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# TABLE OF CONTENTS

VITA................................................................ii

LIST OF FIGURES................................................... V

Chapter........

I  INTRODUCTION.................................................................1

   Experiment I.................................................................2

    Subjects................................................................2

    Procedure.................................................................3

    Results.......................................................................4

    Discussion.................................................................5

II.  THE CODING THEORY OF MEMORY DEVELOPMENT....................6

    Quantative Aspects.......................................................8

       PI Release Tasks.......................................................8

       Recognition Techniques...........................................12

    Relational Aspects.....................................................14

       Sentence Memory Studies.........................................14

       Imagery Studies.......................................................17

    Experiment II.............................................................18

       Subjects................................................................18

       Procedure..............................................................18

       Results..................................................................19

       Discussion.............................................................19
<table>
<thead>
<tr>
<th>Chapter continued</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>III. DEVELOPMENT OF LEARNING</td>
<td>21</td>
</tr>
<tr>
<td>Experiment III</td>
<td>22</td>
</tr>
<tr>
<td>Subjects</td>
<td>22</td>
</tr>
<tr>
<td>Procedure</td>
<td>23</td>
</tr>
<tr>
<td>Results</td>
<td>24</td>
</tr>
<tr>
<td>Discussion</td>
<td>24</td>
</tr>
<tr>
<td>IV. SUMMARY AND CONCLUSIONS</td>
<td>26</td>
</tr>
<tr>
<td>V. FOOTNOTES</td>
<td>29</td>
</tr>
<tr>
<td>VI. FIGURES</td>
<td>30</td>
</tr>
<tr>
<td>VII. BIBLIOGRAPHY</td>
<td>34</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

1. Brown's (1975) model of memory development.......................30
2. Amount recalled as a function of age and instruction condition...31
3. Amount recalled as a function of instructions to image vs. tell meanings, vs. tell correct voice..................................32
4. Amount recalled as a function of age, instructions and repetition..........................................................33
Introduction

It is an old and well established fact that the ability to retain information over time improves greatly during early and late childhood and reaches asymptote in late adolescence (Willoughby, 1929, Hurlock & Schwartz, 1932; Dudycha & Dudycha, 1941). The reasons why memory improves so dramatically with age during childhood are still relatively unclear.

Current theories of memory development claim that the primary factor responsible for age related improvements in memory is the child's increasing ability to adopt strategies (cf., Hagen, Jongeward, & Kail, 1975; Kreutzer, Leonard & Flavell, 1975; and Brown, 1975). Some of these strategies include greater usage of rehearsal, intentional nonprocessing of irrelevant material, and the production of mnemonic devices. According to Hagen et. al. (1975) "Changes in memory performance with age reflect the development of an ever-expanding repertoire of strategies rather than a shift in the fundamental bases of cognition" (p. 96). The role of developing coding schemes is somewhat downplayed, as the child by age six or seven is assumed to be a fairly sophisticated coder of information.

Brown (1975) proposed a comprehensive model, incorporating these formulations within an information processing framework. Figure I presents this model. The major prediction from this and other "control process" models of memory development is that if
a deliberate mnemonic strategy is required, developmental differences will be obtained (cf., Flavell, 1970). Furthermore, when no such mnemonic strategy is required, the task will be relatively insensitive to developmental trends (Brown, 1975). In other words, if two different ages were required to engage in the same strategy, no differences in recall between the ages should result.

**Experiment I**

This experiment was a modification of the incidental learning tasks used by Craik and Tulving (1975). In this task, subjects are instructed to process words to various degrees of semantic elaboration. After this, they are surprised by a request to recall as many words as they can. The purpose of this experiment was to provide a test of one aspect of Brown's (1975) model. From Figure 1, it can be seen that if a task is selected which does not induce subjects to actively and knowingly attempt to memorize a list of items, e.g., an incidental learning task, then no developmental differences in amount recalled should be found. Furthermore, if the task does tap semantic features, then differences would be expected in the pattern but not necessarily the level of performance" (Brown, 1975, p. 138). In other words, this model makes the prediction that if an incidental learning task is given to subjects of different ages, manipulating the amount of semantic processing in such a task would reveal developmental differences in patterns of recall (i.e., clustering, primacy and recency effects, etc.) but not the levels of performance (i.e., number of items recalled).

**Subjects** Kindergarteners, sixth graders, and college students participated in the study, with 80 subjects per age group. The
mean ages were 6.10, 12.04, and 22.17, respectively. The children came from an upper middle class district. The college students were volunteers from the introductory psychology course. Two of the kindergarteners were rejected and replaced, since they did not follow instructions in the Acoustic condition.

