

## A Developmental Study of the Prelinguistic Auditory Store (PAS)\*

RANDALL W. ENGLE

*University of South Carolina, Columbia*

Lists of digits 5 and 7 items in length were presented to second graders, sixth graders, and low-IQ sixth graders in either the visual or auditory modality. Half the auditory lists were followed by the redundant nonrecalled, auditorily presented word "recall" which served as a list suffix. The second graders had the most errors in the ordered recall task followed by the low-IQ sixth- and normal sixth-graders in that order. The size of the modality and suffix effects for the various groups seemed to indicate that, for the younger subjects, a larger proportion of the recall after auditory presentation comes from the Prelinguistic Auditory Store than for the older subjects.

The modality in which verbal materials are presented has taken on new and increased importance in studies of human learning and memory in recent years as a result of the finding that auditory presentation yields much higher performance on short-term memory tasks than does visual presentation. The auditory superiority is typically confined to the last few serial positions in the list although several studies have reported auditory superiority over the entire list (Murdock & Walker, 1969; Routh, 1976).

The modality effect has been found with short-term memory tasks testing for order and item information and with both recall and recognition (Penney, 1975). It is probably safe to say that it is one of the most replicable and strongest of the phenomena observed in short-term memory research. Aside from its pervasiveness, the modality effect is also theoretically interesting because it is taken as part of the evidence for the existence of an auditory sensory memory somewhat similar in nature to the visual icon and given the label Prelinguistic Auditory Store (PAS).<sup>1</sup>

The majority of the work on the PAS has been done by Robert Crowder and his colleagues (Crowder, 1972; Crowder & Morton, 1969) using a procedure called the suffix technique. This technique consists of presenting lists of verbal items to be recalled in the correct order in the same general way one would

\*Part of these data were presented at the Ninth Annual Gatlinburg Conference on Mental Retardation. Reprints may be obtained from Randall W. Engle, Department of Psychology, University of South Carolina, Columbia, South Carolina, 29208.

<sup>1</sup>Dr. Crowder, in a personal communication, has suggested that the name Prelinguistic Auditory Store is more appropriate and fits the nature of the store more than does Precategorical Acoustic Store; thus the newer term is used here.

conduct a memory span test except that the experimental condition also receives a redundant nonrecalled suffix after the last list item. For example, a list of digits might be followed by the suffix "zero" with the subject told beforehand that the zero need not be recalled and may be ignored if he so chooses. The suffix generally causes a large increase in errors over the last one or two serial positions when compared with a nonsuffix control condition. It is assumed by Crowder (1972) that recall of the last few items is so good in the nonsuffix condition because the subject can very quickly read them out of the lingering PAS into the short-term memory in the 1.5–2 seconds before the PAS trace decays. If the list is followed by a suffix, however, the last memory items are displaced from PAS by the suffix and there is nothing the subject can do to keep the suffix from replacing the memory item in the store.

The nice thing about the suffix procedure is that, by varying the nature of the list items and the suffix and the temporal parameters between them, the characteristics of the Prelinguistic Auditory Store can be determined. Some of these characteristics described by Crowder (1972) are: (1) The PAS seems to be speech specific since nonspeech sounds such as buzzes, taps, or tones cause no suffix effect. (2) The PAS seems to be coded by physical features since changes in pitch of voice from the list to the suffix cause reduction in the effect of the suffix. (3) Semantic content does not seem to be important to PAS since the suffix can be any speech sound such as backward speech, words, digits, and, perhaps most interestingly, the word "recall," and a suffix effect will be found. (4) The PAS appears to store only vowels and not stop consonants since no suffix effect is found if the stop consonant is the only distinguishing characteristic of memory items (ba, da, ga) but a suffix effect is found when the vowel is the distinguishing characteristic (ba, bi, bu). It should be mentioned that several studies have observed a suffix effect with visual presentation (Engle, 1974; Kahneman, 1973). However, Hitch (1975) has found that the visual suffix effect could be attenuated by teaching the subject to ignore the suffix while the auditory suffix effect could not be so attenuated. This probably indicates that the visual suffix effect is due to attentional factors while the auditory suffix effect is not.

