information to LTS and/or retrieving information from LTS. Further, since rehearsal processes are related to the recall of information from LTS, the importance of rehearsal in understanding these developmental data is indicated.[1]

The importance of rehearsal in children's memory has also been suggested by the work of Belmont and Butterfield (1971), Flavell (1970), Hagen (1971), Liberty and Ornstein (1973), and others. Data gathered by these investigators indicate that the frequency of spontaneous rehearsal in memory tasks increases with age, that children may become more active memorizers as they mature, and that rehearsal and organizational training procedures may enhance recall performance in certain situations. However, in contrast to the detailed analyses of adult rehearsal patterns (Rundus 1971), information concerning the dynamics of children's rehearsal is lacking. The present study utilized the overt rehearsal technique introduced by Rundus and Atkinson (1970) to gather some of this needed information concerning age changes in rehearsal strategies.

In each of two experiments subjects were asked to rehearse aloud as each item in a free recall task was presented. The contents of each rehearsal set (i.e., the words rehearsed as each item was displayed) were recorded and subsequently related to the obtained recall data. The two experiments differed in terms of the list organization provided, so that relationships between rehearsal, organization, and recall could be explored in a preliminary fashion. In experiment 1 unrelated items were employed as stimuli, while familiar taxonomic categories provided the basis of the word lists in experiment 2. Unrelated and taxonomically related lists were selected because free recall with these materials involves the measurement of different types of organization in the output protocols of subjects and because, surprisingly, these different types of output organization exhibit different developmental patterns. Although recall improves with age with both sets of materials, only with related words does output organization (i.e., category clustering) increase with age as well (Bousfield, Esterson, & Whitmarsh 1958). With unrelated materials over certain age ranges there are increases in the number of words recalled, but no corresponding increments in output organization (i.e., subjective organization) are observed (Laurence 1966; Nelson 1969).[2]

These differences suggest that, to some extent, different processes might underlie age differences in the recall of related and unrelated materials; based on different evidence, Postman (1972) recently has made a similar point concerning adult differences in performance with these lists. Because of these differences it is important to determine the extent to which similar age-related patterns of rehearsal might be obtained under these different conditions of list organization. Three basic questions motivated the present experiments: (1) Will the obtained relationships between rehearsal and recall be similar with these different types of to-be-remembered materials? (2) To what extent will age differences in

[1] Although a dual-store model of memory has been assumed in this paper, the rehearsal strategies under study are clearly those which, according to other theorists (e.g., Craik 1973; Craik & Lockhart 1972), are responsible for increasing the depth of processing of information.

[2] Category clustering (Bousfield 1953; Bousfield & Bousfield 1966), which reflects the extent to which a subject structures his recall around an experimenter-provided list organization, is measured in studies employing related materials. In contrast, subjective organization (Bousfield & Bousfield 1966; Tulving 1962), which reflects the extent to which a subject imposes a personal structure on the materials, is typically recorded in experiments utilizing unrelated words.

rehearsal techniques parallel age differences in measures of output organization? (3) When presented with related lists, will subjects use the categorical structure of the materials in the construction of their rehearsal sets?

Experiment 1

Method

Design and materials.—At each of three grade levels (third, sixth, and eighth), two groups of subjects were formed. All subjects were presented with a list of 18 unrelated words for five alternating study-recall trials. One of the two groups at each grade (covert control) received typical free recall instructions stressing remembering as many words as possible. The second group (overt rehearsal), in addition, was instructed to rehearse aloud while each item was being presented. To partially control for list-specific effects, two different lists of unrelated high-frequency nouns (Thorndike & Lorge 1944) were created, and one-half of the subjects in each group were assigned to each list. Both lists were pretested to insure that third graders could read and understand the items. The stimulus words were printed in capital letters on white index cards, one noun to a card.

Procedure.—Each subject was tested individually, seated at a table across from the experimenter. The subject was shown each to-be-remembered word for 5 seconds. Oral recall began immediately following the presentation of the last list item, with subjects free to recall the words in any order. The recall period continued until subjects indicated they could remember no additional words. All subjects read aloud each word as it was presented and, in addition, the overt-rehearsal subjects rehearsed aloud during the period that each item was displayed. For each set of materials 18 different random orders of presentation were generated, and each subject received the words according to a unique sequence of five of these orders, one for each trial. A tape recorder, whose microphone was visible on the table between the subject and experimenter, was employed to record the words recalled by all subjects and the rehearsal protocols of the overt-rehearsal subjects. The constant rate of presentation of the materials was maintained with the aid of a specially constructed timing device which also imposed a tone on the tape to differentiate the rehearsal sets of the overt-rehearsal subjects.

