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A DEVELOPMENTAL STUDY OF THE EFFECTS OF REDUNDANT AND NON-REDUNDANT INFORMATION ON VISUAL RECOGNITION MEMORY

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A DEVELOPMENTAL STUDY OF THE EFFECTS OF REDUNDANT AND NON-REDUNDANT INFORMATION ON VISUAL RECOGNITION MEMORY

by

GLORIA DAVIS

A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

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Abstract

A DEVELOPMENTAL STUDY OF THE EFFECTS OF
REDUNDANT AND NON-REDUNDANT INFORMATION
ON VISUAL RECOGNITION MEMORY

by

Gloria Davis

Adviser: Professor Joseph Glick

The question asked in this study was whether the young child has difficulty with a multi-stimulus array because of the additional number of features to be analyzed and encoded, or because attention must be distributed across a stimulus array. This was explored by reducing the stimulus load in a multi-stimulus array while retaining the requirement that attention be spatially distributed. Recognition memory for a given form was looked at in a few different contexts: with 1 other stimulus (PAIR condition), with 3 different stimuli (HIGH information condition), and with 3 identical stimuli (LOW information condition).

One hundred and twenty subjects (5-year-olds, 8-year-olds, and college students) were tachistoscopically presented with 2- and 4-item visual arrays, followed by a single test stimulus. The stimuli were abstract geometric forms. The subjects' task was to say whether or not the test stimulus was the same as a stimulus just

seen. The time interval between the presentation of the array and the test stimulus was varied. The interstimulus intervals used represented different stages in the information processing sequence.

At each age level, there were two levels of stimulus complexity: for 5-year-olds and 8-year-olds--SIMPLE and MEDIUM, for adults--MEDIUM and COMPLEX. Half the subjects from each age group were given a LOW followed by a HIGH series of arrays; the other half were given the reverse order. The data consisted of the subjects' "same" and "different" judgments. The measure used--A'--is based on the number of hits and false alarms.

Higher mean scores were obtained with older subjects, with less complex stimuli, with less information, smaller arrays, and longer processing times (performance was significantly lower at 50 msec. than at the longer ISIs). The need to distribute attention spatially was found to be the most significant cause of lowered performance. A larger decrement in performance resulted from an increase in number of items (from two in the PAIR condition to four in the LOW) than from an increase in the amount of information (from two patterns to be discriminated in the LOW condition to four patterns in the HIGH). However, when the amount of information in a 4-item array is reduced, there is significant improvement in performance. PAIR performance is best, followed by the LOW condition, with performance worst in the HIGH condition. In all information conditions, the overall performance of 5-year-olds was significantly below that of 8-year-olds and adults.

The study points up some limitations of parallel unlimited capacity models, and the results are more consistent with parallel limited capacity and serial processing models. Within what was measured here, there was no evidence for developmental differences in perceptual processing strategies, but there were significant differences in response strategies. Five-year-olds tended to say "different" more frequently and to respond randomly or in a perseverative manner. In the last session of the experiment there appeared to be a negative "practice effect" for 5-year-olds which was related to an increase in response bias (more frequent "different" judgments). In contrast, the performance of the 8-year-olds remained steady while the performance of adults improved with practice (indicating the latter group was "learning to learn"). The results are consistent with the view that, for optimal performance, young children need novelty and item shift.

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INTRODUCTION

Statement of the Problem

There has been a great deal of tachistoscopic research demonstrating the complexity of the processes underlying the first few seconds of visual perception and memory. As summarized by Morrison, Holmes, and Haith (1974): it has been found that a large amount of information initially enters the visual system where it becomes available for processing. This information persists in a raw visual form--in "visual information storage" or "iconic memory"--for approximately 0.25 seconds. While in visual information storage, items are actively analyzed and coded and transferred to a more permanent storage medium (short-term memory) where they are further coded and rehearsed, thereby being maintained in memory for longer periods of time than in storage.

The processes found to occur in such brief tachistoscopic presentations would seem to be relevant to "everyday" perception since with the large amount of varied information which is potentially available to the perceiver, one might assume that a great deal is rapidly perceived. Further, as discussed with respect to visual scanning, tachistoscopic perception (location of fixation, for example) "can be viewed as a perceptual-motor process but it can also be viewed as a cognitively mediated process which reflects the individual's strategies for acquiring visual information" (Day, 1975, p. 154). It offers another window through which to view the changes in internal mental processes which occur with development. To the extent that a relationship can be found to exist, it demonstrates the power of cognitive processes.

What has been demonstrated in a number of tachistoscopic studies is that there is an increase in short-term memory with increasing age. When presented with multiple stimulus arrays, the 5-year-old has been consistently shown to be at a disadvantage. In Haith, Morrison, Sheingold, and Mindes' (1970) early study where 5-year-old children and adults were shown tachistoscopically 2-, 3-, and 4-item arrays of geometric forms, it was found that while with adults there was an increase in number of items recognized when array size increased, children did not rise above 1.67 items correct no matter how many items were presented. Blake (1974) found no age difference in processing speed on single item arrays but a detrimental effect on children's recognition memory when the size of a tachistoscopic array was increased. On her recognition memory task, 4-year-olds reached an asymptote of 1.7 items on 2-item arrays but only 1.4 items on 4-item arrays. Adults and 8-year-olds, with the same increase in array size, demonstrated an increase in the number of items recognized (2.3 items for 8-year-olds and 2.5 items for adults).

As pointed out by Day (1975), the field of view is influenced by the "amount" of visual information present in a field of specified visual angle where "amount" may depend upon both number of items and the characteristics of the items (e.g., complexity, confusability). Various studies have shown that not only are fewer items required to "overload" children than to "overload" adults (as in the studies described above) but that the child has far greater difficulty than the adult in dealing with complex stimuli (Chi, 1977; Munsinger, 1965; Welsandt, Zupnick, & Meyer, 1973).

It has also been emphasized that while the size of the useful field of view varies with processing load, it is also a function of the perceiver's mode of processing (Bartram, 1978). Numerous studies have shown that children are less systematic in their exploration of visual stimuli (Vurpillot, 1976), that they do not focus on the informative portions of a display (Mackworth & Bruner, 1970), and that they lack efficient strategies for encoding (Boswell, Sanders, & Young, 1974; Chen, 1978; Chi, 1977; Morrison et al., 1974).

The purpose of the present study is to further explore in a visual memory task what accounts for the detrimental effect of increasing array size on the young child's performance. The question asked is whether the young child has difficulty with a multi-stimulus array because of the additional number of features to be analyzed and encoded (there is a "stimulus overload") or because attention must be distributed across a stimulus array. Which contributes more to the young child's difficulty in dealing with a multi-stimulus array has been unclear.

With adults it has been found in visual search tasks (Gardner, 1973; Shiffrin & Gardner, 1972; Shiffrin & Geisler, 1973) that when the amount of information to be differentiated in the field is reduced by having identical noise items and a very distinctive target (non-confusable with the noise items), detection performance remains invariant despite the size of the set.[1] We are asking whether a reduction in the amount to be differentiated and the use of distinctive stimuli will facilitate visual memory as well as visual search. It is hypothesized that it will have such an effect on adult recognition performance. With young children it may not be enough to reduce stimulus load. Perhaps because of the distribution of attention that a multi-stimulus array demands, whatever the contents of the array, an appropriate strategy for feature analysis

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[1]For example, search time for the target is as rapid when it is shown with 9 identical noise items as when it is shown with 3.

or encoding is required, and this may not be within the capabilities of young children.

This study was designed to explore these questions by reducing the stimulus load in a multi-stimulus array while retaining the requirement that attention be spatially distributed. We attempted to separate out the effects of two factors: the number of items and the amount to be differentiated within the visual field by varying the nature of the items in the array.

The general design of the study will be briefly described and will be followed by the theoretical basis for the study.

Outline of the Study

A condition where the total amount of information is reduced and yet where attention is divided over a number of items was provided by adapting a technique used in visual detection tasks to a short-term memory task. Recognition memory for a given form--to be called the critical stimulus--was looked at in a few different contexts (in the examples to follow the circle is the critical stimulus):

1) in an array with 1 other stimulus, for example, the circle and a square; to be called the PAIR condition.
2) in an array with 3 different stimuli, for

example, the circle, a square, a triangle, and an oval; to be called the HIGH information condition.

3) in an array with 3 identical stimuli, for example, the circle and 3 triangles; to be called the LOW information condition.

In this last condition the amount to be differentiated is the same as in a 2-item array; however, there is an increase in the number of items which have to be attended to.

The successive "yes-no" recognition task used by Blake and Vingilis (1977) was employed here. Arrays of 2 and 4 stimuli were shown tachistoscopically. Recognition memory was tested by a "yes-no" recognition test; that is, the presentation of a 2- or 4-stimulus array was followed by a single test stimulus which was either one of the stimuli just shown or a different one.

The time interval between the presentation of the array and the test stimulus was varied. This enabled us to examine the stage(s) in the processing sequence where the differences between children and adults occur and where there are differences in recognition memory between the different experimental conditions.

The three age groups which were compared are 5-year-olds, 8-year-olds, and adults.

The stimuli used are abstract geometric forms which were designed to be minimally confusable. Determination of distinctiveness was based on previous piloting results (with young children) and analysis of features. Abstract forms which are unfamiliar were chosen rather than alphabet letters or digits in order to equate degree of familiarity for the different age groups.

Background of the Problem

Information processing theorists have examined the issue of how the processing efficiency for one item in a briefly presented array is affected by the number and nature of the other items presented. Within the three fundamental types of information processing models there is a basis for predicting that, if the amount to be differentiated in a multi-stimulus array is reduced, recognition accuracy of the items in the array will be increased.

All of the processes to be discussed would seem to be applicable to adults and perhaps 8-year-olds. Some of the mechanisms require a minimally organized approach to the visual field in order for subjects to benefit from a reduction in information. That is, regardless of the efficiency of the subjects' strategies one would expect subjects to perform better in the LOW than in the HIGH information condition. Such mechanisms would seem to be equally available to adults and young children.

As was previously stated, it may be that in order to gain from a reduction in information in an array with 4 items some kind of systematic strategy is required. Some of the mechanisms which can account for increased accuracy of recognition with reduced information (in a multi-stimulus array) involve an organized approach to feature analysis and/or encoding on the subjects' part. These are less likely to be utilized by young children.

It is predicted on the basis of the theories to be discussed that adults will demonstrate greater recognition accuracy for the critical stimulus in the LOW than in the HIGH information condition. Several alternative possibilities for the performance of young children on these tasks will be based on information processing theory in conjunction with developmental theory and findings.

Information Processing Models and Related Findings

Parallel Unlimited Capacity Models

The question raised in the present study has its origins in parallel unlimited capacity models such as those developed by Gardner (1973), Shiffrin and Geisler (1973), and Shiffrin and Schneider (1977).

Theorists such as Gardner (1973) assert that there is no perceptual limitation in a detection task; two factors--a decisional property plus perceptual confusions--explain the data which he and others have obtained. In his model it is assumed that each character in a display has its separate input channel and that information can be transmitted over all of these channels simultaneously. Similarly, Shiffrin and Geisler (1973) concluded from a series of experiments that the initial stages of visual processing, up to and including letter or pattern recognition, occur without capacity limitations and without attentional control.

A principal component of response latency in Gardner's model is the decision time required for a central attentional mechanism to examine the inputs from the various channels and choose as a basis for response the one whose input most closely meets the criterion of a signal. The decrease in accuracy with increases in the array items found in detection tasks results from confusions between the target and noise items plus the decisional structure of the detection task.

The greater the number of different noise letters in a display, the larger the number of possible signal-noise confusions (Estes, 1972). Gardner (1973) found in his series of detection experiments with adults that when noise items are never confused with the critical alternatives, detection performance remains invariant with increases in the number of items in the array. The subjects' task was to detect whether a T or F had been shown with one, two, or three Os, in a rapid tachistoscopic presentation.

Conversely, when noise items are confused with the critical alternatives (the noise item was a T-F hybrid Ͱ), detection performance decreases with increases in the number of items in the array.

Gardner's work has been done in signal detection; however, it has implications for visual memory tasks. As in detection tasks, in a short-term memory task such as Blake's (1974), there is more to be differentiated (with 4 items as compared to 2) and an increase in the possibility of confusion between the features or other aspects (e.g., overall shape) of the various items, resulting in less accurate recognition.

In studies of visual search it has been found that children perform better with a less confusable field. There have been no investigations of whether children's detection performance remains *invariant* with increases in set size when the noise items are identical and distinctly different from the target (as in Gardner, 1973). Gibson and Yonas (1966) demonstrated that reducing target-field confusability significantly reduced search speed, in subjects 7 years of age or older. Younger children took longer than older ones and adults; however, context confusability was equally damaging at all age levels.

