Life-Span Differences in Semantic Integration of Pictures and Sentences in Memory

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Pezdek, Kathy. Life-Span Differences in Semantic Integration of Pictures and Sentences in Memory. Child Development, 1980, 51, 720-729. This study examined life-span developmental differences in spontaneous integration of semantically relevant material presented in pictures and sentences. 45 third graders, 45 sixth graders, 45 high school students, and 30 adults over 60 were presented a sequence of 24 pictures and sentences, followed by 24 intervening items. Each intervening item corresponded to, but was in the opposite modality from, one of the original items and was either semantically relevant or irrelevant to the corresponding original. In a “same-different” recognition test, data suggested that the sixth-grade and high school subjects semantically integrated original items with relevant intervening items that were in the opposite modality and made subsequent recognition responses on the basis of the integrated memory. Third graders and older adults, however, showed no evidence of spontaneous, cross-modality semantic integration. Further, increasing the temporal delay between presenting the to-be-integrated items, from 5 min to 1 day, decreased overall response sensitivity but did not alter the patterns of integration results. The findings are discussed in terms of age differences in the spontaneous use of strategies for effective memory processing, with the extreme age groups processing more formal characteristics of the stimuli in memory, and the middle 2 groups processing deeper, more semantic information.

The ability to integrate semantically relevant information in memory is an important aspect of the process of comprehension. Research in the area of memory and comprehension has increasingly focused upon analyzing the cognitive strategies involved in semantic integration. In research with adults, integration has been reported, using descriptive sentences (Bransford & Franks 1971), linear syllogisms presented verbally (Potts 1977), prose passages (Bransford & McCarrell 1975), and line drawings (Pezdek 1978).

Semantic integration and other constructive processes have also provided an important framework for investigating developmental changes in comprehension and memory (see Paris & Lindauer 1977). This can be attributed to the focus in this line of research on functional operations of memory, with ecologically valid tasks that extrapolate to everyday activities. A second reason for studying developmental differences in semantic integration is based on a model for distinguishing memory tasks developed by Brown (1975). Brown’s model assumes (1) that “tasks will be developmentally sensitive to the degree that they demand strategic transformations for their effective execution” (Brown 1975, p. 134), and (2) that semantic tasks are more sensitive to developmental differences than are episodic tasks. Hence, tests of semantic integration should be most sensitive to developmental differences in memory where they exist.

Previous research has demonstrated children’s semantic integration ability (1) in a Bransford and Franks (1971) paradigm with sentences (Paris & Carter 1973), (2) using verbal discourse with free recall (Barclay & Reid 1974) as well as cued recall (Paris & Lindauer 1976), and (3) with verbal and pictorial materials, using recognition procedures with each modality tested separately (Brown 1976; Paris & Mahoney 1974). At the older end of the age spectrum, integration is of par-
ticular interest in view of the fact that the elderly have reportedly shown decrements in numerous indexes of memory capacity (Craik 1977; Perlmutt 1978). Using the Bransford and Franks (1971) procedure, Walsh and Baldwin (1977) reported that older adults (mean age, 67.3 years) and younger adults (18.7 years) did not significantly differ in the degree to which they integrated sentences in memory.

The present study addresses the notion of cross-modality semantic integration, that is, integration of information that is presented partly in the verbal modality and partly in the pictorial modality. More specifically, this study examines life-span differences in this process. Cross-modality semantic integration is a cognitively interesting phenomenon because the cross-modality integration task presents a more rigorous test of the notion of semantic integration than previous single-modality sentence-integration or picture-integration studies. In order for two items to be semantically integrated in memory, a subject must be able to recognize the common meaning shared by the items, despite differences in the formal features of the items. This process is necessary even when the to-be-integrated items are both sentences or both pictures. In a cross-modality task, however, the to-be-integrated items have an additional dimension of formal difference—one member of each pair is presented verbally and the other pictorially. Thus, more cognitive mediation would be necessary to reach a level of processing sufficiently "deep" (see Craik & Lockhart 1972) to contact and integrate the common meaning of a picture and a sentence than would be required with two pictures or two sentences. Therefore, although previous studies have reported that young children and older adults can integrate information in single-modality tasks, the present cross-modality integration task would be expected to be more sensitive to age differences, and age differences in integration would be predicted.