Although the experiment was designed to monitor the spontaneous use of rehearsal strategies, subjects were acquainted with alternate techniques to make certain that they understood the rehearsal instructions. Accordingly, subjects were given experience with a practice list and were instructed simply to rehearse aloud whatever list items went through their minds as they saw and labeled each stimulus word. If, on the practice list, a given subject spontaneously rehearsed several different items together, the experimenter told him that although that strategy was perfectly appropriate he could also, if he wanted, rehearse the presented item alone. Opposite instructions were given subjects who spontaneously rehearsed items in relative isolation. In all cases, however, subjects of all ages continued to rehearse in their initial manner.

Subjects.—A total of 168 subjects, 56 at each of the third, sixth, and eighth grades (approximate ages = 8.5, 11.5, and 13.5 years), was randomly assigned to the overt and covert free recall conditions. At each grade level, half of the 28 subjects in each major group were male and half were female. The subjects attended schools in a predominately middle-class suburban area, and the experiment was conducted during the late winter and early spring months of the academic year.

Results and Discussion

Although recall performance increased across trials, preliminary analyses of both recall and rehearsal data indicated similar age relationships at each of the five trials. In addition, there were no effects due to materials (i.e., the lists used by the different subgroups). Accordingly, unless otherwise indicated, the data reported below have been collapsed across these two variables.

Recall.—Recall probability, as a function of serial position, is indicated for the overt-rehearsal groups in panel *A* of figure 1. Consistent with previous developmental work, the major differences among the groups are in the prerecency portions of the curve, with the magnitude of the primacy effect increasing directly with age. The functions generated by the control subjects were similar, although the overall level of recall for these subjects was higher and, for the two older groups, the magnitude of the primacy effect was somewhat reduced. Overall recall probability was .47 for the overt-rehearsal subjects and .57 for covert-control subjects, $F(1,156) = 45.26$, $p < .001$.

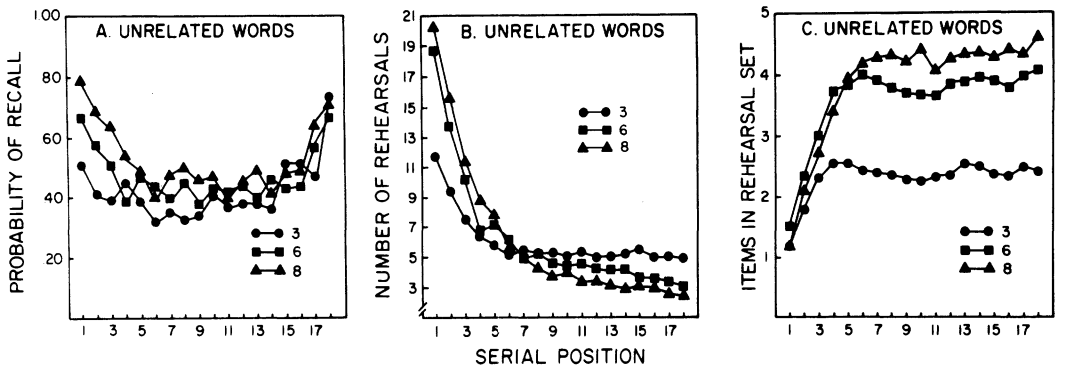

FIG. 1.—Mean proportion of unrelated items recalled (panel *A*), mean number of rehearsals of items (panel *B*), and mean number of different items in each rehearsal set (panel *C*) as a function of serial position for third-, sixth-, and eighth-grade subjects in experiment 1.

This depression in recall performance under overt-rehearsal conditions is consistent with the adult literature. Fischler, Rundus, and Atkinson (1970), for example, found that the recall of covert-control subjects, especially in the middle serial positions, was superior to that of overt-rehearsal subjects, although both groups showed typical bow-shaped serial position patterns. It is possible that the increased time required by overt pronunciation could have resulted in a reduction of effective processing time per presented word. On the other hand, the overt-covert difference might reflect the usage of several different mnemonic strategies by the control subjects and the greater emphasis upon rehearsal by the overt-rehearsal subjects. However, in the present experiment, since the overt groups exhibited typical age-appropriate patterns, it probably is the case that the overall characteristics of the task were not distorted by the introduction of overt rehearsal.[3]

An analysis of variance performed upon the data of the overt-rehearsal subjects indicated significant effects of age, $F(2,78) = 12.36$, $p < .001$, serial position, $F(17,1326) = 14.04$, $p < .001$, and age × serial position, $F(34,1326) = 1.76$, $p < .005$. There was not a significant effect due to sex of subject, and sex did not interact with any other factor. Subsequent two-tailed t tests indicated that the three age groups differed significantly from each other in terms of average recall at serial positions 1–2, while there were no differences among the groups at serial positions 17–18. Further analyses on the primacy effect, comparing the average of serial positions 1 and 2 (representing the beginning section of the curve) with that of positions 9 and 10 (representing the middle section), indicated reliable primacy effects for the sixth- and eighth-grade subjects but failed to find a significant effect for the third-grade subjects.