In a study of visual search Day (1978) found that subjects 7, 9, and 12 years old were slowed by background variation and were more accurate on uniform than on non-uniform matrices. Background variation was no more disruptive for younger than for older subjects. One could conclude that there is not a qualitative process change in the ability to allocate attention selectively. However, Day (1978) discusses studies which have reached the opposite conclusion, and points out the need to use a greater variety of experimental contexts to understand developmental changes.

Unlike visual search and signal detection tasks, visual memory tasks involve not only perceptual processing but also the encoding of information into short-term working memory. While it is postulated that there are no limitations on capacity during perceptual processing, short-term working memory is believed to contain a relatively limited amount of highly coded information (Shiffrin, 1976). Sensory information enters the system and is encoded in a series of stages. In the earliest stages this encoding is believed to be automatic.

The subject has some control over the later stages of processing.

> Selective attention is relegated entirely to the action of control processes in STS (short-term store) following the completion of the automatic stages of sensory processing. . . . Sensory information is dumped into STS in parallel from all sensory sources . . . most of the information . . . will be lost very quickly so that the subject must select certain important components for rehearsal, for coding and for decision making. The most important function of STS . . . is that of active control of thinking, problem solving,

> and general memorial processes. Two of the most important of these are rehearsal and coding. (Shiffrin, 1976, pp. 215-16)

Within this framework, the 3 redundant stimuli in the LOW information condition can be grouped on the basis of identity and encoded into short-term memory as one pattern, thus making it possible for there to be more attention available for encoding the critical stimulus.

There is some evidence in the adult literature on "same-different" judgments for a rapid global determination of identity. In "same-different" experiments (where 2 stimuli are presented either simultaneously or sequentially) if component features or dimensions are compared using a self-terminating strategy, "same" reaction times should be slower than "different" reaction times (RTs), since all comparisons must be completed before an identity judgment can be made. However, it has been found that with simple codable or multidimensional stimuli, "same" RTs are equal to or faster than "different" RTs (Blake & Beilin, 1975).

To explain such results Bamber (1969) has proposed a two-process model in which one comparison process, a fast identity reporter, would initiate "same" judgments, while a slower serial processor would initiate "different" judgments. Based on an unpublished study done by Gibson and Yonas, Gibson (1969) suggests, in similar fashion, that some higher order feature of the pair taken as a whole--some overall structure--is searched for first in a simultaneous presentation.

Young children have also been found to make faster "same" than "different" judgments (Blake & Beilin, 1975; Gibson, 1969; Tversky, 1973). Whether this would enable them to organize the field so that three identical stimuli are treated as one unit in encoding is open to question.

Parallel Limited Capacity Models

In contrast to parallel unlimited capacity models, limited capacity theories suggest that subjects have difficulty with a multi-stimulus array primarily because of the spreading of attention over an increased number of items, and it makes no reference to the nature of the items.

Models such as Rumelhart's (1970) assert that the probability that a given number of features are extracted from the critical item before iconic fading is complete, and thus the probability of correct detection, must decrease with increases in the number of array items. In Rumelhart's model, when presented with 4 different items, subjects attend to each item but process fewer features from each. Each character in a display is assumed to be composed of a number of critical features, and information concerning these features is extracted in parallel from all of the characters in the display, the process continuing until the characters in the visual system have decayed below threshold.

Both Rumelhart's (1970) and Gardner's (1973) models may contribute to an understanding of the processes that occur when a stimulus array is increased from 2 to 4 items and recognition memory is tested. With 4-item arrays, fewer features or other aspects may be processed from each stimulus and consequently the 4 items may be less well differentiated from each other. Both because there is less processed from each item and more to be differentiated the result is greater confusability of the different stimuli.

In the tasks described here, this model would not predict better recognition memory for the critical stimulus in the LOW information condition than in the HIGH, unless a preattentive processing stage is assumed. Neisser (1967) postulated preattentive processes which occur in parallel and segregate the figural units in a visual field in a global and holistic manner. The preattentive processes can keep one part of the field, for example, a *q* on a page, a separate and integral unit while it is being compared to other letters on the page.

Let us say that initially the 3 redundant stimuli are grouped in some way and treated as a unit. If subsequently features are simultaneously extracted from the 4 designs, the criterion number of features for synthesis of the redundant stimulus will be analyzed sooner, thus allowing time for the processing of the 1 different design before the icon fades. The assumption made is that the features extracted from the 3 redundant stimuli will be integrated and encoded as one visual pattern. Such mechanisms may well be too complex for young children.

Serial Processing Models

These propose that only a part of the input field is analyzed at any given moment; visual activity is sequential if it consists of successive interrelated steps (Neisser, 1967). Thus, an increase in number of items in an array results in an increase in processing time. There is much debate in the extensive information processing literature as to the adequacy of this kind of model, e.g., Gardner (1973) discussed here. It has been found that the serial model does not adequately deal with various kinds of data (Estes, 1972).

Within a simple sequential model, processing of the critical stimulus in the experiment proposed here should not be affected by the nature of the other stimuli in the array (whether there are 3 identical or 3 different stimuli). However, it is generally believed that early in the sequence of visual processing a set of feature detectors (of edges, angle, line, intersection, etc.) operate on the incoming information. Laberge (1976) suggests that when a feature detector or code is activated it may remain in an excited state for some period of time before it drops to the normal state it customarily maintains as a long-term memory structure. If the pattern is presented again while it is in this active state, processing should be more rapid.

In the LOW information condition described here, when a stimulus has activated a few feature detectors, if the next item in the sequence is identical it should be more rapidly processed. The subject would arrive more quickly, in the processing sequence, to the 1 different stimulus and more features could be analyzed and encoded from it before the icon faded. Such a mechanism would seem to be equally applicable to children of various ages and adults because the continued excitation of a feature analyzer seems to be of an automatic nature.

With the assumption of some preliminary organization of the field we have a model that contains aspects of both parallel and serial processing, such as Neisser's (1967). He postulated that preattentive processing occurs before sequential processing. In the study proposed here the 3 redundant stimuli in the LOW information condition can be grouped as one unit, at a preattentive stage, and subsequently analyzed and encoded. If this occurs, it is likely that there will be more time available for the critical stimulus than where there are 4 different stimuli.

Neisser (1967) suggested that young children and illiterates have difficulty with some of the preattentive mechanisms; in the example given earlier, he describes keeping the q as a separate and integral unit while comparing it to other letters as an acquired skill. "It would be a mistake to assume that the preattentive mechanisms of figural unity are all innate, although some of them must be" (Neisser, 1967, p. 89).

Summary

The processes dicsussed in conjunction with the descriptions of the different models involve both feature analysis--which is believed to begin early in visual storage--and encoding--which is believed to occur later in short-term working memory. With redundancy of stimuli, feature analysis and thus encoding of all stimuli can be facilitated. In parallel limited capacity and serial models, redundancy of stimuli may facilitate more rapid feature analysis, while in the parallel unlimited capacity model where automatic processing of all features is assumed, redundancy is believed to reduce confusability.

There is one similar basis in all three models for the prediction that there will be more accurate encoding of the critical stimulus in the LOW than in the HIGH information condition. In the three models some kind of grouping or chunking can occur. In a parallel unlimited capacity model it occurs after the stage of feature analysis while with parallel limited capacity and serial models it occurs prior to feature analysis. Within the parallel unlimited capacity models one would predict significant age differences in encoding since it is here that cognitive factors play a significant role. Let us turn now to the developmental findings.

Developmental Studies

It is the encoding stage of the processing sequence to which many adult-child differences are attributed. It has been found that age differences in processing multi-element arrays could not be attributed to age changes in visual sensitivity or to sensory storage capacity (Morrison et al., 1974; Sheingold, 1973). Morrison et al. (1974) found that there were no age differences in the amount of information initially available for processing. Their results also indicated that age differences are not due to changes in verbal labeling skills. It did appear that adults engaged in active visual rehearsal.

While mnemonic strategies and retrieval factors seem to be one source of adult-child differences, a number of studies point to encoding processes as a major source of the limitations in children's memory span performance (e.g., Blake & Vingilis, 1977). In her review, Chi (1976) lists studies, including her own (Chi, 1977) which illustrate that the differences in encoding speed between children and adults increases disproportionately as the stimuli become more complex and unfamiliar. Blake (1974) found that adults needed a 15 msec. exposure duration while children needed 30 msec. to encode a single stimulus with the same degree of accuracy. In contrast to this 2:1 ratio, Munsinger (1965) obtained approximately equal recognition accuracy by exposing each form for only 5-18 msec. to adults but 80-400 msec. to 5-year-olds; the stimuli used were complex random shapes.

Various authors (Chi, 1976; Morrison et al., 1974) have concluded that the basic "hardware" of visual memory exists at all age levels; the changes that occurred with age involve the "software" of memory--the organized strategies or programs for encoding and rehearsing information input to the visual system. In Blake's (1974) study she examined the three strategies discussed here: serial, parallel limited capacity (parallel-dependent) and parallel unlimited (parallel-independent). She found indications of the use of a parallel independent strategy on the part of 8-year-olds and adults, whereas there was a suggestion of the use of a parallel dependent strategy on the part of 4-year-olds (as well as inefficient serial scanning).

Chen (1978) hypothesized that younger children's difficulty in processing a multi-element visual array is partly due to their difficulties in generating a sequential encoding strategy. The results showed that when 5-year-olds were not provided with an encoding strategy they recalled fewer items than 8-year-olds and adults. With the experimental provision of a sequential encoding strategy, the performance level of the 5-year-old group alone was significantly increased, and it was increased to the level of 8-year-olds.

Chen (1978) discusses two possible changes which may have taken place in dealing with the flow of information in short-term memory when given a sequential encoding strategy: (1) the encoding process becomes a systematic operation and processing time is more efficiently used; (2) information can be grouped into larger chunks. The sequential encoding instructions may have provided subjects with color categories by which the whole array of 8 letters could be grouped into 2 units of 4 letters. Thus the problem of stimulus overload was less likely to occur.

It has been discussed here that the LOW information condition provides for the possibility of grouping on the basis of identity. Chi (1976) summarizes studies which indicate that adults often actively group a string of inputs during stimulus acquisition whereas there is no evidence that children do. In most studies the nature of the grouping required is more complex than in the study proposed here. For example, Dempster (1978), who found evidence of chunking with 12-year-olds but not 7-year-olds, used verbal materials (consonant letters, words, consonant-vowel letters).

Bartram (1978) asserts that the structure which the perceiver imposes upon the stimulus will be a function of the repertoire of chunk patterns (or chunk generation rules) he possesses and the relationships between some subset of these and the structural constraints in the stimulus. Morrison et al. (1974), who looked at spatial chunking tendencies (although it was not the main interest of the study), found evidence of this even with young children. They looked at evidence of processing in parallel several adjacent stimulus items. It has been taken as evidence of "chunking" that subjects often give as incorrect responses the stimulus item adjacent to the target items. All subjects showed a higher than chance frequency of adjacency errors, although the proportion of such errors increased with age.

Summary of Hypotheses and Issues to Be Explored

In the area of visual memory, as was mentioned regarding visual search, there seems to be a need to provide different kinds of tasks in order to better understand children's limitations. The task used here is one such attempt. Its purpose is to determine whether the young child has difficulty with a multi-stimulus array because of the additional number of features to be analyzed and encoded, or because attention must be distributed across a stimulus array.

LOW vs. HIGH Information Condition

Adults

We predicted on the basis of various aspects of information processing theories that adults will perform better in the LOW than in the HIGH information condition.

In light of what has been discussed thus far and other considerations to be raised there are three alternative possibilities for young children.

5-year-olds

The first possibility is more accurate recognition for the critical stimulus by both adults and children in the LOW than in the HIGH information condition, with the performance of the younger children being lower than that of adults but following the same pattern. It would indicate that the difference between children and adults in this kind of information processing task is simply quantitative. The improvement that occurs with the less complex field in the LOW information condition can be due to the reduced confusability between different aspects of the field, to more rapid feature analysis, or to ease of feature analysis and encoding due to chunking of the identical items. We can conclude that part of the young child's poor visual memory for a multi-stimulus array is due to the amount to be differentiated in the visual field.

If confusability is more of a problem for young children than adults, young children may demonstrate more improvement from the HIGH to the LOW information condition than adults.

It may also be that having 3 identical stimuli increases the perceptual saliency of the different stimulus --it has been argued that discrepant stimuli are more likely to be attention arousing than stimuli less differentiated from others in the stimulus field (Gollin, Saravo, & Salten, 1967).

The second possibility is that recognition memory will be the same in both the HIGH and LOW information conditions. Assuming that such a difference will be found with adults, this would reflect a qualitative difference between adults and young children.