The present study attempts a developmental analysis of the PAS. It was felt that, since PAS appears to play a vital role in speech perception and contributes to general short-term memory processes, a study of the store in children would be worthwhile. We are beginning to achieve some understanding of the visual sensory memory in children primarily through the work of Haith and his colleagues (Haith, 1971); however, we need to have similar knowledge for the auditory modality. It was with this in mind that the following research was undertaken.

Three groups of children, a second-grade group, a sixth-grade group, and a low-IQ sixth-grade group, were presented with lists of digits to remember in the correct order. (The low-IQ group was included because of Baumeister's (1974) suggestion that low-IQ children rely more heavily on auditory sensory memory

than do normal children.) The digits were presented to the three groups either visually or auditorily, with half of the auditorily presented lists followed by a suffix and half not followed by a suffix. It was hypothesized that, according to the strong view of modality effects taken by Crowder and Morton (1969), if the suffix eliminates the remnant of the memory list from PAS, this should make the auditory suffix condition equivalent to the visual condition. The difference between the performance in these two conditions and the performance in the auditory nonsuffix condition should represent the contribution of PAS to the recall performance in the nonsuffix condition, i.e., to standard auditory presentation of digit lists.

## METHOD

### *Subjects*

The subjects were all taken from public elementary and middle schools in Columbia, South Carolina. The schools serve a population that is heterogenous with respect to race and socioeconomic class. Three groups of 15 children each were selected from a second grade, a sixth grade, and a special class for low-IQ students. All subjects were selected on the basis of mental and chronological age such that the mental age of the low-IQ group would approximate that of the second-graders and the chronological age of the low-IQ group would approximate that of the sixth-graders. The mean and standard deviations of IQ, mental age (MA), and chronological age (CA) for the three groups are shown in Table 1.

The IQ data for all subjects were obtained from the Otis-Lennon test which had been administered by the school system.

### *Materials*

Lists of digits five and seven items in length were constructed from a random number table with the constraints that no digit could appear twice in a list and no obvious associations could occur. There were 30 lists of five items and 30 lists of seven items. Ten 5-item lists and ten 7-item lists were arbitrarily assigned to each of the auditory suffix, auditory nonsuffix, and visual conditions. This assignment of list to conditions remained constant throughout the experiment. The subject

TABLE 1  
Mean and Standard Deviation of IQ, Mental Age (MA), and Chronological Age (CA)  
for the Three Groups

	Second-graders		Low-IQ Sixth-graders		Sixth-graders	
	Mean	SD	Mean	SD	Mean	SD
IQ	110.46	10.22	78.6	9.79	105.1	9.37
MA	8.90	.87	9.0	.89	12.0	1.08
CA	7.90	.29	11.8	.70	11.5	.40

received the lists in blocks of 10 lists with all lists in a block being the same length. The lists were either spoken aloud by the experimenter at a rate of one item per second or presented by slide projector at the same rate.

The visual presentation was by Kodak projector and was timed by making a continuous switch closure across the "Forward" circuit on the projector. This was measured to yield a rate of approximately one digit per second. The auditory presentation was timed by turning off the lamp of the projector and using the sound of the progressing projector as a metronome, thus yielding the same rate of presentation for auditory and visual conditions.

### *Design and Procedure*

The three conditions of stimulus presentation were auditory suffix, auditory nonsuffix, and visual. In the auditory suffix condition the subject heard a list of either 5 or 7 digits followed by the word "recall" in the same cadence and at the same intensity as the digits. It was felt that using the word "recall" as a suffix would be less confusing to the younger subjects than using the "zero" customary in these experiments. In the auditory nonsuffix condition the subject heard only the list of digits with instructions beforehand to begin recalling the list after the last digit was presented. Visual presentation, as the name implies, was silent and by slide projector.

The subjects were tested three at a time in a session lasting about 45 minutes. They were instructed to write the lists of digits on an answer sheet and to write the digits in the order in which they were presented. They were told that if they forgot which digits went in the proper spaces they could either guess or leave them blank.