Subjective organization.—Subjective organization, evaluated in terms of Bousfield and Bousfield's (1966) observed (O) minus expected (E) intertrial repetition (ITR) measure, was recorded for adjacent pairs of trials for all subjects. In general, these O(ITR) − E(ITR) scores were very low, with minimal differences being observed across ages and trials. Thus, consistent with previous work, groups of subjects which differed from each other in recall performance did not differ in terms of measured output organization; the mean O(ITR) − E(ITR) scores were .20, .35, and .37 for the third-, sixth-, and eighth-grade subjects, respectively. Similarly, the increase in organization over trials was minimal, with no increment being obtained after the second pair of trials; the O(ITR) − E(ITR) scores were .16, .36, .37, and .35 for the four trial pairs, respectively. The analysis of variance performed on these data failed to find significant effects due to age, $F(2,156) = 1.97$, $p > .10$, or trial pairs, $F(3,468) = 2.32$, $.10 > p > .05$. On the other hand, the difference between the overt and covert subjects, while small, was significant. The mean subjective organization scores were .22 and .40 for

[3] Further support for this assertion is seen in Naus, Ornstein, and Aivano's (1974) finding that the effects of processing time per item were reflected equally in the serial position curves of overt-rehearsal and covert-control subjects.

the overt and covert subjects, respectively, $F(1,156) = 5.06$, $p < .05$. Thus, the covert-control subjects are superior in terms of recall and subjective organization. However, the relationship between recall performance and subjective organization does not appear to be an important one when viewed in the context of (1) the very low objective levels of obtained organization, (2) the absence of significant age and trials effects, and (3) the lack of an interaction between age and groups (overt/covert rehearsal). Further, the absence of this interaction, indicating that age differences in subjective organization were not observed with either the overt or covert subjects, is consistent with the view that the overt-rehearsal procedure does not alter the recall task in any major way.

Rehearsal frequency.—Several characteristics of the subjects' rehearsal protocols were examined in an effort to relate recall performance to rehearsal. First, recall differences might be mediated by different base frequencies of rehearsal. To examine this possibility, the number of rehearsals of list items per rehearsal set (i.e., the total number of verbalizations—unique items plus repetitions—in each set) for each of the age groups was computed. The mean numbers of such rehearsals per rehearsal set were 6.05, 6.36, and 6.24, respectively, for the third-, sixth-, and eighth-grade subjects, indicating no differences among the groups, $F(2,78) < 1.0$.

The total number of rehearsals of each word taken over all rehearsal sets on a given trial was then examined. The number of rehearsals of each item as a function of serial position is shown in panel *B* of figure 1. Note that the items initially presented were rehearsed more frequently than the middle and terminal items. Indeed, the data for the sixth and eighth graders are rather similar to those presented by Rundus (1971). Thus, the items that these subjects recall from LTS are accompanied by greater amounts of rehearsal. There are some aspects of these data, however, which suggest that the number of times an item is rehearsed is not the critical determiner of recall performance. First, note that the items in the middle and terminal serial positions are actually rehearsed more by the third graders than by the sixth and eighth graders and, of course, they are recalled less well. Also note that the third graders rehearse the beginning few items more than the middle items but that there is no difference in recall of these two classes of words. Thus, reference to panel *A*, discussed above, indicates that the serial position curve for the third graders is relatively flat over the entire prerecency portion, suggesting that the greater rehearsal of the initial items did not result in their greater recall. An analysis of variance applied to these rehearsal frequency data yielded a significant age × serial position interaction, $F(32,1326) = 8.28$, $p < .001$, confirming visual inspection of panel *B*. Subsequent two-tailed t tests indicated that the third graders' rehearsal on serial positions 1–2 was significantly less than that of the sixth and eighth graders, although their rehearsal at serial positions 13–14 was greater than that of the eighth graders. Further, a t test indicated that the primacy effect for the third graders, measured in terms of the difference in rehearsal frequency for serial positions 1–2 and 9–10, was significant.

Rehearsal content.—Since the number of rehearsals received by an item does not seem to be related to recall, at least for the youngest subjects, then what is? An examination of the content of rehearsal sets was undertaken to determine if differences in rehearsal style might be related to the age differences in recall performance. Table 1 indicates several rehearsal sets for a typical eighth-grade subject and a typical third-grade subject. Note that when the first item is presented, this eighth-grade subject repeats the word three times. When the second item is presented, both words are

TABLE 1

TYPICAL REHEARSAL PROTOCOLS (UNRELATED WORDS), EXPERIMENT 1

WORD PRESENTED	REHEARSAL SETS	
	Eighth-Grade Subject	Third-Grade Subject
1. Yard	Yard, yard, yard	Yard, yard, yard, yard, yard
2. Cat	Cat, yard, yard, cat	Cat, cat, cat, cat, yard
3. Man	Man, cat, yard, man, yard, cat	Man, man, man, man, man
4. Desk	Desk, man, yard, cat, man, desk, cat, yard	Desk, desk, desk, desk

rehearsed. When the third and fourth words are presented, all previous items are rehearsed together in each rehearsal set. Although this pattern cannot be maintained over all of the items on the list, this is an active pattern of rehearsal in which there is a considerable effort being made to incorporate several items into each rehearsal environment. This pattern, in fact, is very similar to that found by Rundus (1971) with college-age subjects. In contrast, table 1 indicates that the typical third-grade subject tends to rehearse the item currently being presented either alone or in combination with only one other item. In comparison with the rehearsal technique of the eighth grader, this is a very inactive or passive strategy.