**Procedure** The instructions for each condition were as follows;

(a) Physical: You are going to hear a long list of words. Half of the words will be said by a man, the other half will be said by a woman. When you hear a word, listen to who says it, and when you hear the beep seven seconds later, say "woman" or "man" depending upon who said it. For example, if you heard a woman say the word "SHOE" when you hear the beep seven seconds later, say "woman." If you heard the word "SHOE" said by a man, when you hear the beep, say "man."  
(b) Acoustic: You are going to hear a long list of words. Half of the words will be said by a man, the other half will be said by a woman. When you hear a word, think of another word that rhymes with it so when you hear a beep seven seconds later, say the word you thought of. For example, if you heard the word "SHOE" think of a word that rhymes with it, so when you hear the beep, you might say "glue," or "blue," or "too," or "boo," etc.  
(c) Semantic: You are going to hear a long list of words. Half of the words are going to be said by a man, and the other half will be said by a woman. When you hear a word, tell me what that word means. For example, if you heard the word "SHOE," you might say that "it is something you put on your foot," or "it is an article of clothing," or "it is something that has to be polished." When you hear the beep seven seconds later, get ready to hear the next word.  
(d) Imagery: You are going to hear a long list of words. Half of the words will be said by a man, and the other half will be said by a woman. When you hear a word, try to imagine what the object looks like. For example, if you were to hear the word "SHOE," try to imagine what a shoe looks like. Try to imagine what color it is, if it has laces or buckles, what the heels look like, and maybe even what it smells like.

After the instructions, a practice list of four items was administered to ensure that all the subjects understood the instructions. If they did not, the instructions and practice list were repeated. Subjects in the imagery condition were asked to describe their images of two of the four words on the practice list to ensure
that they understood the instructions. The words were presented at a rate of one every ten seconds. Twenty seconds after list presentation, the subjects were asked to free recall the words.

The words, taken from the norms of Paivio, Yuille, & Madigan (1968), were high in meaningfulness (all above 6.66) and high in imagery (all above 6.0). Two different lists of 24 items were used. The words were checked with the kindergarten teachers to ensure that they were within the vocabulary of all subjects. All groups had an equal number of males and females. Subjects were run individually.

Results The results were analyzed by a 3 (Age) by 2 (List) by 4 (Instructions) analysis of variance. There were significant effects of Age, $F(2,216)=132.931$, $p<.001$, and Instruction Condition $F(3,216)=117.649$, $p<.001$. There was also a significant Age by Instructions interaction, $F(6,216)=18.989$, $p<.001$. No other interactions were significant. Post hoc comparisons (Newman-Keuls test, the value set at $p<.05$) on the means revealed no significant differences between any of the age groups in the Physical condition. In the Acoustic condition, kindergarteners recalled significantly fewer items than the sixth graders and the college students; the latter two groups did not differ significantly. In the Semantic condition, sixth graders recalled significantly more items than kindergarteners, and college students recalled significantly more items than the sixth graders. In the Imagery condition, sixth graders recalled significantly more items than the kindergarteners, and the college students recalled significantly more items than the sixth graders. The Acoustic instructions produced significantly greater recall than the physical
instructions for all age groups except the kindergarteners. The Semantic and Imagery instructions produced significantly greater recall than Physical and Acoustic conditions for college students and sixth graders. Finally, the Imagery conditions did not differ significantly from the Semantic conditions for any age. These results can be seen in Figure 2.

Discussion The main effects, which showed that as age increased, recall increased, do not confirm the predictions offered by Brown's (1975) model. Furthermore, if optional strategies and "meta memories" were the primary functions responsible for memory development, then one would not predict the large interactions between instruction condition and age in this incidental learning task where the probability of these devices operating would be expected to be equally low for all conditions. Therefore, the large interactions obtained in this experiment suggest that strategies per se are not as important in accounting for memory development than is assumed.

There are several interesting aspects of the interactions. When the subjects were induced to process only the physical aspects of a word, no developmental differences in recall were obtained. However, when the subjects were induced to process the semantic or imaginal aspects of the words, large developmental differences in recall were obtained. One interpretation of these interactions would suggest that the development of memory involves the development of the ability to semantically process information. The following section will provide a theory which will hold this interpretation as its basic postulate.
The Coding Theory of Memory Development

The following coding theory of memory development is an extension of the theories developed in the area of verbal learning attempting to explain the learning and memory performance of college students. It involves the combination of Craik & Tulving's (1975) coding elaboration theory, and theories which suggest that memory traces are organized in a multicomponent fashion.

First, it is postulated that memory traces are organized in a multicomponent fashion (cf., Osgood, Suci, & Tannenbaum, 1957; Bower, 1967; Wickens, 1970; Norman & Rumelhart, 1970; and Morton, 1970). That is, meaning may be described by a vector of attributes in a semantic space. To give an over simplified example, the meaning of the verbal label "BANANA" might consist of some combination of the following semantic attributes; edible, fruit, yellow, oblong in shape, a flavor, good, etc. This series of attributes is hypothesized as existing independently of BANANA itself, and serves to define BANANA in semantic space.