A reduction of information, per se, may not suffice to improve visual memory performance in young children. During a rapid tachistoscopic presentation the young child may not fixate on those aspects of the forms which can provide information regarding identity. Thus simplifying the content of the array by having identical items may not be of benefit. The problem may be at the level of extraction of information from the individual item.

Vurpillot (1976) points out that the more restricted the exploration, as in a tachistoscopic presentation, the more important the localization of visual fixations would seem to be.

The problem may lie at another level of organization. As Bartram (1978) points out, in his discussion of post-iconic visual storage, the structure in the stimulus array does not determine the structure in recall. Because attention has to be spatially distributed and this must occur rapidly, some kind of strategy or organized approach may be required in order to benefit from the reduced information. Each of the identical items may be treated as a discrete unit rather than as one chunk, thus, analysis and/or encoding of the critical stimulus will not be facilitated. We have seen that young children do not spontaneously use an efficient encoding strategy, and that there is little evidence that they group or chunk items.

Bartram (1978) asserts that the subject has available a repertoire of heuristics which operate upon the stimulus array to segment it into "chunks." These heuristics may be relatively simple, embodying such Gestalt principles as proximity, common shape, color, etc. or may be relatively sophisticated involving abstract relationships, as in chess. The effect of the application of such heuristics to the stimuli can be conceptualized in terms of a redistribution of attention across the stimulus array, so that it is segmented into a number of higher order discrete units.

According to Bartram, the task of chunking on the basis of physical identity involves a simple heuristic. Nevertheless, it may be beyond the capabilities of a young child, particularly in a tachistoscopic presentation. For Gibson (1969) the pickup of structure is a perceptual economy that develops with age and experience. She asserts that the length of a perceptual span does not seem to distinguish the perception of adults from that of children. It is the ability to find the structure that makes the difference.

The task of encoding the designs in an organized fashion may be of particular difficulty for the young children because there are a number of unfamiliar designs in the study. Mandler and Robinson (1978) found that for 7-, 9-, and 11-year-old children recall was much more dependent on familiar schemata than for adults.

A third possibility is that there will be less accurate recognition memory for the critical stimulus in the LOW than in the HIGH information condition. Young children may indeed perceive the identity of the 3 stimuli and respond to them as a unit. Because they are a dominant part of the field they may focus their attention on them, so that there is less accurate memory for the critical stimulus. Thus, the young children may not show the lack of a systematic strategy but rather a strategy that is inappropriate to the task. That is, the "rule" they may follow is "pay attention to the identical stimuli," whereas the requirements of the task are to remember all the designs.

The 3 identical stimuli may represent a perceptual "demand" and the children's attention may be caught by it. As Gibson (1969) has described it, a developmental change in perception is for attention to become less captive. The adult may also experience the "demand" quality of the 3 identical stimuli and be able to compensate for it. There were indications that both these processes occur, in the pilot studies performed.

8-year-olds

Discussion thus far has been restricted to 5-year-olds and adults. It is anticipated that while there will be qualitative differences between these two age groups, the differences between 8-year-olds and adults will be quantitative, as was found in some previous tachistoscopic studies (Blake, 1974; Chen, 1973). Studies have shown that 8-year-olds can use an effective encoding strategy (Chen, 1978; Sheingold, 1973).

It is predicted, then, as for adults, that 8-year-olds will perform better in the LOW than in the HIGH information condition.

LOW vs. PAIR Condition

If subjects at any age level perform as well in the LOW information as in the PAIR condition, it would strongly indicate that, within limits, processing limitations are due to the amount of information to be differentiated within an array, not the number of forms, per se. Such a finding would support a parallel unlimited capacity model.

Age Differences

Regardless of the pattern of results it is predicted that adults will be more accurate than 8-year-olds, and 8-year-olds will be more accurate than 5-year-olds on the visual recognition tasks presented.

Stimulus Complexity

At all age levels it is predicted than there will be a decrement in performance with increased stimulus complexity. At each age level, there are two levels of stimulus complexity. For 5-year-olds and 8-year-olds the two levels of stimulus complexity presented are SIMPLE and MEDIUM, for adults--MEDIUM and COMPLEX. The SIMPLE stimuli were chosen as being perhaps the only ones on which the young children could perform above chance level. The SIMPLE stimuli were not used with adults because a ceiling effect was anticipated; this seemed to occur in the Blake and Vingilis (1977) study where simple stimuli were used. As has been discussed, young children need significantly more time to process complex stimuli.

For purposes of analysis, the adults' MEDIUM condition was equated with the children's SIMPLE, and adult COMPLEX with the children's MEDIUM. Thus, across age levels two levels of stimulus complexity could be compared.

Duration of Interstimulus Intervals

The patterns of performance for the three age groups at the different stages of the information processing sequence may shed light on the validity of the mechanisms described in the discussion of information processing models.

The interstimulus intervals (ISIs)--50 msec., 250 msec., 500 msec., and 1000 msec.--which were chosen represent different stages in the information processing sequence. The ISI of 50 msec. has been described as reflecting what has gotten into the system (Morrison et. al., 1974).

Differences between children and adults in terms of "what's getting into the system" have been described as "hardware" limitations whereas adult-child differences in the encoding stage have been considered to reflect strategies, i.e., "software." Morrison et al. (1974) found no adult-child differences at brief interstimulus intervals although they did find them at the longer durations. Similarly, Blake and Vingilis (1977) did not find adult-child differences at 50 msec. on 4-item arrays.

The ISI of 250 msec. has been described as reflecting the duration of the visual trace. As reviewed by Blake (1972), Sperling and many other investigators have determined that for adults the visual image persists for about a quarter of a second. In partial report studies such as Morrison et al.'s (1974) and Sheingold's (1973) there has been a curvilinear trend: Accuracy is highest at the shortest interstimulus intervals, there is a decrease from 0 to 200 or 250 msec., and then an increase in accuracy to 250 or 300 msec. Sheingold found that between 500 and 1000 msec. the 11-year-olds and adults improved in accuracy while the 5- and 8-year-olds decreased in accuracy. Similarly, Morrison et al. (1974) found that adults increased in the 450 to 1000 msec. interval whereas for the 5- and 8-year-olds there was a nonsignificant downward trend in performance. Accuracy, however, was highest at the early ISIs.

On the other hand, Blake and Vingilis (1977) found that accuracy was highest for all subjects at 250 and 1000 msec. They point out that in partial report studies, with some exceptions, the earlier the indicator appears the better, since the indicator reduces processing load; it restricts the subject's processing to only a portion of the array. In a successive "yes-no" recognition task, on the other hand, the second test stimulus does not restrict processing; it must always be compared with all the items in the original array. Thus, in this task, performance improves until the subject has had time to analyze and encode the original items sufficiently to make a comparison. The curvilinear trend in the partial report studies, however, has not been adequately explained.

What occurs after a 1000 msec. ISI is considered to reflect what has been encoded and perhaps rehearsed. The ISI of 500 msec. reflects recognition at an earlier point in encoding. A comparison of performance after an ISI of 500 msec. and after an ISI of 1000 msec. can enable us to see whether there are changes early or later in encoding.

Order Effects

The effect of counterbalancing the LOW and HIGH conditions (see Table 1) will be examined. Previous researchers have found significant and contradictory results regarding the effect of order and practice: improvement with practice (Hoving, Spencer, Robb, & Schulte, 1978) or a decrement in performance with repetition of the task (Dempster, 1978; Rosner, 1972) at the younger ages.

Chapter II

METHOD

Design

There are five main independent variables:

1) Amount of Information: PAIR (2 different stimuli); LOW (3 identical, 1 different stimuli); HIGH (4 different stimuli).
2) Stimulus Complexity: SIMPLE, MEDIUM, COMPLEX.
3) Age: 5-year-olds, 8-year-olds, and adults.
4) Duration of Interstimulus Interval (interval between presentation of the target stimulus array and presentation of the test stimulus): 50, 250, 500, and 1000 msec.
5) Order: the LOW and HIGH conditions were counterbalanced. For half the subjects the LOW condition was followed by the HIGH condition; for the other half the HIGH was followed by the LOW.

An additional independent variable is number of sessions: one, two, or three. The number of sessions was not the same for the three different age groups. From observations made during pilot testing, three sessions seemed to be the minimum number within which the children's attention could be maintained. It was felt, however, that it would only be possible to obtain the participation of college students if they were asked to take part in one or, at the most, two sessions. The design used made possible a test of the effect of the number of sessions. Half the adult sample had one session and the other half had two. Half the 8-year-old sample had two sessions while the other half had three. All the 5-year-olds had three sessions.

See Table 1 for an outline of the design.

The amount of information in the visual field and the duration of interstimulus intervals are within subject variables. Age, stimulus complexity, order, and number of sessions are between subject variables.

A comparison of correct responses in the PAIR, LOW, and HIGH information conditions was made a within-subjects variable because there is considerable variability in tachistoscopic performance. With a between-subjects design, unless one uses a very large sample, we cannot assume that the two samples are initially equivalent in the necessary perceptual skills. The problem can be avoided if we look at change within a subject under different conditions.

The dependent variable is the subjects' judgments whether the recognition test stimulus is the "same" as a stimulus in the array, with a correction for false alarms. The measure used is A' which is described in the Results section.

There were 40 subjects at each age level (total N = 120). Half the subjects in each age group received one level of stimulus complexity; the other half received a different level. For 5-year-olds and 8-year-olds the two levels of complexity were SIMPLE and MEDIUM, for adults --MEDIUM and COMPLEX.

Each subject from each age group was randomly assigned to one of the conditions with the restriction that in each of the subgroups there should be an approximately equal number of males and females.

At each level of stimulus complexity the PAIR, LOW, and HIGH conditions consisted of 4 blocks of 6 trials. Each block of 6 trials was presented at one of the 4 interstimulus intervals: 50, 250, 500, and 1000 msec. Thus, each subject was shown 4 blocks of PAIR arrays, 4 blocks of LOW information, and 4 blocks of HIGH information arrays. There was a total of 12 blocks of experimental trials (72 trials).

The 4 blocks of LOW and HIGH information trials were counterbalanced for each age group, at each level of stimulus complexity. There were two sequences: (1) One group of 10 subjects was shown a series of 4 blocks of HIGH information arrays followed by a series of 4 blocks of LOW information arrays. (2) For the second group of 10 subjects the order was reversed.

The PAIR condition was not presented in a series of

4 blocks, but was partly used to provide some variation from the more difficult 4-stimulus arrays. It was felt that some change in the nature of the arrays would have a beneficial effect on the young children's performance (Dempster, 1978; Rosner, 1972). Two of the 4 blocks of PAIR trials were presented after the introductory sequence of practice trials, 1 block of PAIR trials was presented during the LOW series and 1 block during the HIGH information series (see Table 2).

Task

The task in each trial is the following.

After focusing on a fixation point for 750 msec. the subjects were shown an array containing 2 or 4 stimuli. The stimulus array duration was 125 msec. After a dark interstimulus interval (to be varied as described above) the recognition test stimulus was displayed for 125 msec. The subjects were asked whether the test stimulus was the same as a design just seen.

The sequence is as follows:

FIXATION POINT..	ARRAY..	INTERSTIMULUS INTERVAL..	RECOGNITION TEST STIMULUS
750 msec.	125 msec.	50, 250, 500, or 1000 msec.	125 msec.

Subjects

There were 120 subjects: 40 kindergarteners (21 males, 19 females), 40 third-graders (20 males, 20 females), and 40 college and graduate students (19 males, 21 females). The kindergarten Ss ranged in age from 5 years to 6 years, 2 months, with a mean age of 5 years, 6 months. The third-graders ranged in age from 7 years, 11 months to 9 years, with a mean age of 8 years, 6 months. The adult Ss ranged in age from 17 years, 7 months to 25 years, 3 months, with a mean age of 20 years, 5 months.

The kindergarteners and third-graders were enrolled in suburban public schools in middle-class communities: Harrington Park, New Jersey, and Farmingdale, New York. The adults were undergraduates and graduate students enrolled in a number of different colleges who were tested in a psychology laboratory at the Fairleigh Dickinson University in Teaneck, New Jersey. They were paid $5 for one session and $6 if they came for two sessions.

All 120 subjects had passed pretests which tested their ability to match the designs, to comprehend the tachistoscopic task and to visually recognize stimuli from 2-item arrays.

There were 17 Ss who were excluded from the study for the following reasons: (a) Four subjects could not have the required number of sessions within five days because of illness. (b) One college student assigned to the MEDIUM condition did not pass the memory test. (c) One foreign-born 8-year-old assigned to the SIMPLE condition did not pass the memory test. (d) Seven 5-year-olds assigned to the MEDIUM condition did not pass the pretest: two were unable to correctly match the designs, five did not pass the memory task. (e) Two 5-year-olds assigned to the MEDIUM condition refused to return. (f) Two 5-year-olds assigned to the SIMPLE condition did not pass the pretest: one failed the matching task, the other failed the memory task.