Data such as these, for all of the subjects, are summarized in panel *C* of figure 1, which contains a plot of the number of different items rehearsed together as a function of serial position. By definition, only one item can be present in the first rehearsal set (on trial 1, at least), while two can be present in the second set, three in the third, etc. The curves for all three groups rise over the first few serial positions and then level off at markedly different asymptotes. Note that while the sixth- and eighth-grade subjects are rehearsing between 4.0 and 4.5 items together over the majority of the rehearsal sets, the third graders are only rehearsing approximately 2.5 items. Thus, while the older children are intermixing a relatively large number of items, the third graders seem, by and large, to be rehearsing the item currently being presented in a very limited context. The analysis of variance performed on these data indicated significant effects for age, $F(2,78) = 13.82$, $p < .001$, and age $\times$ serial position, $F(34,1326) = 7.49$, $p < .001$. This latter interaction reflects the fact that the groups cannot differ over the first few serial positions but they diverge beyond the first several positions. Subsequent t tests, for example, indicated that all three groups differ at serial positions 9–10. There were no effects due to sex of subject or the interaction of sex with any other factor.

Interpretation.—These data imply that there are developmental changes in rehearsal content and that the rehearsal environment of items may be a more critical determiner of recall performance than the number of times an item is rehearsed. For the older subjects, the items that were rehearsed a great number of times were in fact rehearsed in a great variety of different contexts. On the other hand, the items that the third graders tended to rehearse a great deal tended to be rehearsed in a rather restricted environment. These findings also are consistent with the results of a number of rehearsal training experiments. Thus, for example, Palmer and Ornstein (1971) found that the primacy effect is eliminated in serial probed recall when adults are forced to rehearse the currently presented item either alone or with the previously presented word. In the present experiment, third graders exhibited a great tendency to rehearse in this restricted fashion, and they, too, had a serial position curve with a flat primacy portion. Similarly when Palmer and Ornstein's adults were asked to include items in many different rehearsal sets by rehearsing cumulatively, enhanced primacy effects were obtained. In the present experiment, sixth and eighth graders showed a much greater tendency to incorporate each item into a number of different rehearsal sets, and they, too, exhibited increasingly pronounced primacy effects. Although Palmer and Ornstein interpreted their data as indicating that transfer to LTS may be a direct function of rehearsal frequency, it is possible that their effects represent the role of rehearsal context and not frequency.

Improvement with age in the recall of unrelated materials thus seems at least in part due to the development of active rehearsal patterns. This finding seems noteworthy because changes in measured output organization (i.e., subjective organization) cannot account for developmental differences in the recall of these materials. However, to what extent is this developmental rehearsal-recall relationship a general one? Will similar patterns be observed in other situations which differ in terms of the available list organization, and hence the options for output organization, or might organizational factors reduce the importance of rehearsal? More specifically, will developmental changes in rehearsal patterns be observed when related materials serve as to-be-remembered items, since both recall and output organization (i.e., clustering) increase with age under these conditions?

Experiment 2 was designed to explore this issue by examining the extent to which an explicit list organization would affect the generation of rehearsal strategies. Given that third graders have knowledge of the categories represented in a related list, it was thought

that these children might rehearse more actively with these materials than with unrelated words. Also of interest is the question of whether the subjects, particularly the older ones, would utilize the category structure in the formation of their rehearsal techniques. This is an interesting developmental question since evidence (see, e.g., Liberty & Ornstein 1973) suggests that young children often do not use information they have available in memory for the creation of mnemonic strategies. In the present task, the utilization of categorical information could depend upon whether the category members are presented contiguously or in a random fashion. Under random presentation conditions, the rehearsal of related items together depends upon the retrieval of category members which are not simultaneously available in STS. In contrast, when blocked presentation is employed several instances of a given category are present in STS, thus increasing the likelihood of organization affecting rehearsal. On the other hand, it seems possible that the explicit list organization of categorized materials might influence recall directly, without affecting measured rehearsal.

Experiment 2

Method

Design and materials.—At each of three grade levels (third, sixth, and ninth), two groups of subjects were formed. All subjects were presented with a list of 20 familiar categorized items for four alternating study-recall trials. One group of subjects at each grade level received the words in a blocked pattern such that members of each category were presented contiguously, whereas a second group was exposed to the words in a random sequence. All subjects were given overt rehearsal instructions. As in experiment 1, two sets of materials were created, and one-half of the subjects in each group were assigned to each list. Both lists were composed of four categories of five high-frequency items each. These lists were pretested extensively to select materials such that third graders would have knowledge of the categories and instances.