A number of studies have reported developmental differences in spontaneous use of depth of processing and mediating strategies at both ends of the life span. Murphy and Brown (1975), Sykes (1976), and Weiss, Robinson, and Hastie (1977) have reported that, although children have the ability to deeply process materials and abstract the gist from stimuli presented, they do not spontaneously adopt these more efficient learning strategies. This "production deficiency" has been discussed elsewhere (see Hagen, Jongeward, & Kail 1975) and is consistent with Brown's (1975) conclusion that tasks that require strategic transformations of stimulus materials will be more sensitive to developmental differences in processing. A parallel finding has been reported with older adults (see Eysenck 1974; Hulicka & Grossman 1967). Eysenck (1974) found, for example, that although the young adult subjects showed recall superior to that of older subjects, only the older subjects were facilitated by a deep-level processing task when specifically instructed to use it.

The present study tests whether relevant information, presented in two different modalities, is integrated in memory by third graders, sixth graders, high school seniors, and adults over 60. Although previous studies have reported no age differences in single-modality integration tasks, age differences in cross-modality integration in the present study are predicted since it is argued above that (1) deeper semantic processing or more strategic transformations are required in cross-modality integration than in within-modality integration, and (2) as Brown (1975) stated, tasks that require more strategic transformations are more developmentally sensitive.

This study employed the cross-modality integration paradigm used by Pezdek (1977) with adults. In the presentation phase, subjects viewed a series of slides describing several scenes. Each scene was described by two slides. Either a single picture was followed sometime later by a sentence (the intervening item), or a sentence was followed by a picture (the intervening item). Half of the intervening items were semantically relevant to the original item with which each had been matched, and half of the intervening items were semantically irrelevant. Test items were in the modality of the original item for each scene and either depicted an integration of the original and intervening items or repeated the original item. The task of the subjects was to decide whether each test slide was identical with one previously seen.

If semantic integration occurs across modalities, then subjects should be less able to recognize an original item when a semantically relevant item intervenes than when an irrelevant item intervenes. The signal detection measure of $d'$ would reflect this change in recognition sensitivity in distinguishing original items from changed test items. As a result of integrating the original items with the semantically relevant intervening items, $d'$ values would be lower in the relevant than irrelevant
intervening item condition. Further, in comparing \( d' \) values in the relevant versus irrelevant intervening item conditions for each age group, it is predicted that this difference will be significant for the middle two age groups (i.e., recognition sensitivity will be higher with irrelevant than relevant intervening items) and not significant for younger children and older adults. The principal prediction in the present study is thus an inverted U-shaped function of integration with age.

Another purpose of this research was to determine how the integration process is affected by increasing the temporal interval between the to-be-integrated items and whether this factor interacted with age in affecting integration. Pairs of related items were separated at presentation by 5 min, 15 min, or 1 day. It is predicted that increasing the temporal separation of to-be-integrated items will decrease integration with subjects in the middle two age groups but will not affect results of subjects in the extreme age groups, who would be less likely to integrate even at the briefest delay.

**Method**

**Subjects.**—Subjects were selected from four age groups. Forty-five third graders and 45 sixth graders participated from Morgan and Preston Elementary Schools, Rialto, California. The young adults were 45 high school seniors who volunteered from psychology classes at Eisenhower High School in Rialto. The elderly adults were 30 volunteers from a senior citizen center in Costa Mesa, California. These subjects ranged in age from 60 to 75 years, with most around 66 years of age (an exact mean age is not available because most of the elderly adults preferred not to give any personal information). None of the senior citizens was educated beyond high school, most described themselves as living on modest incomes, and none was physically disabled or heavily medicated. Approximately equal numbers of males and females participated in each group, but sex of subject was not specifically controlled for.