Apparatus

A three-field Scientific Prototype Model 3GB was used in conjunction with an auxiliary timer. The three fields of the tachistoscope contained the fixation point, the target array and the recognition test stimulus. The luminance of the three fields was approxmiately .024 foot-candles for the fixation field, .065 foot-candles for the target field and the test stimulus field. The interstimulus interval was dark.

Stimulus Materials

The fixation point was a small white cross on a black background, which appears gray at the illumination setting used. High illumination was used to minimize masking effects (Eriksen, 1969).

Thirty-six stimuli were chosen from a group of 48 designs after the latter had been ranked on complexity by adults and divided into three groups: SIMPLE, MEDIUM, and COMPLEX, by the experimenter. The stimuli used are shown in Figure 1.

The 48 stimuli had been chosen from a larger group of 60 designs, some of which had been tested for confusability in a pilot study with prekindergarteners. Twelve stimuli were not included in the ranking because they seemed to be the most confusable on the basis of the pilot study performed and the experimenter's judgment.

The stimuli were shown on 5 x 7 cards. They are black line drawings, printed on a white background, contained within a square. The size of each design is approximately 11 mm., subtending a visual angle of 33' at the field-subject distance of 1149.3 mm. Each form is 31.4' above, below, to the left, or to the right of center. All of the stimulus information is contained within ±1.05° of the center of the field. For cards containing 2 items, the forms appear above and below the center.

The recognition test stimulus was in the center of the card.

As in Blake's (1974) study, forms in the 2-item arrays were randomly assigned to the above and below positions with the restrictions that (1) each form appear once in each block of 6 trials, (2) no pair combination be repeated across all trials, and (3) each form appear 2 times in both positions across the 4 blocks of trials. A fourth restriction is that each stimulus will be the recognition test stimulus (correct or incorrect) an equal number of times.

For the 4-item arrays in the HIGH information condition forms were randomly assigned to position with the restrictions that (1) each form appear twice in each block of 6 trials, once either above or below center and once to the left or right, (2) no form be repeated within an array and no combination of 4 forms be repeated across all trials, and (3) each form appear an equal number of times in each of the 4 positions across the 4 blocks of trials.

To control for confusability of stimuli within the LOW and HIGH information conditions, each stimulus in the HIGH information condition can be paired with every other one in the LOW information condition. This yields 12 variations for that latter condition. For example, if $\mathrm{B} \genfrac{}{}{0pt}{}{\mathrm{A}}{\mathrm{D}} \mathrm{C}$ is shown in the HIGH information condition the following arrays will be shown in the LOW information condition: $\mathrm{A} \genfrac{}{}{0pt}{}{\mathrm{A}}{\mathrm{D}} \mathrm{A}$ $\mathrm{B} \genfrac{}{}{0pt}{}{\mathrm{B}}{\mathrm{D}} \mathrm{B}$ .. $\mathrm{B} \genfrac{}{}{0pt}{}{\mathrm{A}}{\mathrm{B}} \mathrm{B}$ $\mathrm{C} \genfrac{}{}{0pt}{}{\mathrm{A}}{\mathrm{C}} \mathrm{C}$ .. $\mathrm{B} \genfrac{}{}{0pt}{}{\mathrm{A}}{\mathrm{A}} \mathrm{A}$ $\mathrm{B} \genfrac{}{}{0pt}{}{\mathrm{C}}{\mathrm{C}} \mathrm{C}$, etc.

Five of these variations were chosen for the LOW information condition. As can be seen, the location of the critical stimulus was varied. Five variations were chosen so that for the subgroups of five subjects (8-year-olds and adults) the stimulus arrays would be the same.

For both the HIGH and LOW information conditions the test stimulus was the same. The test stimulus was selected from the array 50% of the time (that is, it was the "same"). When it was the "same," two-thirds of the time it was the critical stimulus and one-third of the time the redundant stimulus. While we were primarily interested in recognition accuracy for the critical stimulus when it was in the two different contexts, memory for the redundant stimulus was tested to ensure that the subjects attend to all the stimuli. If only memory for the critical stimulus was tested, the task would become similar to visual search where the redundant stimulus is simply "noise" (in the LOW information condition). Some subjects might then develop a strategy of ignoring the redundant stimulus.

The stimulus arrays were shown to all subjects for 125 msec. This provides an exposure duration which is sufficiently long for young children (Morrison et al., 1974) and yet does not allow enough time for eye movements; a single fixation is believed to occur every 200 msec. (Neissner, 1967).

Number of Sessions

Half the adults saw the designs in a single session lasting about an hour and 15 minutes. There was a short break between the two experimental conditions. Half the adults and half the 8-year-olds saw the designs in two sessions lasting about 35 minutes each. The practice session and the first experimental condition took place in the first session. The younger children and half the 8-year-olds were seen in three sessions: one practice session and two test sessions which lasted about 25 minutes each.

All subjects were seen within a period of five days.

Procedure

The experimenter informed the subjects that she was interested in how many designs children and adults can remember when the designs are seen very quickly. The young children were told "I have some little pictures to show you in a big funny-looking box. I'm interested in finding out how many little designs children and adults can remember. Come and see what we're going to do. We're going to play this game for three days. You can tell me when you want to go back to your room."

Pretest and Familirization Procedure

Each of the 12 designs in a given stimulus complexity condition (SIMPLE, MEDIUM, or COMPLEX) was shown on separate separate cards, one at a time. The subjects' task was to match each one with a design in a matrix which contained the 12 designs. Subjects who made more than two matching errors and those with one or two errors who could not respond correctly when given a second opportunity to match the designs, were eliminated from the experiment.

The purpose of this procedure was to familiarize the subjects with the set of stimuli and to eliminate those who could not make accurate judgments of identity with unlimited viewing time.

Practice

Following the familiarity task there was a training procedure outside of the tachistoscope: "Now, this is what we're going to do. I'm going to show you a card with a design on it. Then I'm going to show you a card with another design. I want you to tell me if the second picture is the same as the first--answer 'yes' or 'no.' . . . Now here are two designs on a card. Tell me if the second picture is the same as any of the pictures on the first card. Answer 'yes' or 'no.'" There were three stimulus cards with a single design followed by three stimulus cards with 2-item arrays.

At the tachistoscope: "Now you're going to see the designs in here. Before you see the designs you'll see a tiny cross in the middle of a card. Keep looking at the cross in the middle. That will put your eyes in the right place for looking at the designs. After the cross, you'll see a design. Then it will be dark in there and you'll see another design. Tell me if it's the same as the design on the first card."

The interstimulus interval for all the practice trials was 500 msec.

Four tachistoscopic trials with 4 different 1-item cards were administered. The stimulus duration and the duration of the test stimulus was gradually decreased: trial 1--400 msec., trial 2--250 msec., trials 3 and 4--125 msec. This was followed by 4 tachistoscopic trials with 2-item cards, with the same sequence of stimulus durations. The last sequence was 6 trials with 4-item arrays; there were 2 trials at each exposure duration.

The subjects were told when they made errors and were shown the cards out of the tachistoscope. For subjects who had more than one error on the 1-item arrays or more than one error on the 2-item arrays, the sequence was repeated. They were eliminated from the study if they were not correct on 3 out of 4 items on the 1- and 2-item arrays during the repeated sequence.

The content of the 4-item arrays was determined by the experimental condition with which the subjects were beginning, that is, there were 3 identical, 1 different stimulus in the practice arrays for those beginning with the LOW information condition, and 4 different stimuli for those beginning with the HIGH condition. Feedback was not given during practice on the 4-item arrays.

Test Sessions

Within each of the conditions--PAIR, LOW, HIGH--the order of the interstimulus intervals at which each sequence of 4 blocks of trials was presented was varied. There were five variations: one sequence of interstimulus intervals for each of the five variations of stimulus arrangements which were used (previously described). Also, for each of the five variations of stimulus arrangements the placement of the PAIR trials in the LOW and HIGH conditions was varied.

Before each block of 6 test trials, the duration of the interstimulus interval was shown to the subjects using two blank white cards. The experimenter said: "For each group of cards that I'm going to show you the dark time will be different. I'm going to show you how long the dark time will be with two plain white cards."

The second experimental condition (LOW or HIGH) was preceded by a block of 6 practice trials with 4-item arrays with the same exposure duration sequence as in the first practice session. Again, the arrays in the practice trials contained the type of information to be presented in that experimental condition. This second practice series was introduced to the subjects by a statement "Now you'll see a bunch of cards like these." The subjects had the opportunity to observe the nature of the arrays; however, it was not verbally specified by the experimenter.

The subjects were told that if their eyes felt tired they should tell the experimenter. They were reassured that it is hard to see all the designs and that it takes time to get used to the speed of presentation. If subjects were reluctant to say whether the test stimulus was the "same" or "different" than the designs on the first card they were asked to guess.

After each block of 6 trials, the group of cards in the tachistoscope had to be changed by the experimenter. This took several minutes. During these breaks, to occupy the 5- and 8-year-olds Lego and Etch-a-Sketch were available. There were also snacks (peanuts and raisins) for the children.

Throughout the test sessions no feedback was given regarding the correctness of responses. If subjects asked about this, the experimenter responded: "I won't be telling you whether you're right or wrong; just do the best you can."

Chapter III

RESULTS

The data consists of the subjects' judgments whether on each trial the recognition test stimulus is the "same" as a stimulus in the array. Since in a two-alternative forced choice task, there is a 50% probability of guessing correctly, the measure used in the analysis of data--A'--introduces a correction for guessing. For each subject, the number of hits and false alarms (false recognitions) was obtained.

A' is similar to d' in signal detection theory but does not make the same assumptions (Snodgrass, Volvovitz, & Walfish, 1972). A' is a non-parametric measure of the average area under all possible memory-operating-characteristic curves drawn through the single point representing hits plotted against false alarms. It is neutral with respect to the underlying model appropriate for the memory process. It has the advantage of being defined over the entire range of hit/miss ratios, including when the hit rate and/or the false alarm rate is 100% or 0%. For data in which hits and false alarms are based on a small number of trials, as in this experiment, this occurs fairly frequently (Snodgrass, Burns, & Pirone, 1978). The formula for calculating A' is in the Appendix.

In the PAIR (2 stimuli), LOW (1 different, 3 identical stimuli) and HIGH (4 different stimuli) conditions, in each block of 6 trials, at each of the 4 interstimulus intervals, there were three correct "same" and three correct "different" responses. However, one of the "same" responses was omitted in the main analysis of the results for the LOW and HIGH conditions for the following reason. In the LOW condition, two-thirds of the time the "same" stimulus was the critical stimulus (the 1 different stimulus) and one-third of the time, the redudant stimulus (the 3 identical stimuli). As was discussed in Chapter II, while we were interested in memory for the 1 different stimulus, memory for the 3 identical stimuli was also tested to ensure that the subjects would attend to them. If only memory for the critical stimulus was tested, the task could become similar to visual search (for some subjects) where the redundant stimulus is simply "noise."

The subjects' responses to the redundant stimulus and to its equivalent in the HIGH condition (where it was 1 of 4 different stimuli) were omitted from the main analysis.

In the PAIR condition there were no such constraints and all the responses were included in the analysis.

A five-way repeated measures analysis of variance ($3 \times 4 \times 3 \times 2 \times 2$) was carried out on the A' scores. Age, stimulus complexity, and order are between subject variables and array conditions and interstimulus intervals are within subject variables. The analysis of variance was performed on the means for the A' scores. Since the 5-year-olds and the 8-year-olds were shown SIMPLE and MEDIUM stimuli while the adult group was shown MEDIUM and COMPLEX, for the purpose of analysis with respect to complexity the adult MEDIUM condition was equated with the children's SIMPLE and COMPLEX with the children's MEDIUM condition.

The following questions were asked:

1) What are the effects of the three array conditions: PAIR (2 items), LOW and HIGH information (4 items)?

2) How does the performance vary after the different interstimulus intervals (ISIs): 50, 250, 500, and 1000 msec.? The first two ISIs give information about the stage of visual information storage and the ability to "read off the icon," the second two ISIs yield information about encoding.

3) What are the age differences obtained under the different conditions?

4) What is the effect of stimulus complexity on performance?

5) What is the effect of the order of the two conditions LOW and HIGH which were counterbalanced? In half the cases LOW was administered first, in the other half HIGH preceded.