Procedure.—All subjects were tested individually, under conditions similar to those employed with the overt-rehearsal groups of experiment 1. Under blocked conditions of presentation, the positions of the category blocks and of the items within the categories were randomized from trial to trial. Each subject in both the random and blocked conditions received the stimulus materials according to a unique sequence of random orders of presentation. The instructions to subjects called attention to the categorical structure of the to-be-remembered words, and, following the experiment, subjects were asked to sort a deck of cards containing the words into the taxonomic groupings; all subjects were able to do this.

Subjects.—A total of 96 subjects, 32 at each of the third, sixth, and ninth grades (mean ages = 8.3, 10.6, and 13.9 years), was randomly assigned to the random and blocked presentation conditions. At each grade level half of the 16 subjects in each major group were male, half female. The subjects attended schools in a middle-class suburban area, and the experiment was conducted during the fall and early winter months of the academic year.

Results and Discussion

As was the case in experiment 1, preliminary inspection of the data indicated that the relationships among the age groups were similar at the different trials and that there were no effects due to materials. Accordingly, unless otherwise indicated, the data reported below have been collapsed across these two variables.

Recall.—The probability of recalling an item is indicated as a function of serial position in panels *A* and *B* of figure 2 for the random and blocked conditions, respectively. The major differences between the third- and sixth-grade subjects are in the beginning of the list, while the ninth graders appear superior to the other subjects at most serial positions. Further, a comparison of panels *A* and *B* indicates that recall under blocked conditions was superior to that under random presentation for all age groups. In addition, for the subjects receiving the items in a blocked fashion, especially the ninth graders, an interesting scalloping pattern can be detected at the category boundaries (positions 6, 11, 16), with each category showing a primacy effect.

An analysis of variance performed on these data confirmed visual inspection of the curves. There are significant effects of age, $F(2,84) = 22.34$, $p < .001$, and conditions (i.e., blocked versus random presentation), $F(1,84) = 12.77$, $p < .001$, but no age × conditions interaction, $F(2,84) < 1.0$. The absence of an age × conditions interaction sug-

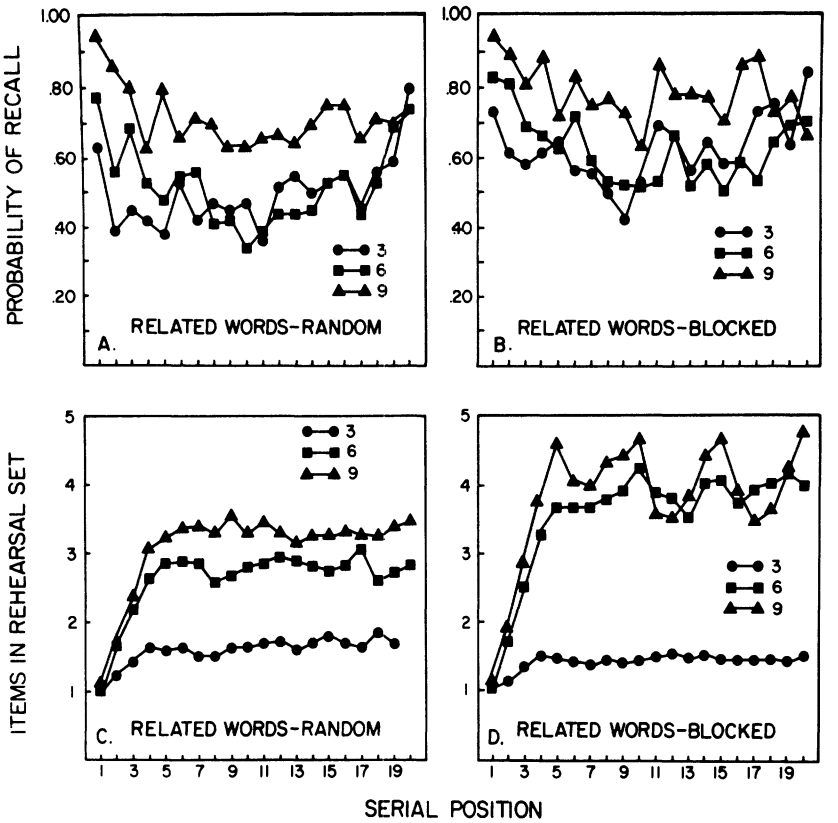

FIG. 2.—Mean proportion of related items recalled under random (panel *A*) and blocked conditions (panel *B*) of presentation, and mean number of different items in each rehearsal set under random (panel *C*) and blocked conditions (panel *D*) of presentation, as a function of serial position, for third-, sixth-, and ninth-grade subjects in experiment 2.