Second, it is postulated that if an item is "elaborately" coded, to use Craik & Tulving's (1975) terminology, the probability of recall should be greater than when the coding is not elaborate. "Elaboration" will refer to two aspects of coding. First, elaboration refers to the number of semantic attributes activated at the time of coding; it is assumed that the more activated at the time of coding, the greater will be the probability of recall. The
second aspect of elaboration refers to the relational aspects of coding operations when two or more items are involved. Relationally rich coding would be when the items shared a strong relationship, or congruency, while relationally impoverished coding would be when items shared few or no relationships. To give a concrete example of relational aspects of coding, an experiment by Schulman (1974) will be briefly described. He presented either congruent encoding questions, e.g., "Is soprano a singer?", or incongruent questions, e.g., "Is mustard concave?" to college students. He found that the congruent encoding questions and their nouns were recalled better than the incongruent questions and their nouns. He inferred that this advantage arose because a congruent query fosters a relational encoding of the noun and its descriptor, while incongruent queries foster independent encodings. (One may consult the Craik and Tulving (1975) paper for further data on this issue of relational or qualitative aspects of coding.)

The present coding theory of memory development combines these two postulates such that the paradigms of the multiplicity of coding theories serve as the empirical referents for quantitative aspects of elaborate coding. That is, quantitative elaboration is defined in terms of how many semantic dimensions are activated during the coding of an event. Elaborate coding would result when a large number of semantic dimensions are used to code information, and impoverished coding would result when only a few semantic dimensions are used to code information. Memory development, is therefore stated to be partly due to an increase in the number of semantic dimensions used to code information which in turn will lead
to increases in recall performance. Data from PI release tasks and recognition memory tasks will be cited as evidence that as age increases, the number of dimensions used to code words increases.

The second aspect of memory development is said to be due to the child's increasing ability to combine two or more events relationally. Data from sentence memory studies and imagery studies will be cited as evidence that as the child develops there is an increase in the extent to which events are coded in relationally richer fashions.

In summary, it is assumed that the more elaborately an event is coded, the more unique it will be in memory for retrieval, and thus, the greater will be the probability of recall. Stated briefly, memory development during early and late childhood is primarily due to the increasing ability of the child to code information elaborately, both quantitatively and relationally.

The organization of the remainder of this paper will be as follows: first, data suggesting that quantitative and relational aspects of coding change with increasing age will be presented. Then, data suggesting that some of the functions responsible for memory development are also responsible for learning development will be presented.

Quantitative Aspects of Coding

PI Release Tasks. One task which taps the dimensions used to code words is the release from proactive inhibition (PI) paradigm. The basic procedure (cf. Wickens, 1970) commences with the presentation of a triad of words that may be considered to be members of a common class, e.g., a taxonomic category. After a brief
presentation of this triad of words, a distractor task to prevent rehearsal follows for 20 secs., after which a recall of the three words is requested. This constitutes a single trial. After an 8 sec. recall period, another triad from the same class follows, and so on for three trials. The control group continues in the same fashion on the fourth trial; but for the experimental group, the fourth trial triad consists of materials drawn from some different class. The terms "experimental" and "control" do not refer to materials, but rather to the presence of a shift in category on trial four (experimental group), or the absence of a shift (control group). It is arranged so that the control group's fourth-trial triads are the same as those for the experimental group. Thus, it is the experiences on the first three trials which differentiate the experimental and control subjects. The particular triads are, of course, counterbalanced across trials so that each triad occurs equally often in each trial position.

What is typically found is that on trial one, recall is good, but declines steadily for experimentals and controls across the succeeding trials. In the experimental group, when there is a shift to a new class of psychologically differentiated materials on trial four, there is a marked improvement in recall. This increment in performance is referred to as release from FI, its magnitude being determined by how different the trial four triad is coded from those coded in the preceding three trials. If the shift is one in grammatical class or number of syllables in the words, the release is minimal, but if the shift is one of Battag & Montegue (1969) taxonomic category or sense impression, the
release is substantial (Wickens, 1970). According to Bennett and Bennett (1974), PI is released if the items on the previous trials have primed the subject to encode them along a similar dimension, such that the new dimension will be readily distinguishable at the time of retrieval.

If young children do not elaborately code the items during the PI trials, the probability that the items will overlap in meaning should be low for a number of dimensions. Thus, if the present coding theory of memory development is correct, there should be age related changes in the degree of PI release for a number of coding dimensions.

The experiments using the PI release technique with children suggest that the number of dimensions showing release increase with age. Thus, although children as young as six years old demonstrate PI release for letters and digits (e.g., Cann, Liberty, Shafto, & Ornstein, 1973) and certain taxonomic categories (e.g., Kail & Schroll, 1974; and Pender, 1969), they do not show PI release for as many other dimensions as do older subjects.