When the experiment began it was intended to completely counterbalance the ordering of the three conditions and, within each condition, to present the block of 5-item lists first for half the subjects and the 7-item lists first for the other half of the subjects. To test three subjects for each combination of condition and list length would have required 18 subjects per group. It was possible to obtain only 15 subjects per group that met the a priori criteria of MA, CA, and IQ so the counterbalancing scheme was completed except for the last condition and list length combination.

## RESULTS

Recall was scored using two different measures. By one procedure, if the correct digit was not in the proper space on the answer sheet an error was scored for that serial position in the list. The number of errors at each serial position was summed over the ten lists in each block yielding a score that could range from 0 to 10 for each serial position at each of the three conditions and two list lengths.

The second method of scoring was performed at the suggestion of a reviewer that the former method caused a loss of too much information about partial recall.

To counter this criticism a method was used somewhat similar to that used by Huttenlocher and Burke (1976). If the subject recalled the correct digit in the proper space a score of 1.0 was recorded for that serial position. If the correct digit was recalled one space removed from the initial input position a score of .75 was recorded for the original input position; if the digit was recalled two spaces removed a score of .50 was recorded for the original position; and if the digit was recalled three spaces removed a score of .25 was recorded for the original position. If the digit was either not recalled or recalled four or more spaces removed from the input position, a score of 0 was recorded for that position.

For both measures separate analyses of variance were performed for 5-item and 7-item list data. The two methods of scoring yielded identical conclusions and all further discussion will pertain to the former more stringent method. Each of the comparisons discussed below was a Scheffé comparison at the .05 level.

The data from the 5-item lists are shown in Fig. 1. The main effect of Group,  $F(2,42) = 19.87, p < .001$ , was a result of the three groups all being significantly different from each other with the sixth-graders performing best, low-IQ sixth-graders next best, and second-graders worst. Modality was significant with  $F(2,84) = 64.2, p < .001$ . Comparisons showed that the auditory nonsuffix yielded much higher performance than auditory suffix or visual conditions; however, there was no reliable difference between the visual presentation and auditory suffix conditions. The main effect of Serial Position was significant,  $F(4,168) = 89.27, p < .001$ , as was the Serial Position  $\times$  Group interaction,  $F(8,168) = 3.40, p < .001$ . Scheffé comparisons showed this interaction to result from larger differences among the groups at the last four serial positions than for

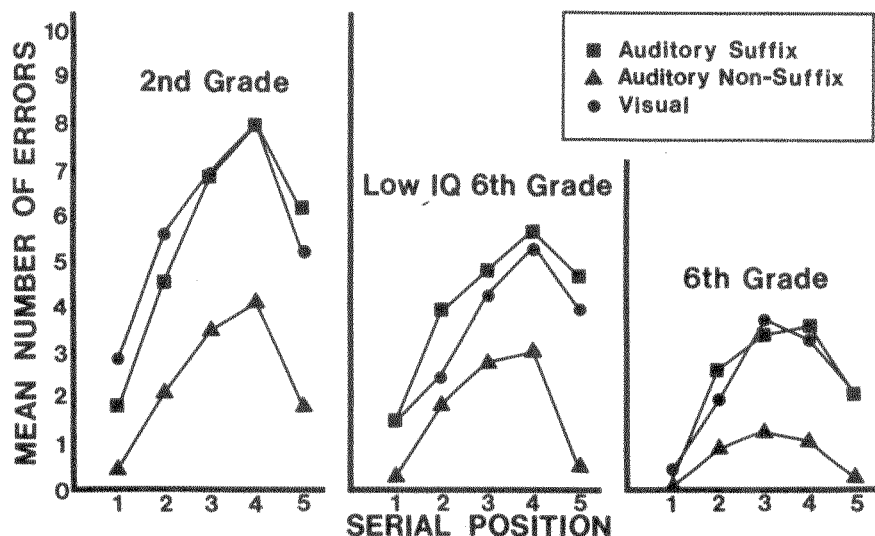


FIG. 1. Mean number of errors for the five-item lists.

the initial position. A breakdown according to group showed that for the second-graders, the auditory nonsuffix condition differed from the visual condition at every serial position but the first. The sixth-grade and low-IQ sixth-grade groups were alike in showing significant differences between the suffix and nonsuffix conditions at all serial positions but the first and differences between the nonsuffix and visual conditions only for positions 3-5.