gests that facilitation due to blocked presentation was roughly constant across the three ages. In addition, there were significant effects due to serial position, $F(19,1596) = 8.93$, $p < .001$, age × serial position, $F(38,1596) = 2.61$, $p < .001$, and conditions × serial position, $F(19,1596) = 2.22$, $p < .01$. There was no significant effect due to sex of subject nor did sex interact with any other factor. To further explore the age × serial position interaction, the data for the blocked and random conditions were pooled over serial positions 1–2 and 19–20. Subsequent two-tailed t tests indicated that the three age groups differed from each other at the initial positions but that there were no differences at the final positions. The conditions × serial position interaction reflected the scalloping seen in the serial position curves of the blocked subjects. Although the age × conditions × serial position interaction was not significant, the scalloping effect seemed to be most pronounced with the ninth-grade subjects; accordingly, post hoc t tests were performed on the data of the ninth-grade blocked subjects. These analyses indicated that the decline in recall probability from the first item in each category to the last item (position 1 vs. 5; 6 vs. 10; 11 vs. 15) was significant in each case. Further, the rise in recall probability at the category boundaries, similar to Wickens's (1970) release from proactive interference effect, was significant at two of the three boundaries (positions 10 vs. 11; 15 vs. 16). Similar informal tests on the data of the sixth graders indicated that the decline in recall probability was significant for two of the four categories, while the rises at the category boundaries were not significant.

Clustering.—Category clustering, evaluated in terms of the Bousfield and Bousfield (1966) observed (O) minus expected (E)

stimulus category repetition (SCR) measure, was recorded for each trial for all subjects. In contrast to the low level of subjective organization observed in experiment 1, these O(SCR) − E(SCR) scores were substantial, and clear developmental differences were observed; the mean clustering scores were 2.52, 3.24, and 6.82 for the third-, sixth-, and ninth-grade subjects, respectively. In addition, paralleling the recall findings, the blocking manipulation resulted in increased clustering for the subjects who received the items in a blocked order in contrast to those under random conditions of presentation, and this facilitation was observed for subjects at all grade levels. The mean O(SCR) − E(SCR) scores were 5.25 and 3.14 for the blocked and random presentation subjects, respectively. The analysis of variance performed on these data resulted in significant effects for age, $F(2,84) = 46.99$, $p < .001$, and conditions, $F(1,84) = 29.52$, $p < .001$. Consistent with the observation that blocking the items did not differentially affect subjects at any one grade level, the age × conditions interaction was not significant, $F(2,84) < 1.0$. The analysis indicated additional effects due to trials, $F(3,252) = 63.16$, $p < .001$, and age × trials, $F(6,252) = 13.28$, $p < .001$. These effects reflect the fact that clustering increased over trials and that the differences among the grade levels were greater at the later trials.

Rehearsal content.—The number of different items in each rehearsal set is shown as a function of serial position in panels *C* and *D* of figure 2, for the random and blocked conditions, respectively. Although the overall number of items rehearsed together, especially in the random conditions, is lower than that in experiment 1, similar age relationships in terms of rehearsal content are seen in the two experiments. These data indicate that the expectation that the young children might rehearse more actively with the categorical materials was not realized. Third graders, under both random and blocked conditions, rehearsed items in relative isolation, even though greater clustering in recall was observed under blocked presentation. Thus, for these subjects, list organization affected recall and output organization, but not rehearsal. However, list organization did influence the rehearsal techniques of older subjects. Under blocked conditions of presentation the sixth- and ninth-grade subjects rehearsed more items together than they did when the materials were presented randomly. Further, for the ninth-grade blocked subjects, and to some extent for the sixth graders, figure 2 indicates that the number of items in each rehearsal set varied as a function of location within a category; the resulting scalloping pattern parallels the recall data for these subjects.

The results of an analysis of variance performed on these data were basically consistent with examination of the curves. Effects due to age, $F(2,84) = 21.72$, $p < .001$, and serial position, $F(19,1596) = 49.55$, $p < .001$, were significant, as was the interaction between these variables, $F(38,1596) = 7.41$, $p < .001$. This age × serial position interaction reflects the fact that the age groups do not differ over the first few serial positions in terms of the number of items in each rehearsal set but that differences are observed over the later serial positions. Although the conditions effect only approached significance, $F(1,84) = 3.60$, $p < .10$, the conditions × serial position interaction, $F(19,1596) = 2.82$, $p < .001$, was significant, indicating differences between the blocked and random groups after the initial serial positions. Further, the age × conditions × serial position interaction, $F(38,1596) = 1.63$, $p < .01$, reflects the fact that this increase in rehearsal set size under blocked conditions is observed for the sixth- and ninth-grade subjects but not the third graders. Additional *t* tests were performed on the data of the sixth- and ninth-grade blocked subjects to explore the scalloping effect. For the ninth graders these tests indicated that there was a significant increase in the number of items per rehearsal set as a function of position within category, as well as a significant drop between categories. For the sixth graders the increases in rehearsal set size are significant for two of the four categories; the decreases at the category boundaries were not significant.