In one of the first experiments utilizing the PI release technique with children, Pender (1969), tested the three dimensions of the Osgood, Suci, & Tannenbaum (1957) semantic differential with children. She found that although second and sixth graders demonstrated substantial release for the evaluative dimension, they did not show significant release for either the activity or potency dimensions. College students demonstrate PI release for all three dimensions (e.g., Wickens & Clark, 1968). Therefore, it seems as though the potency and activity dimensions do not become salient
dimensions of relatively automatic encoding until fairly late in development.  

Another dimension which seems to develop relatively late is the sense impression attribute. "Sense impression" refers to a salient dimension of physical appearance, e.g., "snow" has the characteristic of being white, while "wheel" has the characteristic of being round. While college students demonstrate release for shifts of shape to color, (Wickens et al., 1972) younger children do not (Kroes, 1970).

These results are difficult to account for in terms of optional strategies used by the older subjects. This is because the subjects in the PI release task are not able to say how the items on the release trial are different from the preceding items, or why they are easier to remember (cf. Wickens, 1970).

Wickens (1970) observed that some dimensions produce more release than others. For example, Wickens et al. (1972) found that some shifts utilizing sense impression, e.g., shape to color, produced larger amounts of release than others, e.g., hard to soft. It would be interesting to see if the dimensions showing less release develop later than dimensions showing large amounts of release. It might be that the most salient dimensions of word coding develop earlier than less salient dimensions. It could also be the case that while some dimensions are salient for young children, they are not for older subjects.

In summary, these results indicate that although young children code information in a variety of ways, they do not code it to the
same degree of elaboration as older children and adults. Clearly, more research utilizing this paradigm is necessary. It may prove to be helpful in following the development of dimensions which are used by children in coding information.

Recognition Techniques Another technique which has been used to identify coding dimensions is the recognition procedure. This procedure involves presenting a list of items, one at a time for learning. A recognition test follows which contains words which were included within the original list, and foils which were not in the list. It is generally found that subjects make more errors on a foil which contained many of the same attributes as a word presented in the list, than on a foil which did not share many of that item's attributes (cf. Underwood, 1965). For example, if one of the words in the list was "boat," more false positives would be made to "ship" than to the word "cup."

Underwood (1969) has suggested that as a child matures, the primary attributes involved in learning may change, with the associative verbal attributes becoming more and more common. In line with this, the present coding theory makes the prediction that as children mature the proportion of false positives to semantically related foils vs. semantically unrelated foils should increase. This prediction has received some support from studies utilizing this recognition procedure with children.

Bach & Underwood (1970) presented 40 words to second and sixth graders. For recognition, the subjects were given a multiple choice test for each of the 40 items. Four alternatives were available for each word, namely, the correct word, a semantic
associate of the correct word, a word that sounded like the correct word, and a control word bearing no obvious relation to the correct word. They found significant interactions between age and error type showing that: (a) both grades made more errors on associative and acoustic foils than on control foils, (b) second graders made more errors on acoustic than on associate foils, and (c) sixth graders made more errors on associative foils than on acoustic foils.

Freund & Johnson (1972), using a design analogous to the one used by Bach & Underwood (1970), found that first graders made more errors on orthographic than acoustic or semantic associate foils, while third graders and college students made equal numbers of errors on the three types of foils. They attributed the lack of a preponderance of associative errors on the part of the college students to their control words which may have had conceptual category relations to the items in the list.

Felzen & Anisfeld (1970) compared third graders' and sixth graders' performance on a continuous recognition procedure. They found that semantic foils were selected more than control foils. Furthermore, sixth graders made more errors on semantic foils as compared to control foils than did third graders. However, they found that foils that were acoustic associates were more effective than semantic associates in producing errors at both ages.

To summarize, these studies all find that as age increases, the preponderance of false positives to semantic foils as compared to control foils increases. However, they are not in complete accord in showing that the oldest subjects give more false positives to semantic foils as compared to acoustic foils. The reason for this
discrepancy between these studies is unclear. Thus, there is a need for more research utilizing this paradigm before definitive statements about developing attribute dominance can be made, and special precautions have to be made when considering false recognition data (cf. Lindauer & Paris, 1975).

Relational Aspects of Coding

Sentency Memory Studies Sentences provide one of the most elaborate forms of transmitting and receiving information. Paris (1975) has argued that the child's increasing ability to comprehend inferred relationships within sentences is due to the development of greater amounts of elaborative processing, temporal ordering capabilities, and greater knowledge of environmental relations. This conclusion was based upon several studies he and his colleagues performed comparing children of different ages on various sentence memory tasks.