As we have seen (Table 2--Procedure) the PAIR condition was not counterbalanced. Two blocks of PAIR trials were presented to all subjects following the practice sessions; one block of PAIR trials was presented during the LOW condition and one block during the HIGH.

The main effects of age, complexity, information, and interstimulus interval (time) were significant at the .01 level or below (see Table 3). There was also a significant age × order × information interaction. These results indicate that, in general, higher mean scores were obtained with older subjects, with less complex stimuli, with less information (2 rather than 4 different designs), smaller arrays and longer processing times (see Table 4).

These overall differences, except for the complexity finding, were investigated further by performing Scheffe tests on the group means. The direction of the significant effect of complexity was clear since only two levels are involved. As was expected, higher mean scores were obtained with the less complex stimuli. We will look at the results for the other variables separately.

Interstimulus Interval

It was found that performance was significantly lower at 50 msec. than at 250, 500, and 1000 msec. (at the .01 level on the Scheffe test). The means are in Table 4.

That performance at 50 msec. is significantly lower is similar to what Blake and Vingilis (1977) found. They discuss this result in terms of subjects needing more time for encoding. According to Hoving, Spencer, Rabb, and Schulte (1978), although the development time of the icon is typically thought to be in the range of 100 msec. it may be as long as 300 msec. for certain forms and illumination levels. Thus, at 50 msec. subjects may be "reading" from a less fully developed visual image.

Significant differences were not found between the other time intervals. Similarly, Blake and Vingilis (1977) found that for all age groups accuracy was highest at intervals of 250 and 1000 msec. (compared with 1, 50, 100, and 3000 msec.). They did not use a 500 msec. interval as in this experiment.

Information (Array Conditions)

The question asked in this study is whether a young child has difficulty with a multi-stimulus array because of the additional number of features to be analyzed and encoded (HIGH vs. LOW and PAIR) or because attention must be distributed across a stimulus array (PAIR vs. LOW and HIGH). For the sample as a whole, the results indicate that both requirements of the task affect performance. The results for the different age groups will be looked at separately when the Age × Order × Information interaction is discussed. However, there is no indication that either of the task requirements has a relatively more detrimental effect on young children's performance than on the performance of the two other age groups.

The need to distribute attention spatially (over 4 rather than 2 items) is the most significant cause of lowered performance. The A' scores for the PAIR, LOW and HIGH conditions are .814, .699, and .642 respectively. A larger decrement in performance resulted from an increase in number of items (from 2 in the PAIR condition to 4 in the LOW) than from an increase in the amount of information (from 2 patterns to be discriminated in the LOW condition to 4 patterns in the HIGH).

Here, then, unlike what has been found in visual search studies, performance does not remain invariant, despite the size of the set, when there are identical noise items. However, the results for the sample as a whole do demonstrate that when the amount of information in a 4-item array is reduced (the LOW condition as compared to the HIGH), there is a significant improvement in performance. Thus, PAIR performance is best, followed by the LOW condition, with performance worst in the HIGH condition.

Age

The finding of a significant age effect is due to the differences between 5-year-olds and the two other age groups. The performance of both the adults and the 8-year-olds was significantly better than that of the 5-year-olds ($p = .01$ on the Scheffe test). Equating the Adult MEDIUM condition with SIMPLE for the children, and the Adult COMPLEX condition with MEDIUM, seemed to wipe out any potential age differences between 8-year-olds and adults. As can be seen in Table 4 the means are almost identical.

When we compare adult and 8-year-old overall performance in the MEDIUM condition--the condition they both have in common--there is no significant difference. The mean A' scores are .7750 in the Adult MEDIUM condition and .7613 in the 8-year-old MEDIUM condition; $p > .10$.

Age × Order × Information

The age × order × information interaction was explored further in two ways. Pair by pair comparisons were made using the Tukey HSD test.[1] Table 3 gives the means; the

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[1]According to Winer (1971), because the Tukey HSD test is applicable in a relatively broad class of situations, and because it is simple to apply, there is much to recommend it for general use in making a posteriori tests. While it tends to yield too few significant results, the Scheffe method is even more conservative with respect to Type I error--this method leads to the smallest number of significant differences.

pair comparisons which yielded significant differences (at the .05 level) are starred. Also, further analyses of variance (AGE × ORDER) were performed within each of the Information conditions--PAIR, LOW and HIGH--to clarify the age × order interaction. These will be subsequently discussed.

Table 5 enables us to look at the relationship between information conditions and order within ages, and to make across-age, across-information comparisons, e.g., Adult HIGH vs. 5-year-old LOW. Comparisons within Information conditions will be based on the follow-up analyses of variance and will be omitted here.

In the pair by pair comparisons the means in the Adult and 8-year-old Pair conditions are highest, and comparisons between them and the other means yield the greatest number of significant differences. The Adult PAIR means are significantly higher than the Adult HIGH means, but not the Adult LOW. Similarly, the 8-year-old PAIR means are significantly higher than the 8-year-old HIGH means, but not the 8-year-old LOW. For both these age groups it reflects the finding (reported earlier) that although recognition memory decreases when array size increases (with no increase in information) the difference between a 2-item and 4-item array is greatest when there is an increase in the amount of information in the 4-item array.

The age × order × information interaction is attributable to several findings:

1) Five-year-old PAIR (HIGH to LOW) performs significantly better than 5-year-old LOW (both orders) and 5-year-old HIGH (both orders), while 5-year-old PAIR (LOW to HIGH) does not. This interaction will be looked at in the age × order analysis of variance performed within the PAIR condition. The result indicates that for 5-year-olds recognition memory is significantly better with a 2- than a 4-item array, regardless of the contents of the array, but only under some circumstances.

Five-year-old PAIR (HIGH to LOW) also performed significantly better than Adult HIGH (HIGH to LOW)--the one instance where 5-year-old performance is significantly better than adults' (or 8-year-olds').

For the other two age groups there was no effect of order on PAIR performance.

2) Adult LOW condition performs significantly better than Adult HIGH, in the HIGH to LOW, but not the LOW to HIGH order. This result is primarily due to the relatively large, although not statistically significant, difference between Adult HIGH performance in the two orders (.724 in the LOW to HIGH order and .609 in the HIGH to LOW order). The latter result is at the level of 5-year-olds' performance in the HIGH to LOW order.

In the LOW information condition, ADULT performance is similar in both orders: .740 in LOW to HIGH and .762 in HIGH to LOW.

It may be that practice affects performance in the HIGH and not the LOW condition. Following practice in the LOW condition, performance is better in the HIGH, almost reaching the same level as performance in the LOW information conditions.

A reverse order effect was found for 5-year-olds' HIGH performance. This will be discussed in the next section.

3) There were no significant order effects in the 8-year-old group.

Age × Order

The results of the age × order analyses of variance are summarized in Table 5. Three × two analyses of variance were carried out on the A' scores within the three Information conditions: PAIR, LOW and HIGH. Both age and order are between subject variables. As in the prior analysis, pair by pair comparisons were made using the Tukey HSD test (.05 level).

These analyses were performed to further explore the age × order × information interaction. The results of these analyses show that this interaction is attributable to the HIGH and PAIR conditions (as indicated in the previous section).

LOW Information Condition

Performance in the LOW condition can be described as most "stable." The variable of age is significant in the LOW condition but there are no significant order or age × order effects (see Table 6).

The 5-year-olds performed significantly worse than the LOW items than the 8-year-olds and adults. Thus, when attention must be distributed over 4 items which contain redundancy, young children perform more poorly than the older groups.

PAIR Condition

Within the PAIR condition, the main effects of age and order are significant and there is a significant age × order effect. The 5-year-olds performed significantly worse on the PAIR items than the 8-year-olds and adults. The significant order effect and age × order effect is due to the fact that, unexpectedly, 5-year-old PAIR performance in the LOW to HIGH condition is significantly worse than 5-year-old PAIR performance in the HIGH to LOW condition, whereas no order effects are found in the 8-year-old or adult groups (see Tables 6, 7, and 8).

HIGH Information Condition

Within the HIGH condition, the main effect of age is significant and there is a significant age × order effect. The age × order effect is attributable to the fact that the 5-year-olds in the LOW to HIGH group perform significantly worse in the HIGH condition than the 8-year-olds and adults in both orders, whereas the 5-year-olds in the HIGH to LOW group do not. In fact, as noted previously, the performance of the 5-year-olds in the latter group is practically identical with the HIGH performance of adults in the HIGH to LOW condition. The HIGH performance of the 5-year-olds in the LOW to HIGH condition is at the chance level.

While the differences between the two orders within the 5-year-old group and the adult group are not statistically significant we can observe reverse trends. The 5-year-olds perform worse when the HIGH condition is preceded by the LOW while the adults perform better under this condition, presumably because of the positive effect of practice (see Table 8).

For the 8-year-olds, again, there are no order effects.

In summary, we find that the age × order × information interaction is due to the HIGH and PAIR conditions, where 5-year-olds demonstrate strong order effects. Five-year-olds' PAIR performance in the LOW to HIGH condition is significantly worse than 5-year-olds' PAIR performance in the HIGH to LOW condition. Five-year-olds' HIGH performance is significantly below that of 8-year-olds and adults in the LOW to HIGH but not in the HIGH to LOW order. An overriding finding is the significant effect of age, with

5-year-olds' performance worse than that of 8-year-olds and adults within all three Information conditions.

Number of Sessions

The effect of number of sessions was examined by t tests which compared A' mean scores for Adults in one vs. two sessions and for 8-year-olds in two vs. three sessions, in the three information conditions: PAIR, LOW and HIGH. No significant differences were found (Table 9).

Response Bias

We now turn from a consideration of the accuracy of responses as measured by A' to an examination of response bias. We investigated response bias to determine to what extent the results obtained reflect different response strategies employed by different age groups under the different experimental conditions.

There were two possible response choices--"same" or "different." To determine whether there were biases to give one or the other response, the mean raw scores for "same" and "different" scores were calculated and compared. Because the number of "same" and "different" responses in the analysis was not equal, a correction was applied to make comparisons possible.

The examination of response bias was primarily focused on the two conditions which provide the main comparison in this study--LOW and HIGH information. However, the number of "same" responses in the PAIR condition and in the different interstimulus intervals was also looked at.

At all age levels it was expected, on the basis of the confusability of items, that the HIGH information condition would yield a greater number of false positives than the LOW information condition. Since there were a greater number of features to be processed in the HIGH information condition (and some of the designs may only hev been partially processed) it was likely that the subjects would confuse the recognition test stimulus (when it was different) with one of the items in the array. Thus, it was expected that the mean number of correct "different" judgments would be less in the HIGH information than in the LOW information condition. This prediction was borne out for the sample as a whole, for adults and for 8-year-olds (Table 13). For the whole sample, for adults in the COMPLEX condition, and 8-year-olds in the SIMPLE and MEDIUM conditions, the total number of "same" responses (correct and incorrect) was significantly greater in the HIGH condition than in the LOW (see Table 11). In the LOW condition, subjects were more likely to respond "different" and when they responded "same" they were more likely to be right (see Table 14).

Because of the stronger tendency to say "same" in the HIGH condition, there is no significant difference between LOW and HIGH correct "same" responses in any of the groups (Table 13).

The results for the 5-year-olds are very different. They adopted a more "conservative" approach (that is, stricter criteria) in the HIGH condition, tending to say "same" slightly less (although not significantly) in the HIGH than in the LOW condition (Table 11). In both the LOW and HIGH conditions, they tended to give fewer "same" than "different" responses (Table 10). This may account for the significantly greater accuracy on the LOW and HIGH "different" than on "same" responses. For the two levels of complexity combined and taken separately, the 5-year-olds' mean correct "same" responses in the LOW and HIGH conditions are not above chance (Table 13). This indicates that 5-year-olds were saying "same" randomly (at least at some interstimulus intervals) as well as less frequently.

Eight-year-olds said "same" significantly more than 5-year-olds in the HIGH condition (Table 10). This tendency was true for adults also, but the difference is not significant. Five-year-olds were the most "conservative" group but adults also tended to be more conservative than the 8-year-olds in the HIGH condition, particularly with stimuli of MEDIUM complexity they were less likely to say "same" (although the difference does not quite reach significance: $p = .06$).

In a different kind of recognition memory task, Berch and Evans (1973) also found that third graders exhibited a more liberal response criterion than kindergarteners. On a continuous recognition memory task where the judgments to be made were "old" or "new" to a series of pictures, the 8-year-olds were more likely to respond old" than the 5-year-olds.

The frequency of blocks of trials where 5-year-olds gave only "same" or only "different" responses would seem to represent a way of coping with a difficult task (see Table 15 for the percentage of blocks of trials, at each age level, where only "same" or only "different" responses were given). In the 5-year-olds' PAIR condition (the easiest task) the frequency of single response trial blocks was considerably less than in the LOW and HIGH conditions.