The Serial Position  $\times$  Modality interaction was significant with  $F(8,336) = 5.47, p < .001$ . Comparisons indicated that the suffix and visual conditions were virtually coincident at every serial position but that both were significantly different from the nonsuffix condition at every position but the first. The amount of this difference increased almost linearly with serial position.

The Group  $\times$  Modality interaction,  $F(4,84) = 3.08, p < .025$ , was found to be due to systematic differences in the size of the modality and suffix effects over the three groups. The suffix and visual conditions again can best be described as nearly coincident but both were significantly different from the nonsuffix auditory condition for all three groups. The interaction results from the difference between the equivalent suffix and visual conditions on the one hand and the nonsuffix condition on the other hand being greater for the second-graders than for the low-IQ sixth-graders, which in turn was greater than the difference for the sixth-graders. This finding will be referred to again after discussion of the 7-item lists. The Serial Position  $\times$  Modality  $\times$  Group interaction was the only nonsignificant interaction found with the 5-item data,  $F(16, 336) = 1.27, p > .05$ .

The data from the 7-item lists are shown in Fig. 2. The analysis demonstrated the significant main effects of Group ( $F(2,42) = 17.92, p < .001$ ), Serial

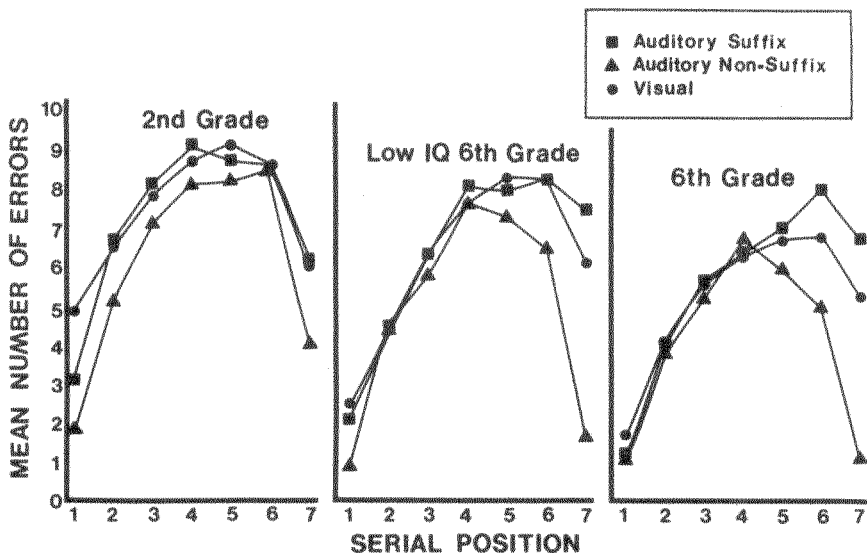


FIG. 2. Mean number of errors for the seven-item lists.

Position ( $F(6,252) = 123.67, p < .001$ ), and Modality ( $F(2,84) = 33.90, p < .001$ ). Again Scheffé comparisons showed the second-graders to perform worse than the low-IQ sixth-graders who performed worse than the sixth-graders. And, as with the 5-item lists, the auditory suffix did not reliably differ from the visual condition but both were significantly different from the nonsuffix condition. The only significant interactions were the Serial Position  $\times$  Modality,  $F(12,504) = 13.02, p < .001$ , and the Serial Position  $\times$  Modality  $\times$  Group,  $F(24,504) = 2.88, p < .001$ .