In one study (Paris & Upton, 1974), six paragraphs were read to children from grades kindergarten through five. Immediately after listening to a paragraph, subjects were asked yes-no questions concerning the story. Four questions were on verbatim information, and included prenominal adjectives, e.g., big, new, red, etc., and locative prepositions, e.g., over, under, etc. The other four questions concerned inferred relations, and included contextual and lexical inferences. Contextual inferences included either presuppositions, the pre-existing conditions necessary to make a sentence or paragraph true; and inferred consequences, the probable conclusion of a series of statements or conditions. Lexical inferences included semantic entailment, that an object is a
subset of a larger class; and implied instruments, that a verb
implies a particular instrument to accomplish the action. They
found that both inferential and verbatim information accuracy
increased with increasing age. Furthermore, there was a significant
interaction between age and question type, showing that the ability
to answer questions about inferential relations increased with age
at a greater rate than did the verbatim questions.

In a similar task, Paris (1975) tested kindergarten, second,
and fourth grade children. However, in this study the children
were also asked to free recall the story as best they could after
the questioning session. Noun and verb categories were included
within the question types. The free recall data indicated signif­
icant differences between the ages, kindergarteners recalling an
average of 1.9 ideas per story, second graders 4.4, and fourth
graders 9.3. The analysis of covariance with correct responses to
noun and verb questions as the covariate showed that the adjusted
mean percentage of correct responses for inferential items signif­
icantly increased with increasing age. In order to determine the
relationship between initial comprehension and free recall, they
performed a stepwise multiple regression analysis to determine
which of the questions best predicted free recall performance.
Next to age, the ability to make contextual inferences was the best
predictor of recall. The percentage of variance accounted for by
accuracy on contextual inference questions increased with increasing
age, 33, 46, and 67% for each grade respectively. Each of these
correlations was significantly better than the preceding grade
indicating the stronger predictive power of contextual inference
ability with increasing age.

From these data, Paris (1975) concluded that "...the operations underlying inferential abilities change with age in a manner different than a simple increase in memory capacity (p. 242)." Stated in the context of the present theory, this means that the development of relational aspects of coding display a growth function different than quantitative aspects of coding. This conclusion, however, is not the only one which can be made from the data. The key issue revolves around the question of how one gets knowledge of presuppositions and inferred consequences out of sentences and paragraphs. It is possible that the ability to make contextual inferences is partly determined by one’s ability to code the possible relations between the various connotative meanings of different words. If one does not code a word along a dimension relevant to a particular inference, it would be unlikely that the inference would be made.

One way to test this interpretation would be to vary the dimension upon which a contextual inference is based. Based upon PI release data, one might expect that contextual inferences based upon knowledge of taxonomic categories would develop sooner than inferences based upon evaluative dimensions. If the ability to make inferences depends upon one’s ability to code along the relevant dimension, inferences based upon activity and potency dimensions would be slower to develop than evaluative dimensions. Contextual inferences based upon sense impression would also be expected to develop later than inferences based upon taxonomic category.

In summary, the data from these two sentence memory studies point to the conclusion that the ability to remember sentences improves
greatly with age. One of the major factors responsible for this improvement seems to be the ability to make contextual inferences. The various factors which are responsible for this increment, however, remain to be specified. It seems as though paradigms utilizing sentence memory tasks might best serve to disentangle quantitative vs. relational aspects of coding development.

**Imagery Studies** It is a well established fact that when college students are instructed to form elaborate images of events, greater levels of recall will result than when they are given instructions not emphasizing imagery production (cf., Paivio, 1969). Since imagery instructions usually yield higher levels of recall than semantic instructions, the postulate of elaboration theory included in the present coding theory of memory development would have to assume that imaginal representations are one of the most elaborate forms of representation available to the information processor. This logic is circular. However, the circle is broken when this logic is applied to the more general theory presented here. This is because the present coding theory of memory development would have to predict that since it is assumed that imagery instructions produce greater amounts of coding elaboration, and it is assumed the development of memory involves the development of the ability to elaborately code information, then younger children should not profit as much from imagery instructions than should older subjects. An experiment was performed to test this prediction in an incidental learning task similar to the design used in the preceding section.
Experiment II

Subjects Third graders from an upper middle class district and college students participated. There were 84 subjects per age group.

Procedure The design was a 2 (Age) by 3 (Instructions) with 28 subjects per condition. The three instruction conditions were labeled Physical, Semantic, and Imagery. The instructions were as follows:

Imagery This is kind of like an imagery test. You are going to hear two words at a time. When you hear each pair, imagine the two of them together. For example, if you heard the words "shoe" and "car" you might think of a car wearing shoes. If you hear the words "key" and "shirt" you might think of a shirt with a key in the pocket. When you hear a "beep" get ready to hear the next pair of words. In summary, when you hear two words, try to form an image of them interacting in some sort of way.