Because of the 5-year-olds' tendency to say "same" slightly less in the HIGH than in the LOW (and also in the PAIR) condition we explored whether the 5-year-olds' bias to say "different" was strongest when faced with difficulty or confused. In general, for 5-year-olds, a more conservative response criterion does not seem to be a consistent response to the greater difficulty of a task. Contrary to such an interpretation, the number of "same" responses is slightly greater in the MEDIUM (the more complex stimulus condition) than in the SIMPLE condition (see Table 11).

Further, we looked at the number of "same" (correct and incorrect) responses given at the different ISIs by 5-year-olds. We would expect fewer "same" responses at the ISI which was found to be most difficult at all ages: 50 msec. However, statistically significant differences were not obtained (see Table 12). By inspection we can see that performance is the same at 50 msec. as at the other ISIs in the 5-year-old SIMPLE condition. In the 5-year-old MEDIUM condition performance is in the expected direction, that is, worse at 50 msec. but the differences are not significant at the .05 level (1-tail test). There is also no indication that the frequency of single response trial blocks (only "same" or only "different" responses) was related to the different interstimulus intervals. It may be that the 5-year-olds' "conservatism" is a response to difficulty in conjunction with other aspects of the task, primarily task order, which we will look at next.

It is when we examine the relationship between response bias and task order in 5-year-olds that we find the most striking effects (see Table 16). Overall, there is a significant decrement in the number of "same" responses from the first series of 4 stimulus arrays (in the second session) to the second series of 4 stimulus arrays (in the third session), regardless of the content of the arrays. That is, whether the sequence is the LOW followed by the HIGH condition, or vice versa, there is a significant decrease in the number of "same" judgments from the second to the third session--48% as compared to 38% (p < .01).

The greatest decrease occurs when the LOW condition is followed by the HIGH--from 49% to 35% (significant at the .005 level). Initially, then, on the somewhat easier task --the LOW information condition--there is no response bias. What may happen in the third session is that the 5-year-olds adopt stricter criteria for sameness or their attitude becomes more negativistic, perhaps because of the greater difficulty of the task.

While an increase in the difficulty of the task seems to contribute to an increase in "different" responses, other possible contributing factors (independent of the contents of the arrays) may be the change in the nature of the arrays which requires a different strategy, and/or fatigue and boredom. We find a decrease in the number of "same" responses--from 47 to 40%--when the HIGH condition (the more difficult condition) is followed by the LOW (this decrease, however, does not reach significance: $p > .05 < .10$).

Further analysis of the results suggests that the decrement in "same" judgments and in performance from the second to the third session is not due solely to a required strategy change. If this were the case we would expect performance on the first of the 4 blocks of trials in the third experimental session to be worse than on the subsequent blocks of trials, since in the later trial blocks children would have had the opportunity to adapt their strategies to the new task. In fact, when we look at performance on the first block of trials in the third session, we find that its mean for corrected scores is highest (see Table 12). In the HIGH condition, it is only on the first block of trials that performance is above chance. Further, the mean for the first block of trials in the third session (.62) is about the same as the mean for the second session (.61). This suggests that it is not the need for a strategy change that impairs performance but more likely a decreasing interest in the task that leads to increasing negativism and, consequently, a disproportionate number of "different" judgments.

In our discussion of response bias we have looked at the tendency to say "same" or "different," for the most part, irrespective of the accuracy of these responses. In the next section--Same vs. Different Responses--we will compare the accuracy of these responses at the different age levels and under different conditions.

Same vs. Different Responses

See Table 13 for the results discussed in this section.

In general, performance was better on trials where the correct response was "different" than on trials where the correct response was "same" in the LOW condition. Within the LOW condition, for the sample as a whole, the percentage of correct "different" responses is significantly higher than the correct "same" responses. Only in the Adult MEDIUM condition is the number of correct "different" responses significantly higher than correct "same" responses in both the LOW and HIGH conditions (although LOW correct "different" responses are significantly higher than HIGH correct "different" responses).

For the 8-year-olds in the SIMPLE condition there is a reverse trend. In the HIGH condition the mean number of correct "same" responses is higher than correct "different," with the difference almost reaching significance ($p = .06$). Within the MEDIUM condition, no significant differences between correct "same" and "different" responses were found.

The performance of the 5-year-olds is consistently more accurate on "different" than on "same" judgments. Blake and Vingilis (1977) also found superior performance on "different" judgments for 5-year-olds. HIGH and LOW correct "different" are both above chance, whereas both LOW and HIGH correct "same" responses are not (but LOW is somewhat higher; HIGH is almost significantly <u>below</u> chance).

Performance on the Redundant Items

See Table 18 for these results.

The analysis of performance on the redundant items was motivated by a question raised in the Introduction--whether the young children's attention would be "captured" by the 3 identical stimuli in the LOW condition. If this were the case, this could help to explain why the 5-year-olds' memory for the critical stimulus in the LOW condition is significantly worse than that of the 8-year-olds and adults.

If the 5-year-olds' memory for the redundant stimulus would match or surpass that of 8-year-olds and adults, it would indicate that the 5-year-olds' poorer performance on the critical stimulus (the different one in the LOW condition) was due to a focusing of attention on the identical stimuli.

The measure used to assess performance on the redundant stimuli in the LOW condition was percent correct. When the redundant stimuli are singled out for statistical analysis, hits are "same" responses and misses are "different" responses; thus, there are no possible false alarms.

With three opportunities to process each stimulus we find that 5-year-olds as well as adults and 8-year-olds perform best on these stimuli. However, the performance of the 5-year-olds is significantly below that of the older age groups. There are various possible explanations for the poorer performance of the 5-year-olds: it may reflect the relative inattentiveness of the 5-year-olds to the task and/or that they used a more conservative criterion for "sameness." It does not seem that the young children's attention was "captured" by the 3 identical stimuli. In fact, if the 5-year-olds were attending to only 1 stimulus in a 4-stimulus array, we would expect 75% accuracy which is, in fact, what was obtained.

Summary of Results

In summary, higher mean scores were obtained with older subjects, with a decrease in complexity, a decrease in information and an increase in interstimulus intervals. The performance of both the adults and the 8-year-olds was significantly better than that of the 5-year-olds. Differences between 8-year-olds and adults may have been masked by the greater complexity of stimuli presented to the latter group (however, when their performances in the MEDIUM condition are compared no significant difference is found). Performance was significantly lower at 50 msec. than at 250, 500, and 1000 msec.

PAIR performance was best, followed by the LOW condition, with performance worst in the HIGH condition. For the sample as a whole, the need to distribute attention over 4 rather than 2 items (the LOW as compared to the PAIR condition) causes a greater decrement in performance than the need to differentiate more information (the HIGH as compared to the LOW condition).

Overall, there was no evidence that either distributing attention or the need to analyze and encode 4 rather than 2 items is a relatively greater problem for 5-year-olds than older age groups. In all the information conditions, the overall performance of 5-year-olds was significantly below that of 8-year-olds and adults. What did emerge from the findings was that both adults and 5-year-olds were affected by the order of presentation of the two conditions--LOW and HIGH information--while 8-year-olds were not.

Unexpectedly, 5-year-old performance in the PAIR condition was significantly worse in the LOW to HIGH order than in the reverse order. Again, in the LOW to HIGH order, the 5-year-olds' performance in the HIGH condition was at the chance level, whereas it was above chance in the reverse order. The adults demonstrate an opposite trend. Adult HIGH performance in the LOW to HIGH order is superior to Adult HIGH performance in the reverse order. This primarily accounts for the fact that Adult LOW performance is significantly better than Adult HIGH in the HIGH to LOW, but not the LOW to HIGH order.

Adults in the HIGH condition seem to gain from prior practice with a somewhat different task (LOW information items) whereas such practice has a reverse effect for young children. This decrement in the performance of the 5-year-olds was found to be related to an increase in response bias from the second to the third session, as indicated by a significant decrease in the number of "same" judgments. A lessening interest in the task may lead to greater negativism and/or decreased attentiveness. The 5-year-olds may make fewer "same" judgments in the later part of the experiment because less information has been abstracted from the visual stimuli. Vurpillot (1976) found in her study of visual comparisons that the duration of exploration of a single pair decreased progressively throughout the experiment. In the 4- and 5-year-olds this did not reflect greater skill in abstracting information but simply a loss of interest because the material was no longer novel. Thus, the younger children eliminated useful information. If fewer details were being abstracted from the stimuli in the later part of the present study, one could expect less frequent "same" judgments. The greatest decrease occurs when there is an increase in the difficulty of the task as well, that is, when the LOW condition is followed by the HIGH.

In a study of memory span in 7- to 12-year-olds Dempster (1978) also found that age differences in memory span are affected by stage of practice. He found a decline in the performance of youngest children (first graders) during the course of practice and an improvement in span for the older children. Here, no effect of practice on 8-year-olds' performance was observed. For both young children and adults, as well as 8-year-olds, performance in the LOW information condition was relatively unaffected by order of presentation.

Chapter IV

DISCUSSION

In keeping with previous developmental research which has consistently shown 5-year-olds to be at a disadvantage when presented with multiple stimulus arrays in visual memory tasks, in the present study we find that the overall performance of the 5-year-olds is significantly below that of 8-year-olds and adults. In an attempt to understand the detrimental effect of increasing array size on the young child's performance, we looked at whether the young child has difficulty with a multi-stimulus array because of the additional number of features to be analyzed and encoded, or because attention must be distributed across a stimulus array. For the sample as a whole, the results indicate that both requirements of the task affect performance. There is no indication that either of the task requirements has a relatively more detrimental effect on young children's performance than on the performance of the two other age groups.

We will first look at the implications of these findings for information processing models, primarily apart from developmental issues, and then at the implications of the developmental differences which were found for theory and methodology.

Implications of the Findings for Models of Information Processing

As was discussed in the Introduction, there is a basis in the various information processing models (parallel unlimited capacity, parallel limited capacity and serial processing models) for predicting that, if the amount to be differentiated in a multiple-stimulus array is reduced, recognition accuracy of the items in the array will be increased. We have seen that, for the total sample, this prediction is upheld.

However, what we also find is that the need to distribute attention spatially (over 4 rather than 2 items) is the most significant cause of lowered performance. This is true for the sample as a whole, with the overall result being contributed to by each of the age groups. Such a finding is more consistent with parallel limited capacity and serial processing models than with a parallel unlimited capacity model. Much of the foregoing discussion of information models will be based on comparisons of the LOW and PAIR conditions. Even though this was not the major emphasis of the study, this comparison seems to shed light on some information processing issues.

As we have seen, Gardner (1973), who asserts that there is no perceptual limitation in a detection task, emphasizes that the decrease in accuracy which is found when there are increases in the array items, results from confusions between the target and noise items plus the decisional structure of the task. However, we find that performance in the PAIR condition (2 items) is superior to performance in the LOW condition (4 items) even though the decisional and perceptual confusion properties of the two tasks are alike. The same stimuli are used in the LOW and PAIR conditions, thus, the confusability between the "noise" (redundant design) and the critical stimulus is similar to the confusability between the two stimuli in the PAIR arrays and between these stimuli and the test stimuli. In both conditions the decision as to whether the test stimulus has just been presented is based on a comparison of the test stimulus with two designs. Thus, since the crucial difference between the LOW and PAIR conditions is the need to spread attention, the present finding does indicate some perceptual limitations.

It can be argued that the result obtained here is not applicable to a parallel unlimited capacity view of perceptual processing since the visual memory task in this study involves not only perceptual processing, as in detection tasks, but also the encoding of information into short-term working memory. In the earliest stages of processing, the pickup of sensory information is believed to be automatic whereas when information is being encoded into short-term memory it is believed that the subject has some control and that what is not coded will be quickly lost. However, since the contour and features being automatically processed from the 3 redundant stimuli are identical they should be encoded into short-term memory as one pattern and consequently, encoding the other stimulus (the critical stimulus) should be as efficient in the LOW as in the PAIR condition. In both the LOW and PAIR conditions only two patterns are being encoded.

The above should be true for adults, in particular. Parallel unlimited models could predict significant age differences in encoding since it is here that cognitive factors are believed to play a significant role. We could expect a significantly greater difference between 5-year-old performance and adult performance at 500 and 1000 msec. (the encoding stage) than at 50 msec. However, while age differences were found in this study, there were no significant age differences in the pattern of performance. All age groups performed better in the 250-1000 msec. interstimulus interval range than at 50 msec. The results at 500-1000 msec. did not differentiate children from adults any more than the earlier stages of information processing.

One would certainly expect as efficient encoding of the critical stimulus in the LOW as in the PAIR condition if, as Estes (1972) argues, input channels have the capability to interact and prevent the further processing of redundant information. The homogeneous noise items (the redundant stimuli) would tend to inhibit each other and, as a result, increase the salience of the target.