Since the triple interaction was significant, separate ANOVAs were performed on the data of each of the three subject groups. For the second-graders, the effect of Modality was significant,  $F(2,28) = 9.99, p < .001$ , with the auditory nonsuffix condition being significantly different from both the suffix and visual treatments, but these latter two means not being reliably different. Since the Serial Position  $\times$  Modality interaction was significant for the second-graders,  $F(12,168) = 2.37, p < .05$ , and the previous suffix effect findings have been constrained to the last 1 or 2 serial positions, post hoc tests were performed between the means of the modality conditions at each of the 7 serial positions. There was only one mean difference that was significant and that was between the auditory nonsuffix and visual conditions on the very first serial position. An ANOVA of just the positions 2–7 for the second-graders showed that the main effect of Modality was still significant,  $F(2,28) = 7.0, p < .001$ , even though the first position had been eliminated and at no *single* serial position did the modality conditions differ. The Serial Position  $\times$  Modality interaction was not significant in this latter analysis of position: 2–7,  $F(10,140) = 1.24, p > .05$ , indicating that there was a general deteriorating effect of suffix and visual presentation over nearly the entire list when compared with the nonsuffix condition.

Inspection of the two right panels in Fig. 2 shows, and ANOVA and post hoc analysis corroborated, that the effects of modality were confined to the final one or two positions for the low-IQ sixth- and sixth-graders. The Serial Position  $\times$  Modality interactions were highly significant with  $F(12, 168) = 8.0, p < .001$ , for the low-IQ sixth-graders and  $F(12,168) = 8.33, p < .001$ , for the sixth-graders. Individual comparisons showed this to result from no difference between the suffix and visual conditions at any position and differences between these two conditions and the nonsuffix condition at only the last position or two.

One final analysis of the data was to calculate difference scores by subtracting the auditory nonsuffix group mean from the averaged suffix and visual group means (Overall & Woodward, 1975). This was done for each of the three groups at each of the two list lengths. Since the auditory suffix and visual conditions were virtually coincident at every point it seems valid to assume that these two conditions are alike in having none of the recall come from the Prelinguistic Auditory Store and that the difference between either or both of these conditions and the auditory nonsuffix condition would represent the contribution of the PAS

to the nonsuffix recall. That is, this difference score should give us a fairly accurate index of the proportion of recall after standard auditory presentation that comes from the PAS. As can be seen in Fig. 3, there is a systematic decrease in the difference score over the three groups for the 5-item list which reflects the significant Groups  $\times$  Modality interaction for that list length. It can also be seen that the difference scores for the 7-item lists did not show such a decrease over the groups and, indeed, might be best described as a flat function.

### DISCUSSION

Crowder and Morton (1969) propose that the redundant auditory suffix eliminates the remnants of the auditory trace and makes the recall of the list followed by the suffix identical to the recall of a list of visually presented items. The present data support that contention since the auditory suffix and visual conditions were virtually identical on every test. In other words, from the present data,