**Procedure.**—All subjects participated individually. Subjects were presented a sequence of slides consisting of 24 original presentation items, followed by 24 intervening items, a fixed 2-min delay, and then the test series of 24 slides. The complete set of 24 original items was shown before the complete set of 24 intervening items was presented. The time interval between presenting the original items and the intervening items was manipulated as a factor in the experiment. When the series of intervening items was presented immediately after the 24 original items, there was, on the average, a 5-min delay between the presentation of each item in a to-be-integrated pair. In the other two delay conditions, this time interval was 15 min or 1 day. In the 15-min delay condition, subjects worked on a maze-tracing task during the delay.

Subjects were instructed to try to comprehend the meaning of each of the 48 items in the presentation phase, as this would be important in a later part of the experiment. The subjects were not informed that the sequence of 48 presentation slides included 24 original items and 24 intervening items. In the recognition test, the subjects were asked to classify each slide as "old" or "new." An old slide was specified as a slide that was exactly the same as one seen before. The young and old adult subjects marked their responses on the protocol sheet provided. The experimenter recorded responses for subjects in the two younger groups.

The slides were presented by a Kodak Carousel slide projector with a shutter attachment regulated by a millisecond timer as well as a manual control. During the presentation phase, slides were exposed for 7 sec with a 1-sec interval between slides with the shutter closed. Third- and sixth-grade subjects were asked to read aloud each sentence in both the presentation and the test phase to insure that they were actually attending to the whole sentence and were familiar with the vocabulary. The test slides were presented manually, one at a time, until the subjects had responded to each. This usually took less than 10 sec per slide.

**Materials.**—The materials were divided into two categories, verbal and pictorial stimu-

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1 Initially, 48 subjects participated in each of the three younger age groups and 32 subjects in the older group. However, one or two subjects in each age group (six subjects total) performed well below chance level on the recognition test, producing low negative \( d' \) scores. The experimenter reasoned that these subjects were not paying attention to the task since the overall accuracy for each of these subjects was less than 30%, where 50% correct was the chance level. The data from these subjects were dropped from the experiment, and the design was then balanced by randomly deleting one subject in each delay condition at each age.
In the verbal category, each of the 12 original items was a sentence, the corresponding intervening item was a picture (either a semantically relevant picture or a semantically irrelevant picture), and the test item was a sentence. The irrelevant intervening items in the study were constructed with the same procedure used to generate the relevant items but were semantically irrelevant to the original presentation items. The subject matter presented in the irrelevant items did not overlap with any other items used throughout the experiment. On half of the trials, the test sentence was the same as the originally presented sentence, and on half of the trials the test sentence was a changed version of the original. The changed version of the test sentence was constructed by incorporating, into the original sentence, an additional detail provided in the corresponding relevant intervening picture. An example of a verbal set is presented in figure 1. All sentences were constructed using a similar grammatical structure. The materials were piloted to insure that third graders could read and comprehend each sentence.

In the pictorial category, the original items were pictures, each corresponding intervening item was a relevant sentence or an irrelevant sentence, and the test items were pictures. On half of the trials, the test picture was the same as the originally presented picture, and on half of the trials it was the changed version of the original picture. The changed test pictures were constructed by incorporating into the original picture the specific detail provided in the corresponding relevant intervening sentence. All pictures were simple line drawings in black and white. An example of a pictorial set is presented in figure 1.

**Design.**—A diagrammatic representation of the experimental design is presented in figure 2, with the number of items included in each experimental condition for each subject indicated. Each subject was presented with both pictorial and verbal materials, semantical-
ly relevant and irrelevant intervening items, and both changed and unchanged test items. Half of the items in each of the verbal and pictorial categories were independently and randomly assigned to the relevant intervening item condition, and the remaining items were assigned to the irrelevant intervening item condition. Half of the items in each of these conditions were randomly chosen to be tested with changed test items, and the remaining items were tested with unchanged test items. The order of presentation was randomized to produce two order conditions, with the restriction that no more than three sentences or three pictures be presented sequentially. Subjects were randomly assigned to each condition of order.

Additional between-subjects variables of age (third graders, sixth graders, high school seniors, and older adults) and temporal delay between presenting the to-be-integrated items (5 min, 15 min, or 1 day) were included in the design. Fifteen subjects in each age group were randomly assigned to each of the three delay conditions.