The analysis of variance also indicated a significant main effect due to sex of subject, $F(1,84) = 4.78$, $p < .05$, and the following interactions: age × sex, $F(2,84) = 3.24$, $p < .05$, sex × serial position, $F(19,1596) = 2.39$, $p < .001$, and age × sex × serial position, $F(38,1596) = 1.57$, $p < .05$. These effects reflect the fact that over the later serial positions the sixth-grade girls included more unique items in their rehearsal sets than the sixth-grade boys. Since no sex effects were obtained for the other grades in this experiment, or for any of the groups in experiment 1, these effects

are both unexpected and difficult to interpret, especially since the age × sex × serial position interaction was not significant in the analysis of variance applied to the recall data. However, even though this interaction was not significant, the recall probability of the sixth-grade girls was superior to the boys at the first few serial positions (.84 vs. .72 at the first position).

A final analysis explored further the composition of the rehearsal sets. As discussed above, the rehearsal set size for ninth-grade blocked subjects, and to some extent the sixth graders, varied as a function of location within a category. For these subjects the size of the rehearsal set increases as each additional item in a category is presented and then decreases at the category boundary, paralleling the recall scalloping. Figure 3 indicates that these changes in rehearsal set composition are not random but represent the inclusion of increasing numbers of items from the category of the word which is currently being presented. Panels *A* and *B* of figure 3 show, for the random and blocked groups, respectively, the number of items per rehearsal set belonging to the category of the current item. The difference between these two panels is very striking, indicating the greater ease of including categorically related items in rehearsal sets when the material is presented in a blocked fashion. However, the ninth graders under the random conditions are also able, to some extent, to use categorical information in the construction of rehearsal sets, even when this requires the retrieval of previously presented information which no longer is present in STS.

An analysis of variance applied to these data confirmed inspection of figure 3. There were significant effects due to age, $F(2,84) = 57.34$, $p < .001$, conditions, $F(1,84) = 20.24$, $p < .001$, and age × conditions, $F(2,84) = 5.47$, $p < .005$. This interaction reflects the fact that the sixth- and ninth-grade subjects include more items belonging to the category of the current word under blocked than under random conditions of presentation; in contrast, the third graders rehearse similarly under the two modes of presentation. Subsequent two-tailed t tests indicated that these differences between blocked and random presentation were significant for the sixth and ninth graders. Further, under random conditions the third and sixth graders did not differ from each other, and both were below the level of the ninth graders. In contrast, the three age groups differed from each other under blocked-presentation conditions.

The following effects were also significant: serial position, $F(19,1596) = 71.35$, $p < .001$; age × serial position, $F(38,1596) = 16.92$, $p < .001$; conditions × serial position, $F(19,1596) = 62.02$, $p < .001$; and age × conditions × serial position, $F(38,1596) = 12.14$, $p < .001$. This three-way interaction modifies the age × conditions interaction and reflects the obvious scalloping for the older subjects under the blocked conditions. Subse-

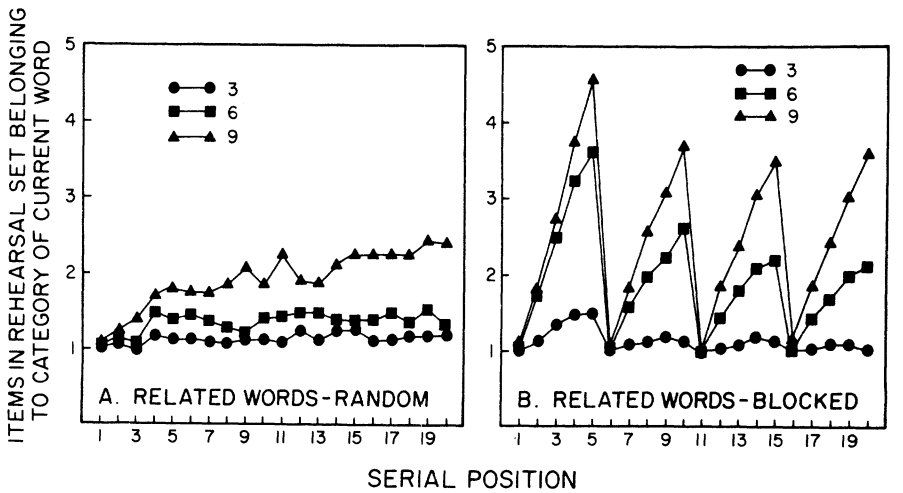

FIG. 3.—Mean number of items per rehearsal set belonging to the category of the currently presented word under random (panel *A*) and blocked conditions (panel *B*) of presentation, as a function of serial position, for third-, sixth-, and ninth-grade subjects in experiment 2.

quent two-tailed t tests indicated that there were significant rises from the first to the last item in each category for the sixth- and ninth-grade blocked subjects; even the third-grade blocked subjects increased the number of categorically related words rehearsed together while the first category was being presented, although the magnitude of this increase is very small in comparison with that of the older subjects. It is clear from inspection of panel *B* of figure 3 that the three age groups did not differ from each other in terms of category rehearsal when the first item in each category was presented; subsequent t tests, however, indicated that all age groups differed in their rehearsal set composition when the last item was presented. Finally, there were no significant effects due to sex of subject, nor did sex interact with any other variable.