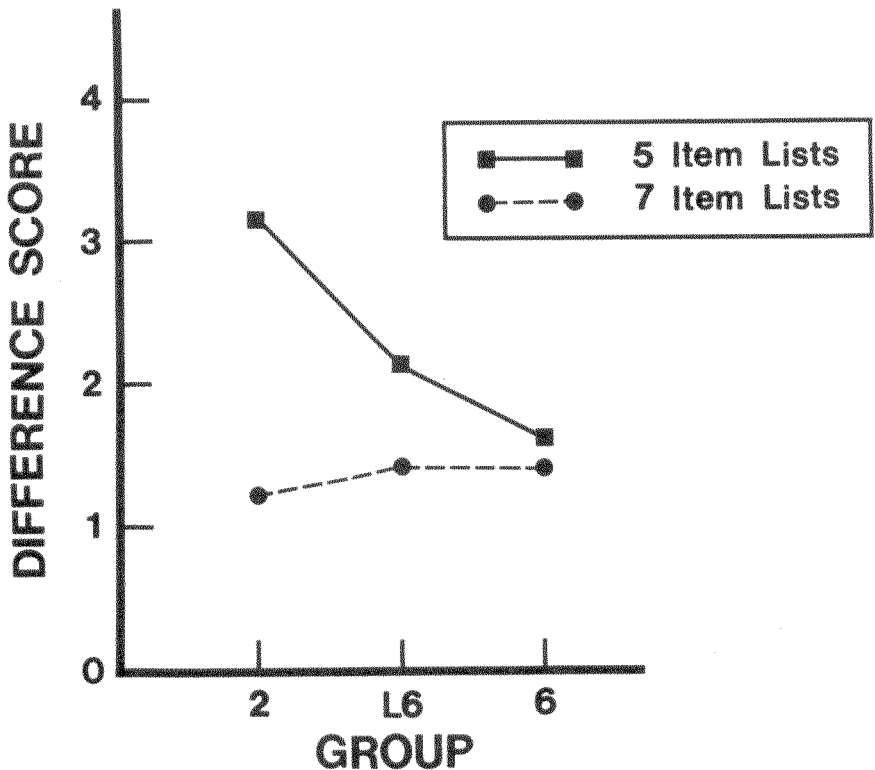


FIG. 3. Difference score calculated by subtracting the auditory nonsuffix mean from the combination visual and auditory suffix mean for each group.



it can be argued that performance in either the auditory suffix or visual conditions represents only recall from the longer lasting short-term store while performance in the auditory nonsuffix condition represents the contribution from the Prelinguistic Auditory Store in addition to recall from the short-term store.<sup>2</sup> With this in mind, the data from Fig. 3, i.e., the difference scores between the averaged suffix-visual means and the nonsuffix means, suggest that there is a systematic decrease in the contribution of PAS for the 5-item lists over the three groups from second-graders to low-IQ sixth-graders to sixth-graders.

Whether this is a result of the PAS capacity being unequal for the three groups or simply different degrees of reliance on a store of the same capacity is not answered by the data. Morrison, Holmes, and Haith (1974) have argued that individual differences in performance on visual sensory store tasks reflect differences in the way information is read out of the visual store and not basic capacity or "hardware" differences. Thus, it probably is safer and more parsimonious to assume that the developmental trends observed here reflect differential use of or read out from the auditory store rather than differential store capacity.

One potential concern in the interpretation of the group differences in modality and suffix effects is whether the differences result from the simple fact that memory span increases in size from second- to low-IQ sixth- to sixth-grade subjects. That is, it might be argued that the difference scores for the 5-item lists decrease over groups simply because the number of errors for the older subjects is so small in the three conditions. This thesis might be defensible if we only consider the 5-item data. However, this argument makes certain predictions about the 7-item lists that are not borne out by the data. If the only difference between the difference data for the second-graders and the sixth-graders on the 5-item lists is one of simple memory span then the sixth-graders should show a larger difference score on the 7-item list than they do on the 5-item lists, and the difference scores for their 7-item data should approach that of the second-graders on the 5-item lists. That is, if the 5-item curve from Fig. 3 is due to floor effects then the 7-item curve should either show an increase over groups similar to the drop for the 5-item curve or a flat function but at the same level as the second-grade 5-item list data. Which one of these two 7-item functions should be found depends on what we assume that the effect would be on the second-graders of trying to remember lists that exceed the memory span by several items. Regardless, the difference score for the sixth-grade group should be higher for the 7-item lists than for the 5-item lists if the boundary effects explanation is to hold. While this finding was not obtained, thus arguing against the boundary explanation, more empirical treatment of floor and ceiling effects is required before firm conclusions can be drawn.

But, assuming the difference data are not due to boundary effects, then it

<sup>2</sup>This generalization may only hold for serial recall of short lists of digits since Engle (1974) showed this not to be the case with free and serial recall of 12-word lists.

remains necessary to explain why the 5-item data are so different from the 7-item data for the second- and low-IQ sixth-graders. One explanation, whose validity and parsimony will have to be proven with future research, is that, indeed, the PAS does contribute more to the total recall of the second-graders in the nonsuffix condition but this is only true if the list length does not exceed by too great an amount the child's memory span. If the list is so long that it exceeds the memory span by more than one or two digits, then the PAS plays a less important role in total immediate recall. This could be due to changes in the way the child reads out the items from the sensory store with changes in list length. For example, it may be that the young child reads the terminal list items out of the PAS and into the short-term memory faster with the slightly supraspan 5-item lists than does the older child or than he himself does with longer lists. As the child develops and becomes more sophisticated in rehearsal and memorizing and increases his memory span he may place less importance on the terminal items and more on those in the primacy positions. It could also be that the child learns the futility of relying on the PAS for recall since Engle and Mobley (1976) have argued that this leads to poorer long-term memory performance than does recall after visual presentation.