Semantic This is kind of like a vocabulary test. You are going to hear words two at a time. When you hear each pair, think of what each word means. For example, if you heard the words "shoe" and "car" you might say to yourself that a car is something you drive, and a shoe is something you put on your foot. If you hear the words "key" and "shirt," you might say to yourself that a key is something that opens locks, and shirts are things that you wear on the upper part of your body. When you hear a "beep" get ready to hear the next pair of words. In summary, when you hear two words, think to yourself what each of the words means.

Physical This is kind of like a test of this tape recorder. You are going to hear words two at a time. When you hear each pair, try to tell if the two words were spoken by the same person, or if two different people said each word. For example, if the words "shoe" and "car" were spoken by the same person, say "same" to yourself. If the words "key" and "shirt" were spoken by different people, say "different" to yourself. When you hear a "beep" get ready to hear the next pair of words. In summary, when you hear two words, think to yourself if the words were spoken by the same or by different people.

The words were presented in pairs, and were taken from the incidental learning experiment described earlier. There were 40 words in all. A practice list of six items was given. The experimenter then quizzed the subjects for what they had heard (Physical), the meanings they thought of (Semantic), or the images they "saw" (Imagery), to ensure that all subjects understood the instructions. The pairs were presented ten seconds apart. The subjects were requested to write their names, ages, and birthdates at the top of the paper.
After this, which took 30 sec., the subjects were surprised by a request to recall as many words as they possibly could. They were given as much time as they needed for recall.

**Results** The data were analyzed by a 2 (Age) by 3 (Instruction condition) analysis of variance. There were significant effects of Age $F(1, 162)=158.553$, $p=.001$, and Instructions $F(1, 162)=104.356$, $p=.001$. The interaction of Age by Instruction condition was also significant $F(2, 162)=30.393$, $p=.001$. A post hoc interaction test showed that the difference between imagery vs. semantic conditions for college students was greater than the difference for third graders, $F(1, 162)=12.802$, $p=.01$. These results can be seen in Figure 3.

**Discussion** There are several interesting aspects of these data. First, they replicate the results of Experiment II. As age increased, the beneficial effects of semantic instructions increased. Second, the interaction between age and semantic vs. imagery instructions support the predictions of the coding theory of memory development. That is, college students benefited more from the imagery instructions as compared to the semantic instructions than did the third graders.

Students of paired associate learning in children would not be surprised by these results, since it is a fairly general finding that the beneficial effects of imagery in paired associate tasks increase with increasing age (cf., Reese, 1970; Rowher, 1970; Palermo, 1970; & Paivio, 1970). Why there are age related improvements in the ability to benefit from imaginal forms of representation is still unclear.
The present theory would suggest that the beneficial effects of imagery are due to the fact that when one is instructed to use imagery, one gains access to an extremely complex and elaborate network of relationships. This conceptualization is similar to the one proposed by Fyleshyn (1973) who argued that an adequate characterization of images requires that we posit abstract mental structures to which we do not have conscious access, and which are essentially conceptual and propositional, rather than sensory or pictoral in nature.

At the present time it is not possible to conclusively state whether this or other possible interpretations are the most useful in promoting additional research. It will be interesting to see if the present coding theory can be extended to explain the age related effects of imagery instructions. The present theory, based upon its predictions concerning qualitative aspects of coding, would suggest that younger children's images are less relational and propositional in nature than are the images produced by older children.
Development of Learning

It might be the case that many of the functions responsible for memory development are also responsible for the development of learning skills. According to Piaget (1970), the fundamental psychogenic connections generated in the course of development consist of assimilations. He represents assimilation according to the following logical expression: \((T+I) \rightarrow AT+E\). This expression reads as follows. When information \((I)\) is to be gained, it is incorporated into a structure \((T)\). Piaget says that this formulation leads to the expression \(AT+E\), where \(A\) is a coefficient expressing the strengthening of this structure, and \(E\) represents the information in \(I\) which was not picked up. Therefore, the larger \(T\) is, the greater will be the ability to assimilate information. The value of \(T\) is said to increase with increasing development.

This logical expression might be translated into more traditional verbal learning terminology. First, suppose that \(I\) is interpreted as the total amount of potential information which the stimulus can transmit. The functional stimulus would be the stimulus which was perceived and incorporated into episodic memory. The \(E\) term would be the amount of information in the stimulus which was not transmitted. This formulation, therefore, might be interpreted to mean that the larger the semantic memory system, or \(T\), the greater will be the probability of recall of an episodic memory trace. Stated more simply yet, the larger the incorporating system, the
larger will be the amount incorporated.

Experiment III

An experiment was performed to test this formulation utilizing an incidental learning task similar to those used in the first two experiments. The three factors manipulated were age (college students vs. third graders), instructions (physical vs. semantic), and repetition (one vs. three presentations of the list.)

If the present interpretation of Piaget's (1970) analysis is correct, that the child's increased ability to acquire information depends upon an increase in size and interrelations of schemata, one would have to predict a three way interaction. The logic for this is as follows. Since the Physical instructions induce subjects to incorporate information into relatively small schemata (T), there will be an abundance of information not picked up (E), and the incremental value of AT on each trial should be small for both ages.