Experimental hypotheses.—The pattern of results which would evidence semantic integration is presented in figure 2. When a relevant intervening item is presented after an original item, it is predicted that the information in the intervening item becomes integrated into, and thus alters the memory of, the original item. In the irrelevant intervening item condition, se-

Fig. 2.—Experimental design with predicted outcomes of the integration hypothesis
mantic integration of the original items with intervening items would not occur. Consequently, recognition test performance would reveal lower \( d' \) values in the relevant than in the irrelevant intervening item conditions. This pattern of integration results was compared across age and temporal delay.

**Results**

The dependent variable of primary interest was the signal detection measure of \( d' \) scores. However, accuracy and error data were examined to insure that floor and ceiling effects did not contaminate the \( d' \) measure. The mean hit rate and false alarm rate were computed across all subjects in the four age groups in the 5- and 15-min delay conditions. The mean probability of a hit was .82 (\( s^2 = .037 \)), and the mean probability of a false alarm was .34 (\( s^2 = .061 \)). These data strengthen the reliability and robustness of the interpretation of the \( d' \) results that follow.

The \( d' \) values were included because the conditions of the experiment suggested that response bias as well as sensitivity might affect the accuracy data. The values of \( d' \) reflect the degree of integration, by measuring subjects' recognition sensitivity in distinguishing the originally presented items from changed test items. (See Banks [1970] for an explanation of signal detection theory.) The \( d' \) values were computed for each subject's responses in each condition of modality, type of intervening item, and identical or changed test item. Thus, for each subject, the \( d' \) values in each experimental condition were based on three "signal" (identical) and three "noise" (changed) test items. The procedure outlined by Hochhaus (1972) was followed for calculating \( d' \) values. The mean \( d' \) values for each age group in each of the experimental conditions are presented in table 1. The rejection region for all of the following analyses is \( p < .05 \).

The principal prediction of integration was tested with a priori tests comparing the \( d' \) data in the conditions of relevant versus irrelevant intervening item. If integration of the original items with the relevant intervening items occurred, then \( d' \) values would be lower in the relevant than in the irrelevant intervening item conditions. A priori tests compared \( d' \) values in the relevant versus irrelevant intervening item conditions in each of the four age groups, across the 5- and 15-min delay conditions. Because the older adults were not tested at 1-day delay, this condition was not included in this analysis. The \( d' \) scores were significantly higher with irrelevant than with relevant intervening items for the sixth-grade sample (3.20 vs. 2.35, \( t_{28} = 3.44 \)) and marginally significant with the high school sample (2.83 vs. 2.30, \( t_{28} = 1.63, .05 < p < .10 \)). In the third-grade and older adult samples, however, there was no significant difference in \( d' \) scores between the relevant and irrelevant intervening item conditions (third graders, 2.19 vs. 2.07; older adults, 1.96 vs. 2.14; both \( t's < 1.0 \)).

Two analyses of variance were next performed on the data to more specifically examine the pattern of integration results. These two conditions were compared across age and temporal delay.
partially overlapping analyses were necessary because the older adults were not included in the 1-day delay condition. Thus, the first analysis was performed on \(d'\) data for the four age groups in the 5- and 15-min delay conditions. The second analysis examined \(d'\) data for only the younger three age groups in the 5-, 15-, and 1-day delay conditions. Within-subject variables of modality of the original item and relevance of the intervening item were included in both analyses. The first analysis revealed a significant effect of age on \(d'\) data, \(F(3,112) = 3.05, \text{MS}_e = 4.75\). Mean \(d'\) scores were higher for the sixth-grade (2.78) and young adult samples (2.56) than for the third-grade (2.13) or older adult samples (2.05). The effect of type of intervening item on \(d'\) was also significant, \(F(1,112) = 4.94, \text{MS}_e = 2.59\). Overall, subjects were more sensitive when irrelevant (2.54) than when relevant (2.22) items intervened. Finally, \(d'\) scores were significantly higher when the original and test items were sentences (2.68) as compared with pictures (2.07), \(F(1,112) = 11.73, \text{MS}_e = 3.79\).