Interpretation.—Confirming the findings of experiment 1 which employed unrelated words, developmental changes in rehearsal activity, paralleling changes in recall performance, were observed with related materials. In contrast, however, to the findings with unrelated materials, clear age-related differences in output organization were also observed. Thus, with taxonomic materials there are corresponding developmental changes in recall, rehearsal activity, and category clustering. Further, and most interestingly, the results of experiment 2 indicate developmental changes in the utilization of categorical information for the formation of rehearsal strategies. Whereas all subjects had knowledge of the categories employed in this experiment, only the ninth graders appeared to use this knowledge to rehearse taxonomically related items together when the materials were presented randomly. Under blocked conditions, when related items were present in STS together, both the sixth- and ninth-grade subjects made considerable use of categorical information in rehearsal.

In general, consistent with experiment 1, the findings of this experiment support the view that rehearsal context is a critical factor in the recall of items from LTS. However, in addition to the expected difference between the related and unrelated word situations in terms of developmental changes in measured output organization, there is a major discrepancy between the two experiments. The fact that the third graders in experiment 2 recalled and clustered more words under blocked than random conditions, without corresponding changes in rehearsal, suggests that variables in addition to rehearsal may influence the recall of categorized material, particularly when the list structure is very obvious. That the third graders' improvement was roughly constant across all serial positions is consistent with the operation of a nonrehearsal mechanism.

General Discussion

These experiments suggest that there are developmental changes in rehearsal techniques that are related to corresponding age differences in recall performance. Young children appear to rehearse in a restricted or passive fashion, while the rehearsal strategies of older children are much more active. These differences in rehearsal techniques are related to the form of the serial position function and to recall of material from LTS. Further, these findings are consistent with a distinction (cf. Craik 1973) between two types of rehearsal processes, one for maintaining information in STS and a second which, in addition, affects the more permanent encoding of information in LTS (and/or the retrieval of this information). It is the development of this second type of rehearsal which has been examined here.

It should be noted, however, that the present experiments do not indicate why the active rehearsal strategies of the older children are generally more effective than the passive techniques of the younger subjects. One possibility might be that active rehearsal represents a type of organizational activity at stimulus input—in the multiple or differential encoding sense (cf. Madigan 1969)—which may not always be reflected in the measures of output organization. The rehearsal of items in many rehearsal sets may permit the encoding of these words in a variety of different list environments, and these multiple encodings may, in turn, provide for varied interitem associations. Perhaps, then, activity of rehearsal is associated with the generation of an organizational plan or scheme at input which provides for flexibility of item recovery at recall testing. This could possibly be the case under conditions in which the structure of the stimulus materials is either not immediately apparent, as with unrelated words, or not easily used, as with randomly presented taxonomic materials. On the other hand, the data suggest that this "mediating" function of rehearsal might be different with a very explicit list organization. The fact that no rehearsal changes

paralleled the third graders' improved recall under the blocked conditions in experiment 2 indicates that nonrehearsal factors are involved in the recall of categorized materials. It seems possible that with a potential organizational scheme explicit in the blocked presentation of these taxonomic items the postulated role of active rehearsal in generating such a scheme may be reduced. Thus, under these conditions, attention to the inherent structure of the materials may result in enhanced recall, and rehearsal techniques may serve only to account for a small component (perhaps the scalloping effects) of the developmental differences in recall.

This very speculative account for the operation of rehearsal raises many questions concerning factors which may affect children's memory. Critical issues include (1) the precise definition and measurement of the assumed organization at input, (2) the relationships between rehearsal and both input and output organization, and (3) the conditions under which passive as well as active rehearsal may lead to organizational activity. Evaluation of the adequacy of this conception of rehearsal thus clearly rests upon a rigorous determination of the interrelationships between rehearsal and various types (e.g., input, output, and list) of organization.

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Errata

In the article "The Ubiquity of Big Brother," by Langdon E. Longstreth et al. (*Child Development,* 1975, **46,** 769–772), page 769, column 1, paragraph 2, line 14 *should read* ". . . only a limited age range is sampled, and, finally, the effect does not always appear, particularly with psychometric measurements. . . ." Page 770, column 1, paragraph 2, line 8 *should read* "Hollingshead [1957]." Page 770, column 2 table 2, line 4 from bottom *should read* "YBs + OSs + YSs. . . ." Page 772, column 2, Hollingshead reference, date *should read* 1957.