Another potential explanation is derived from Huttenlocher and Burke's (1976) recent paper on the development of memory span. They argue that the developmental increase in memory span is due to the child's increasing ability to assign positions to incoming items. They suggest that a young child may be able to assign positions to the first and second items, but not to the third, fourth, etc., although he could again encode the position of the last few items. If, as Penney (1975) suggests, auditory presentation leads to much better retention of order information than does visual presentation, and the Huttenlocher and Burke (1976) theory is only true or more true with auditory presentation, then the present data might be explained in this framework. The younger child might be relying on the PAS for order information a great deal more than would the older child. It may be that with the longer lists the child is not capable of using the PAS information properly.

A problem for both explanations considered here is the serial position data for the second-graders and the 7-item lists. The suffix and modality effects were spread over nearly the entire list and, in fact, were larger on the very first serial position. It may be that, as Crowder and Morton (1969) suggest, the suffix makes the list functionally one item longer. The young child might adopt the strategy of just giving up attempts at trying to remember the list when the list too greatly exceeds the memory span while the older child might continue rehearsal, even with supraspan lists.

Some mention should be made here of the MA, CA, and IQ variables. Baumeister (1974) found that low-IQ sixth-graders had lower memory thresholds than normal second- and sixth-graders. He also argued that his low-IQ subjects relied more heavily on the acoustic storage system than the normal subjects. The

present study shows no clear effect of MA, CA, or IQ in either level of recall or the effects of modality and suffix-nonsuffix. The two studies are, of course, very different in methodology, but the present data argue for an interaction between MA and CA since the low-IQ subjects fell midway between the second-graders and sixth-graders on all indices.

### ACKNOWLEDGMENTS

I would like to express appreciation to W. D. Johnson, Director of Testing, Richland County District 2, Elizabeth Ramey, L. B. Nelson Elementary School, and Julia Boyd, Hanberry Middle School for their assistance and cooperation in the project. Robin Robertson constructed the stimulus materials.

### REFERENCES

- Baumeister, A. S. Serial memory span thresholds of normal and mentally retarded children. *Journal of Education Psychology*, 1974, **66**, 889-894.
- Crowder, R. G. Visual and Auditory Memory. In *Languaged by ear and by eye*. J. F. Kavanaugh & I. G. Mattingly (Eds.). Cambridge, Mass.: M.I.T. Press, 1972.
- Crowder, R. G., & Morton, J. Precategorical acoustic storage (PAS). *Perception and Psychophysics*, 1969, **5**, 365-373.
- Engle, R. W. The modality effect: Is precategorical acoustic storage responsible? *Journal of Experimental Psychology*, 1974, **102**, 824-829.
- Engle, R. W., & Mobley, L. A. The modality effect: What happens in long-term memory? *Journal of Verbal Learning and Verbal Behavior*, 1976, **15**, 519-527.
- Haith, M. M. Developmental changes in visual information processing and short-term visual memory. *Human Development*, 1971, **14**, 249-261.
- Hitch, G. J. The role of attention in visual and auditory suffix effects. *Memory and Cognition*, 1975, **3**, 501-506.
- Huttenlocher, J., & Burke, D. Why does memory span increase with age? *Cognitive Psychology*, 1976, **8**, 1-32.
- Kahneman, D. *Attention and effort*. Englewood Cliffs, N.J.: Prentice-Hall, 1973.
- Morrison, F. J., Holmes, D. L., & Haith, M. M. A developmental study of the effect of familiarity on short-term visual memory. *Journal of Experimental Child Psychology*, 1974, **18**, 412-425.
- Murdock, B. B., & Walker, K. D. Modality effects in free-recall. *Journal of Verbal Learning and Verbal Behavior*, 1969, **8**, 665-676.
- Overall, J. E., & Woodward, J. A. Unreliability of difference scores: A paradox for measurement of change. *Psychological Bulletin*, 1975, **82**, 85-86.
- Penney, C. A. Modality effects in short-term verbal memory. *Psychological Bulletin*, 1975, **82**, 68-84.
- Routh, D. A. An "across-the-board" modality effect in immediate serial recall. *Quarterly Journal of Experimental Psychology*, in press.