The age \(\times\) intervening item interaction was significant at the .06 level, \(F(3,112) = 2.36, \text{MS}_e = 2.59\). The direction of this effect was elucidated in the a priori analyses presented above. The effect of modality significantly interacted with age, \(F(3,112) = 5.72, \text{MS}_e = 3.79\), and with type of intervening item, \(F(3,112) = 5.94, \text{MS}_e = 2.59\). Mean \(d'\) scores were greater for sentences than for pictures with the third- and sixth-grade samples, whereas, with the young and older adult samples, sensitivity to sentences and pictures was similar. The modality \(\times\) intervening item interaction indicated that, with pictures, subjects were more sensitive when irrelevant (\(d' = 2.42\)) than when relevant (\(d' = 1.73\)) items intervened, as predicted by the integration hypothesis. However, with sentences, subjects were similarly sensitive in the irrelevant (\(d' = 2.67\)) and relevant (\(d' = 2.70\)) intervening item conditions. Thus, despite the significant pattern of results supporting cross-modality integration, intervening sentences were more likely to be integrated into original pictures than were intervening pictures to be integrated into original sentences. The modality \(\times\) intervening item interaction did not significantly vary across age groups or delay conditions (i.e., the interactions of age \(\times\) modality \(\times\) intervening item, delay \(\times\) modality \(\times\) intervening item, and age \(\times\) delay \(\times\) modality \(\times\) intervening item achieved \(F's\) of approximately 1). No other effects were significant in this analysis.

The final results of interest involve the effect on integration of increasing the temporal delay between the to-be-integrated pairs of items. The second analysis of variance was performed on the \(d'\) data for the third-grade, sixth-grade, and high school subjects at the three conditions of delay. Sensitivity significantly decreased with increasing delay, \(F(2,126) = 10.72, \text{MS}_e = 4.60\), from 5 min (\(d' = 2.51\)), to 15 min (\(d' = 2.47\)), to 1 day (\(d' = 1.58\)). The effect of delay did not interact with type of intervening item or any other variables. All other results with this analysis were the same as those reported in the previous analysis of variance across the four age groups at the 5- and 15-min delay conditions only.

**Discussion**

The present study explored life-span differences in semantic integration of information presented in pictures and sentences. The \(d'\) data suggest that sixth graders and young adults spontaneously integrated semantically related information presented in sentences and pictures. However, third graders and adults over 60 did not semantically integrate information across modalities. The evidence supporting age differences in cross-modality integration was not confounded by general response accuracy. As can be seen in table 1, mean \(d'\) scores in the middle two age groups were significantly higher than were mean \(d'\) scores in the extreme age groups. The significant \(d'\) difference in relevant versus irrelevant intervening item conditions in the middle two age groups was not, then, simply due to general decreased sensitivity by these subjects.

In the present study, the high school subjects in the 5-min delay condition present a replication of the previously reported cross-modality integration study with college age subjects (Pezdek 1977). In the comparable conditions in the two studies, subjects had higher \(d'\) values in the irrelevant than in the relevant intervening item conditions with both sentences and pictures. Although the difference in \(d'\) scores between the relevant and irrelevant intervening item conditions with young adults in the present study was only marginally significant (\(t_{28} = 1.63\)), this effect was soundly significant in the previous study (\(t_{55} = 2.45, p < .01\)). The replication of the cross-modality integration finding provides additional support for the effect with adults. Pezdek's (1977) results with college subjects aged 19 to 28 years
also supplement the present study by providing a more complete life-span analysis. The fact that cross-modality integration resulted for college age subjects in the previous study suggests that performance on this task does not simply decline after adolescence.

The finding of age differences in integration in the present study is particularly interesting in light of other studies reporting that young children and older adults can semantically integrate information presented within a single modality. A reasonable explanation for the difference obtained in the present study is that cross-modality integration requires a deeper level of semantic processing than within-modality integration. In other words, in order for the semantic content of a picture to be integrated with the semantic content of a sentence, a subject must be able to recognize the common meaning shared by the items, despite obvious differences in the form of the items. Thus, given the previous findings of age differences at both ends of the life span in spontaneous cognitive mediation and depth of processing, it follows that the developmental differences in this study can be accounted for by insufficiently deep processing by the younger children and older adults.