In contrast to what was obtained here, Blake and Vingilis (1977) found that adult accuracy did not decrease significantly at any interstimulus interval with increases in array size. The contrast is striking, particularly because the presentation times in the present study were considerably slower. According to Atkinson and Shiffrin (1971) this should result in better recall. How can we reconcile our results with this and other evidence for parallel unlimited capacity models (Gardner, 1973; Shiffrin & Geisler, 1973)?

The present study may point up some limitations of such models, the nature of which have been discussed by Shiffrin and Geisler. They raise as a key question the extent to which automatic processing applies. Two important factors related to such limitations are believed to be familiarity and complexity (the number of features in the stimuli).

As was just discussed, in parallel unlimited capacity models there are no attention limitations during perceptual processing. An automatic processing sequence acts on the input to encode and abstract many low level features and some relatively high level features.

The abstraction of information from a visual input is assumed to occur in a series of stages involving greater and greater degrees of transformation and encoding. The encoding process consists of making contact in long-term storage with particular features stored there and entering them in short-term storage. At the earliest level, the visual input is transformed into a pattern of color and contrast information coded by spatial position. Further processing results in the detection of simple patterns such as line segments, angles, contours and so forth. These features can be used to generate yet higher order features. As any feature is abstracted it is entered at once into short-term storage where it can engender additional encoding.

According to Shiffrin and Geisler, the extent of automatic processing will be determined in part by past experience. With considerable time and practice we will become familiar with a given stimulus, gradually increasing the accessibility of the image of that stimulus (and its features). Eventually the recognition process will make automatic contact with long-term storage without conscious control on the part of the subject.

In studies where evidence of parallel unlimited processing is obtained, a key element would seem to be the familiarity of the stimuli. In the present study where the MEDIUM and COMPLEX stimuli were relatively unfamiliar, processing to a level of feature analysis enabling pattern recognition and encoding may not have always taken place. This seems to have been the case since post-experiment questioning revealed that, frequently, the adult subjects were not consciously aware that there were 3 identical stimuli in the LOW condition, describing them instead as looking similar. They did, however, successfully recognize the redundant stimuli over 90% of the time. It is possible that a composite image of the redundant stimulus was formed from different features analyzed in the 3 identical stimuli or, alternatively, that serial processing took place and that the three opportunities to encounter the redundant stimulus resulted in a high rate of recognition.

A further provisional explanation offered by Shiffrin and Geisler for the limitations in automatic processing is that the fast loss of information in the iconic phase of short-term storage is caused by interference due to a large number of features continually being abstracted at the lower levels. Since some of the designs in the present study are more complex than those in the other experiments which have been mentioned, there could have been more inter-item interference which resulted in poorer performance. With the relatively simple stimuli used in the Blake and Vingilis study (1977) there seems to be a ceiling effect for adult subjects.

Increased interference can help explain why subjects perform better in the LOW than in the HIGH condition but not why memory tends to be poorer with 4 than with 2 items, since the LOW condition did not contain a larger number of different features than the PAIR condition. The most likely explanation is that with 4 relatively unfamiliar and complex items less feature analysis and, hence, less encoding is possible than with 2 items because of the need to divide attention.

Thus, as was stated previously, the results of this study are more consistent with parallel unlimited capacity and serial processing models which suggest that subjects have difficulty with multi-stimulus arrays primarily because of the spreading of attention over an increased number of items. We have seen that in these models, redundancy of stimuli may facilitate more rapid feature analysis of the single critical stimulus because of activation of feature detectors or chunking (see Introduction). Thus, better performance in the LOW than in the HIGH condition would result. But these models would not predict equivalent performance in the LOW and PAIR condition.

The superior performance in the LOW as compared to the HIGH condition may be attributed to various factors in addition to more rapid feature analysis. In summarizing what differentiates the LOW from the HIGH condition, we can point to what was just discussed: reduced interference in the LOW condition and reduced confusability between the stimuli in the field and between them and the test stimuli.

Further, there is facilitation of the decision process because there are fewer features to be compared with the test stimulus. In the Introduction it was suggested that having three identical stimuli might increase the perceptual saliency of the critical stimulus. Some observational data tends to make the last explanation unlikely. When adult subjects were aware that there were identical items, they sometimes experienced them as having a "demand" quality for which they needed to compensate by searching out the different (critical) stimulus, rather than experiencing the 3 identical stimuli as highlighting the different one.

We are led to conclude that while parallel unlimited processing may occur, it is subject to many constraints. Let us turn now to the developmental differences which were found and their implications for developmental information processing theory.

Theoretical Implications of Developmental Differences

It was predicted on the basis of various aspects of information processing theories that adults will perform better in the LOW than in the HIGH information condition. Three alternative possibilities for young children were discussed and of these, the first was realized. That is, there was more accurate recognition for the critical stimulus by both adults and children in the LOW information than in the HIGH information condition, with the performance of the younger children being lower than that of adults but following the same pattern. As we have seen, the 5-year-olds performed more poorly than the adults and 8-year-olds in the three conditions: PAIR, LOW and HIGH. Thus, the findings indicate quantitative rather than qualitative process changes with age.

The 5-year-olds were not differentially affected by the need to distribute attention across an array or to analyze and encode an additional number of features. Hoving, Spencer, Robb, and Schulte (1978) speculate that young children may do relatively poorly on multi-item displays because of possible age differences in the ability to handle the interference produced by additional items. However, we have seen that in the LOW condition where there is less interference, due to redundancy of items, the performance of 5-year-olds is not relatively better.

That such interference is not a more significant issue for children than adults has also been shown on visual search tasks. As was mentioned in the Introduction, Gibson and Yonas (1966) found that interference from confusable items did not differentially affect subjects 7 years of age and older. Context confusability was equally damaging at all age levels. In general, Day (1978) points out that there are studies which point to only quantitative changes while others to qualitative process changes with age in the ability to allocate attention selectively in visual search.

Similarly, in studies of visual memory, the evidence varies regarding qualitative or quantitative changes in performance with development. The issue has been linked to the question of whether young children have capacity ("hardware") limitations compared to adults, or whether differences in performance are due to different strategies (the "software" of processing). The kind of evidence that has been obtained seems related to methodological and procedural factors such as the nature of the stimuli, the type of memory test used, time, etc. as well as the specific variables chosen to be looked at.

For example, in Morrison, Holmes, and Haith's study (1974) familiarity of stimuli did not differentially affect the performance of 5-year-olds, 8-year-olds and adults. However, major age differences in the slope of accuracy as interstimulus interval increased indicated differences in the coding of information into permanent storage. In her first study, Blake (1974) found evidence for the use of different kinds of processing strategies at different ages. Four-year-old performance indicated parallel dependent or serial processing. Eight-year-olds and adults showed a parallel independent processing strategy as array size was increased from 1 to 2 forms but not when there was an increase from 2 to 4 forms. We have seen that in the Blake and Vingilis (1977) study, adult performance did not show a significant decrement with an increase to 4-item arrays. In both studies the same stimuli were used but the latter task was easier since it involved recognition rather than recall.

In the present study the evidence suggests the use of parallel dependent or serial processing strategies in both children and adults. The results are not directly comparable with Blake's since the stimuli used here are different and the memory task is different from that of her earlier study (Blake, 1974). In that study she found that 4-year-olds perform as well as 8-year-olds and adults on single-item arrays. Here, even when the 5-year-olds are tested on the redundant stimulus their performance does not match that of 8-year-olds and adults.

Thus, in this study on all tasks the young children perform more poorly, even when the adults are presented with considerably more complex stimuli. The evidence seems to point more to capacity than process differences but it can be argued that no matter what the task, adults and 8-year-olds perform better because they employ more effective or more appropriate processing strategies.

While there is no evidence for differences in perceptual processing strategies in this study, there were significant differences in response strategies. In general, 5-year-olds tended to be less attentive, needing more encouragement to remain with the task. When their attention was directed to the task, they tended to say "different" more frequently and to respond randomly or in a perseverative manner (saying only "same" or "different"). This seemed to occur with the more difficult tasks and with increased exposure to the experimental situation. In the last session of the experiment there appeared to be a negative "practice effect." With increasing fatigue and/or lack of interest there was an increase in response bias. In contrast, the performance of the 8-year-olds remained steady while the performance of adults improved with practice, indicating they were "learning how to learn."

As in other areas discussed, we find a diversity of results in the literature regarding differential responses to practice, response biases and changes in response bias within different age groups. Berch and Evans (1973) state that "Certainly to the extent that there are reliable developmental changes in response bias, knowledge of such changes would be of immense value in analyzing a variety of psychological tasks where decision processes play a role in determining performance" (p. 161). The nature of response biases and the ways in which they change seem to be a function of specific tasks.

Blake and Vingilis (1977) did a signal detection analysis and found that there was a tendency for all age groups to use a stricter criterion for "same" judgments at the extreme interstimulus intervals. The increases in β (measures of response criterion) were differentially greater in 5-year-olds at the shortest interstimulus intervals (1 and 50 msec.) and for 9-year-olds at the longest interstimulus level (3,000 msec.). Since performance was best at the middle interstimulus intervals, these findings are consistent with the view that a response bias can develop at least in part as a response to difficulty. Blake and Vingilis pointed out that the drop in "same" judgment accuracy at 3,000 msec. for 5-year-olds and the increased accuracy of all age groups at 250 msec. could not be attributed to criterion changes.

As in the present study, Berch and Evans (1973) analyzed response bias in relation to when it develops in a series of trials. They had found that third graders had a more liberal response bias than kindergarteners, but for both groups the false alarm rate increased across blocks of items. Signal detection analysis revealed that this increase was due to a change in criterion from a relatively conservative level to a more lenient one. In our study we find the reverse for 5-year-olds and no change for 8-year-olds and adults. While here and in the Berch and Evans study, 5-year-olds are "conservative," the signal detection analysis in a "same vs. different" study of Blake and Beilin (1975) tentatively supported the opposite idea--that young children have a less strict criterion for "same." Similarly, Vurpillot and Moal (1970) found that young children tolerated more differences in judging two stimuli to be the same.

When we look at accuracy of "same" or "different" judgments we find contradictory results which appear to have some systematic relationship to the type of response bias which has developed in the particular experiment. Here and in Blake and Vingilis' study 5-year-olds were more accurate on "different" than on "same" judgments, whereas on one task in the Blake and Beilin study, the error rate on "same" stimuli was substantially lower than on "different" stimuli.

It seems then that we can only discuss age-related response biases as they occur in specific experimental contexts until the factors leading to "leniency" or "conservative" criteria at different ages are specified. It may be that leniency is shown by young children when the task seems less difficult or is of greater interest. Young children have been found to respond positively to novel tasks and negatively to familiar ones (Rosner, 1972).

Rosner would relate the decrement in 5-year-olds' performance that was obtained here to the familiarity of the stimuli. She found that an overall decrement in retention was produced in children 4.7 years of age by continual testing with a restricted item pool, while there was a retention gain with the presentation of different item lists on the repeated tests. She reports that young chileren have been found to afford lower preference judgments to previously exposed (familiarized) visual stimuli than to novel stimuli, and their self-regulated viewing time decreases as a function of the amount of stimulus familiarity as well as the total time spent in the viewing situation.

Similarly, Dempster (1978) found that with blocked presentation of stimulus materials (consonant letters, consonant-vowel letters, words, nonsense syllables, digits) there were large and reliable age differences in the effects of practice: a decline in the performance of first graders and an increase in the performance of third and sixth graders. With Alternate presentation the decline did not occur. In Blocked presentation the same materials were presented on successive trials; in Alternate presentation, different series conditions were administered on adjacent trials. However, again we find some contradictory results. Hoving et al. (1978) report that in their research children continue to improve for at least 8 to 10 sessions, with no variation in stimulus materials.

Although in the present study the nature of the task changed somewhat from the LOW to the HIGH condition (and vice versa) the stimuli did not. The change in the nature of the arrays and the inclusion of PAIR arrays apparently was not enough of a change to renew interest. After a break of at least a day, the 5-year-olds' performance remained at its previous level only during the first block of trials but then it declined.

As was discussed in the Results section, the 5-year-olds' increase in "response bias" may partly be attributed to a decrease in the abstraction of useful information due to lessened attention (less thorough exploration of the icon). With a decrease in information regarding the stimuli, "sameness" is less likely to be recognized. What may have changed during the course of the experiment was not only the response criterion but the amount of information upon which responses were based.