However, since semantic instructions induce the subjects to assimilate and the college students would be expected to have larger schemata, the information into a relatively large schemata they would be expected to benefit more from repetition in the Semantic condition relative to the Physical condition than would the third graders.

Subjects The subjects were randomly assigned to one of eight groups. The third graders were obtained from two schools from the same upper middle class district. If a subject made more than 5% errors on the yes-no task, he was eliminated. Nineteen out of 81 third graders were eliminated for this reason. There was no relationship between the number of errors and Instruction condition. The primary factor responsible for the third grader's difficulty was due to their losing appropriate positions on the answer sheet.
So that each school would have an equal number of subjects in each condition, 16 other subjects were randomly eliminated. The final number of subjects per condition was 23. An analysis of the yes-no errors on the remaining subjects showed that the third graders made an average of 2% errors and college students made an average of 1% errors. No college students were eliminated because of performance on the yes-no task.

**Procedure** There were two instructional conditions. Subjects in the Physical condition were given the following written instructions: We are interested in your ability to tell the difference between a man's and a woman's voice. You will hear a long list of words, some of them being said by a man and some of them being said by a woman. Before each word is given, a statement will be made as to whether a man or a woman says it. For example, if the statement is "This word is said by a man," and a woman says the word, mark "NO" on your answer sheet. Thus, you will hear a long list of words, and you will be given a statement about whether a man or a woman says the word. If the word is said by the correct person, mark "YES" on your answer sheet. If the word is said by the incorrect person, mark "NO" on your answer sheet. Each question and answer will take only six seconds, so you must pay close attention and work fast.

Subjects in the Semantic condition were given the following written instructions: We are interested in your ability to identify the correct meanings of words. You will hear a long list of words, and before each word, you will hear a statement about the word. For example, if the statement is, "This is something you drink out of," and the word you hear next is "baskets," mark "NO." Thus, you will hear a long list of words. If the word correctly fits into the statement, mark "YES" and if it does not, mark "NO!" Each question and answer will take only six seconds, so you must pay close attention, and work fast.

The instructions were repeated verbally. A practice list of four items was then administered. The list contained critical 50 words. Ten buffer words, five at the beginning of the list and five at the end of the list were used as controls for primacy and recency effects. The words were presented at a rate of one every six seconds.
The third variable manipulated in this study was repetition. One half of the subjects from each age level heard the 50 items only once. The other half of the subjects at each age level heard the 50 items repeated in the same order three times. Thus, the design was a 2 (Age) by 2 (Instructions) by 2 (Repetition) factorial, with 23 subjects serving in each condition.

Thirty seconds after the presentation of the list, the subjects were surprised by a request to recall as many of the words in the list as they possibly could.

**Results** The recall data was analyzed by 2 (Age) by 2 (Instructions) by 2 (Repetition) analysis of variance. There were significant main effects of Age $F(1, 176)=190.225$, Instructions $F(1, 176)=306.309$, and Repetition $F(1, 176)=227.843$. The significant two way interactions were Age by Instructions $F(1, 176)=93.859$, Age by Repetition $F(1, 176)=23.369$, and Instructions by Repetition $F(1, 176)=94.625$. The three way interaction was also significant $F(1, 176)=37.173$. All effects were significant $p<.001$. These results can be seen in Figure 4.

**Discussion** These data seem to indicate that at least one of the functions responsible for memory development is also responsible for learning development. That is, when subjects are induced to code information in a relatively simple manner, they profit only slightly from repetition. However, when they are induced to use available semantic structures to analyze information, learning, as inferred from performance, increases as a function of trials. Furthermore, it is inferred that the reason why older subjects learn faster than younger ones in the Semantic condition is that they have larger semantic
structures to incorporate information. To put this still differently, it seems as though the strength of an item in episodic memory is determined to a large extent upon how it is integrated into the semantic memory system.

These data also bear on the generality of the formula of Piaget (1970) discussed earlier. This formula suggests that although the amount gained should differ as a function of age as a result of different accommodative schemata, the strengthening function of A, or percent increase, should be the same for both groups. If the recall after trial one is taken as an index of initial structure, and the recall on trial three is an index of the amount of strengthening added to the structure, then the present study provides some support for this formulation. In the Semantic condition, the percent gained by third graders was 221% and the percent gained by the college students was 235%. However, the percent gained in the Physical condition was 188 and 128 for third graders and college students respectively. Thus, it seems as though assimilative processes depend upon the type of structure into which information is incorporated. It could be argued, however, that the physical condition has a lower asymptote than the semantic condition, and therefore, has less "room" for further increment. The psychological meaning of this possibility remains to be elaborated by further study. It seems as though this empirically neglected area of developmental psychology deserves more research relevant to these and other learning related issues.
Summary and Conclusions

These data, taken from different paradigms, seem to orthogonally converge upon the conclusion that as a child matures, he come to code information to ever increasing degrees of elaboration. Increased elaboration has been defined in two ways, quantitative and relational. Quantitative elaboration is empirically defined in terms of the number of attributes used to code an item. Evidence for developmental increases in quantitative aspects of coding ability was provided by PI release studies and recognition tasks. Evidence for relational increases in coding ability is provided by imagery studies and sentence memory studies. It is concluded, however, that much more work needs to be done separating relational vs. quantitative aspects of coding and coding development.