However, describing the results in terms of differences in depth of processing or deficiencies in cognitive mediation does not explain why the two extreme age groups did not semantically integrate related presentation items. The answer to this question may be that young children and older adults do not approach memory tasks (in the laboratory or in everyday experiences) with effective memory strategies (Flavell & Wellman 1977; Paris & Lindauer 1976). Without specific instructions to do so, they do not systematically, recursively process the meaning of information in memory to facilitate later access. On the other hand, older children and young adults apparently approach memory tasks with the goal of comprehending the material to enhance memory. Thus, they spontaneously employ rehearsal strategies that have been shown to be effective for them—largely those strategies that involve elaborating and embellishing the material on the semantic level, including relating new information to previously encountered materials. Such strategies would thus result in constructive processes of integrating semantically related information as a by-product of remembering. These operations are not necessarily part of a conscious plan to remember; in fact, utilization of effective memory strategies appears to be largely automatic after some point in cognitive development. A direction for future research is to investigate whether the younger children and older adults use the same (ineffective) processing strategies. The two extreme age groups may not be engaging deep levels of processing for the same reasons—unavailability of effective strategies, information overload, motivational reasons, etc. Current theories of life-span cognitive development are not sufficiently developed to shed light on this point.

An alternative explanation of the developmental change in the pattern of integration results is that the youngest and oldest subjects had dual coding systems for storing visual and verbal information (see Paivio & Csapo 1969) and the older children and younger adults utilized a single, integrated memory store. This notion is theoretically implausible and unpar-simonious and is not supported by the available research in the literature. Rosinski, Pellegrino, and Siegel (1977), for example, reported that with children as young as 7 years, a single memory system rather than a dual coding system best fits the available data.

A second alternative explanation of the obtained pattern of \( d' \) values for the sixth-grade and high school subjects is that, in the relevant intervening item condition, subjects were deciding whether each test item was old or new by comparing the item with their memory of the intervening item only. Research reported by Pezdek (1977, experiment 2) refutes this alternative explanation of the data.

The significant effects of modality on response sensitivity warrant discussion. Subjects were generally more sensitive to changes in sentences than in pictures. In addition, type of intervening item interacted with modality of the original item in a consistent direction across age groups and delay conditions. This pattern of results suggests that, despite the significant overall pattern of cross-modality integration, intervening sentences were more likely to be integrated into original pictures than were intervening pictures to be integrated into original sentences. A post hoc interpretation that fits this result is the following. The nature of the materials was necessarily such that the pictures contained more information than did the sentences. When presented with a relevant intervening picture in the sentence condition, subjects may have interpreted the picture in terms of the many re-
relationships existing therein. Among these component relationships in the picture would be the relationship similar to that in the previously presented sentence. The memory trace for the original sentence would thus be incremented by this rehearsal from repetition, but, since the picture contained more information than the sentence, it would be seen as different from the sentence and thus be stored separately. Consequently, the relevant items would not be integrated, and at the same time the original sentence would be well recognized in both intervening item conditions. In the picture condition, however, the relevant intervening sentences contained less information than the original pictures, so the relevant sentences could be integrated into the stored representations of the pictures without losing substantial information.

Increasing the delay between presenting the original items and the intervening and test items significantly reduced overall response sensitivity. However, the absence of both a significant delay × intervening item interaction and a delay × age × intervening item interaction suggests that the integration pattern of results was not affected by increasing the temporal delay between the to-be-integrated items.

In conclusion, evidence supporting cross-modality semantic integration was obtained with sixth-grade and young adult subjects in this study, using an ecologically valid task which can readily be extrapolated to processing demands of everyday activities. However, younger children and older adults did not semantically integrate information presented in pictures and sentences. At present, the most convincing explanation for this age difference is in the memory operations spontaneously adopted by subjects in the middle two age groups which resulted in deeper-level processing of the materials, compared with the younger and older subjects. Evidence from other researchers suggests that young children and older adults less readily utilize effective memory strategies such as the deep-level processing of information necessary for cross-modality semantic integration.

References