The incidental learning tasks presented in this paper were said to demonstrate the relationship between developmental increases in the ability to recall information and the degree of sophistication of the subject's semantic memory system. That is, when college students were instructed to process information in an unelaborate fashion, their recall did not exceed that of kindergarteners. However, when the subjects were instructed to process information elaborately, large differences in recall between the ages were found. This was the case when subjects were allowed to generate their own forms of elaboration as in the first experiment, or when all ages were instructed to answer the same yes-no questions as in the repetition
experiment. It is inferred that the superior recall performance of older children and adults in the semantic conditions is due to their larger semantic structures which serve to analyze the items in the list in a richer fashion. The utilization of this larger semantic structure for analysis is said to foster a more unique representation in memory which leads to more retrieval cues at recall.

There remains the question as to why young children do not engage in as many strategies as college students do. It may be the case that these strategies are not as effective for the young children, and as a result, they do not adopt them. For instance, the effectiveness of the control process of rehearsal does not by itself lead to large increments in probability of recall. Rehearsal seems to be effective only to the extent that it taps more elaborate codes. (See Craik & Jacoby, (1975) for a review of this literature.) Thus, it may be that the reason why children rehearse less and rehearse differently than adults (cf. Belmont & Butterfield, 1971; Flavell, Beach, & Chinsky, 1966) is that they are less able to use and benefit from some types of rehearsal which are dependent upon more elaborate semantic memories. In line with this, Ornstein, Naus, & Liberty (1975) have found that ninth graders were better able than younger subjects to use taxonomic information to rehearse related words together, and that in some instances, improvements in recall were fairly independent of the amount of rehearsal for third graders.

Intent to remember information may not be as salient an influence on memory performance as is often times supposed. If it were an extremely salient condition, large differences should be found between conditions where subjects are told that they should remember
items in a list and conditions where they are not so instructed. Several studies have shown that performance under incidental conditions can be as good as performance in an intentional learning situation (Mondani, Pellegrino, & Battig, 1973, Hyde & Jenkins, 1969; 1973). Thus, it may be that "intent" is only important to the extent that it leads to a more elaborate coding of information. Incidentally, this is the same conclusion as that reached by Postman (1964) several years ago in his review of incidental learning.

From this, it might be tentatively concluded that strategies come into play when the child has fairly elaborate semantic structures and can use them effectively. Thus, the emergence of strategies may not be the basic factor responsible for memory development, but rather, may merely be indicators that the child is engaging in greater degrees of elaborative processing.

In the final section, the question is raised as to whether many of the same factors that are responsible for memory development are also responsible for learning development. It is inferred that the reason why older subjects learn faster than younger ones is because they have larger semantic structures into which they can incorporate information.
Footnotes

1. The issue of whether elaboration primarily effects storage or retrieval mechanisms will be sidestepped because this is only a pretheoretical dichotomy (cf., Melton, 1962). Thus, it will be assumed that "elaboration" effects both. That is, the more elaborate the storage, the greater the number of potential retrieval cues.

2. Although Pender (1969) found that children as young as second graders demonstrate release for the evaluative dimension, Cermack et. al. (1972) and Kail & Schroll (1974) found it to produce release only in children in the fourth grade and older. This discrepancy might be due to the fact that they used visual presentations and Pender used auditory presentations. The younger children in the Cermack et. al. and Kail & Schroll studies may have been so preoccupied with "reading" the items that they did not concentrate on coding the items semantically. Further research is necessary before definitive statements can be made about the precise development in the coding of evaluative dimensions.
Figure 1. Brown's Model of Memory Development.
Figure 2. Amount recalled as a function of age and instruction condition
(Physical-tell who says the word; Acoustic-give a rhyme to the word; Semantic-say the meaning of the word; Imagery-form an image).
Figure 3. Amount recalled when items are presented in pairs as a function of age and instruction condition (Physical—say if both words in each pair were spoken by one or two voices; Semantic—think of what each word means individually; Imagery—form an interactive image).
Figure 4. Amount recalled as a function of age, repetition (one or three presentations of the list), and instructions (Physical-yes-no decisions about who says the words; Semantic-yes-no decisions about the meanings of the words).
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