In this study only the adults seemed to benefit from experience, their improvement with practice indicating that they were "learning to learn." Some observational data suggest that adults, as was found by Bartram (1978), learned how to pre-program their distribution of attention or, in Neisser's (1976) terms, developed an anticipatory schema. These are plans for perceptual action which prepare the perceiver to accept certain kinds of information rather than others and control the activity of looking. For example, in the LOW condition several adult subjects reported that they developed the rule "I'll look for the different one first."

For 5-year-olds, the conditions under which they can gain from practice and perhaps "learn how to learn" seem to be restricted--apparently related to novelty, perhaps again to the difficulty of the task, and one would expect, to its intrinsic interest. Rewarding correct responses, as in Blake's (1974) first study may provide the necessary extrinsic motivation, although gains in young children's performance have been obtained without such rewards.

One consistent finding in a number of studies has been that a major source of the limitations in children's memory span performance are encoding processes. The present study also points to such a conclusion although there was no evidence of qualitative differences between the children and adults at different points in the information processing sequence (that is, at the four interstimulus intervals). The recognition memory test used here eliminates report interference or retrieval strategies. Thus, the differences obtained between 5-year-olds and 8-year-olds/adults reflects primarily encoding processes and the earlier stage of visual information storage.

Previous studies (Morrison et al., 1974; Sheingold, 1973) have shown little developmental change in visual information storage, however, these were partial report studies where an indicator pointed to a single item for the subject to report. As Blake and Vingilis (1977) point out, in partial report studies the earlier the indicator appears the better, since the indicator reduces processing load; it restricts the subject's processing to only a portion of the array. In the task here, the test stimulus does not restrict processing; it must always be compared with all the items in the array. Thus, while the information may initially be there for the 5-year-olds in visual information storage, they may be less efficient in making the required comparisons.

The amount of random and perseverative responding in 5-year-olds does not make possible a conclusive analysis of performance at the different interstimulus intervals. With more trials at each ISI or more subjects, a better understanding of the processes could be obtained. Let us look now at other methodological implications of the developmental findings that were obtained.

Methodological Implications of Developmental Differences

The results of the present study and some of the previous research reviewed here raise serious methodological questions about how best to undertake the developmental study of information processing. The contradictory findings regarding the role of practice and the familiarity of the stimulus materials confuse the experimenter who is trying to design a study which will optimize the possibility of successful performance in young children.

We can conclude with Hoving et al. (1978) that "The plethora of procedural and methodological problems in the current developmental literature makes it very difficult to assess the possible changes that may occur with age in either the time parameters of iconic memory or in the selective processing of the icon itself" (p. 49).

Hoving et al. found improvement with 8 to 10 sessions of an information processing task whereas, as they point out, most studies with children use only one or two sessions. In contrast to this, here we find that after two sessions (a practice session and the first experimental session where 4 stimulus arrays were presented) 5-year-olds' performance declined. Yet with fewer than three sessions, their attention to the number of trials required in the task could not have been maintained (based on earlier pilot work). For adults and 8-year-olds we have seen that small differences between number of sessions are not consequential. For adults, having one or two sessions and for 8-year-olds, having two or three sessions did not significantly affect performance.

In a review article Hoving et al. (1978) assert that

> only when adults and children have received a great deal of practice on a limited set of materials, and control level performances have been equated and asymptoted, can we assume that the information used for identifying materials represented in the icon is reasonably equivalent. . . . Most adult studies have used well-practiced subjects, whereas those involving children have not. . . . Our own research (Robb, 1976; Schulte, 1976) indicates that children continue to improve for at least eight to ten sessions." (p. 46)

This discussion can be compared with Rosner's (1972) where the need for item shifts and novelty is emphasized. Thus, she concludes that her results have several implications:

> Methodologically, they indicate that studies which aim at determining young children's memory capacity

> should base their observations on the initial trial(s) of previously practiced Ss and that studies which examine the effects of variables on children's STM should use different lists on successive trials. . . . Pedagogically, they imply that the retention of young children in this type of situation may be maximized by providing Ss with learning-to-learn experience on irrelevant items prior to the presentation of a target item series." (p. 229)

Dempster (1978) also found, as we have seen, that age differences in memory span are affected by method of presentation and stage of practice. He concludes that studies attempting to estimate children's memory capacity should base their observations either under an Alternate method of presentation, or on the initial trials of subjects being tested under Blocked presentation.

In the present study where the stimuli are not varied the 5-year-olds' decrement in performance from the second to the third session and the fact that in the last session they perform best on the first block of trials, are findings consistent with Rosner's and Dempster's conclusions. In this study it may have been preferable (although perhaps not practical) to use a larger number of subjects who were given fewer blocks of trials. Another alternative may have been to make stimulus complexity a within-subjects variable so that young children's interest in the task would be maintained by a change in stimulus materials.

Because of the wide variations found in the effects of such variables as practice and stimulus familiarity, a careful analysis of these seems necessary prior to the use of a particular experimental design. The effects of specific methodologies are probably related to a number of variables which have not yet been specified. In conclusion, it seems that the only safe generalization is a caveat regarding the generalization of results. Researchers need to be cautious about extending the application of their experimental procedures, based upon the results obtained, to other studies.

Conclusion

This study investigated whether the young child has difficulty with a multi-stimulus array because of the additional number of features to be analyzed and encoded, or because attention must be distributed across a stimulus array. Neither of the task requirements was found to have a relatively more detrimental effect on young children's performance than on the performance of the two older age groups. Consistent quantitative changes in performance with age were obtained. Five-year-olds performed more poorly than 8-year-olds and adults in all experimental conditions.

At all ages the need to distribute attention spatially over 4 rather than 2 items is the most significant cause of lowered performance. This finding is more consistent with parallel limited capacity and serial processing models than with parallel unlimited capacity models. While there has been evidence for parallel unlimited processing, this study suggests that unfamiliarity and complexity of stimuli place constraints on its occurrence.

There were no indications of developmental differences in perceptual processing strategies within what was measured in this study, however, the results are consistent with previous findings of differences in encoding processes with age. They also suggest the possibility of differences in visual information storage, although this may be due to the particular memory task used.

Significant differences in response strategies were obtained. While adults demonstrated a positive practice effect, there was a decrement in the performance of 5-year-olds from the first to the second set of experimental trials trials. This was found to be related to an increase in response bias (to make "different" judgments) which seemed to be caused by increasing difficulty and also increasing fatigue and/or lack of interest over the block of trials.

A review of some literature dealing with response bias, changes in response bias and the effects of practice and stimulus familiarity in young children yields contradictory results and conclusions. In general, it was concluded that the varied findings are related to as yet unspecified aspects of different experimental contexts. Thus, these cannot be generalized to new studies. Careful analysis of possible response bias, practice effects, etc. seems necessary prior to the use of a particular experimental design.

Table 1

Design

	5-year-olds				8-year-olds				Adults			
	SIMPLE		MEDIUM		SIMPLE		MEDIUM		MEDIUM		COMPLEX	
Number of Sessions	3	3	3	3	3 2	3 2	3 2	3 2	2 1	2 1	2 1	2 1
Number of Subjects	10	10	10	10	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5
Order: 1st series	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
2nd series	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW

Interstimulus Intervals: Within each Information condition, there are 4 blocks of 6 trials. Each block of 6 trials was presented at one of the 4 interstimulus intervals.

Note. See Procedure (Table 2) for the order in which the PAIR condition was presented. This was not counterbalanced as were the LOW and HIGH conditions.

Table 2

Procedure

I. Familiarization Procedure

A. Matching task

II. Practice

A. Memory task--outside of tachistoscope:

Single item--3 trials

2-item array--3 trials

B. Memory task--in tachistoscope:

Single items--4 trials

2-item arrays--4 trials

4-item arrays--6 trials (LOW or HIGH information arrays; the practice series is the same as whichever series comes first)

III. Experimental Trials

A. PAIR (2-stimulus arrays)--2 blocks of 6 trials

B. First series: LOW or HIGH condition--4 blocks of 6 trials

PAIR--1 block of 6 trials

[Practice: 6 trials with 4-item arrays containing LOW or HIGH information--the same as whichever series comes second]

C. Second series: LOW or HIGH condition--4 blocks of 6 trials

PAIR--1 block of 6 trials

Table 3

Summary of ANOVA on the A' Scores

Source of Variation	df	MS	F	*p*	% Total SS
Age	2	2.906	31.152	< .001	5.59
Complexity	1	0.695	7.538	.008	0.67
Order	1	0.014	0.147	> .500	0.01
Age × complexity	2	0.131	1.418	.247	0.25
Age × order	2	0.215	2.327	.103	0.41
Complexity × order	1	0.072	0.777	.380	0.07
Age × complexity × order	2	0.020	0.213	> .500	0.04
Error	108	0.092			9.58
Information	2	3.670	63.021	< .001	7.06
Age × information	4	0.042	0.721	> .500	0.16
Complexity × information	2	0.013	0.219	> .500	0.02
Order × information	2	0.135	2.310	.102	0.26
Age × complexity × information	4	0.034	0.579	> .500	0.13
Age × order × information	4	0.195	3.343	.012	0.75
Complexity × order × information	2	0.126	2.162	.118	0.24
Age × complexity order × information	4	0.063	1.088	.364	0.24
Error	216	0.058			12.10
Time	3	0.933	14.434	< .001	2.69
Age × time	6	0.040	0.623	> .500	0.23
Complexity × time	3	0.061	0.937	.423	0.17
Order × time	3	0.031	0.475	> .500	0.09
Age × complexity × time	6	0.021	0.321	> .500	0.12

Source of Variation	df	MS	F	p	% Total SS
Age × order × time	6	0.072	1.118	.352	0.42
Complexity × order × time	3	0.083	1.278	.282	0.24
Age × complexity × order × time	6	0.086	1.328	.244	0.50
Error	324	0.065			20.15
Information × time	6	0.115	2.083	.054	0.66
Age × information × time	12	0.031	0.568	> .500	0.36
Complexity × information × time	6	0.028	0.511	> .500	0.16
Order × information × time	6	0.037	0.676	> .500	0.22
Age × complexity × information × time	12	0.055	0.994	.453	0.63
Age × order × information × time	12	0.021	0.375	> .500	0.24
Complexity × order × information × time	6	0.105	1.900	.079	0.61
Age × complexity × order × information × time	12	0.039	0.700	> .500	0.45
Error	648	0.055			34.46
Total	1439	0.072			100.00

Table 4

Mean A' Scores for Interstimulus Intervals, Stimulus Complexity, Information Conditions and Age

	Interstimulus Intervals (msec.)			
	50	250	500	1000
Means	.646	.753	.717	.755

	Stimulus Complexity	
	SIMPLE (includes Adult MEDIUM)	MEDIUM (includes Adult COMPLEX)
Means	.740	.696

	Information		
	PAIR	LOW	HIGH
Means	.814	.699	.642

	Age		
	5-year-olds	8-year-olds	Adults
Means	.628	.764	.762

Table 5

Pair by Pair Comparisons of A' Scores for Age × Order × Information Interaction

	5 PR H-L	5 LO H-L	5 HI H-L	5 PR L-H	5 LO L-H	5 HI L-H	8 PR H-L	8 LO H-L	8 HI H-L	8 PR L-H	8 LO L-H	8 HI L-H	ADPR H-L	ADLO H-L	ADHI H-L	ADPR L-H	ADLO L-H	ADHI L-H
Means	.772	.589	.603	.650	.623	.523	.863	.729	.691	.857	.739	.702	.872	.762	.609	.867	.740	.724
5 PR H-L .772		*	*		*	*												
5 LO H-L .589							*	*		*	*		*	*		*	*	*
5 HI H-L .603							*			*	*		*	*		*	*	
5 PR L-H .650							*			*			*			*		
5 LO L-H .623							*			*			*			*		
5 HI L-H .523							*	*	*	*	*	*	*	*		*	*	*
8 PR H-L .863									*			*						*
8 LO H-L .729													*			*		
8 HI H-L .691										*			*			*		
8 PR L-H .857												*						
8 LO L-H .739																		
8 HI L-H .702													*			*		
ADPR H-L .872																		*
ADLO H-L .762																		
ADHI H-L .609																		
ADPR L-H .867																		*
ADLO L-H .740																		
ADHI L-H .724																		

Key: HI = HIGH; LO = LOW; L-H = LOW to HIGH; H-L = HIGH to LOW

Note. Starred comparisons are significant at the .05 level, Tukey HSD test.

Table 6

Summary of ANOVAs on the A' Scores Within the Three Information Conditions

Source of Variation Between Subjects	SS	df	MS	F	p
PAIR Condition					
Age	0.632	2	0.316	29.210	.000
Order	0.060	1	0.060	5.544	.020
Age × order	0.091	2	0.046	4.221	.017
LOW Condition					
Age	0.470	2	0.235	11.181	.000
Order	0.004	1	0.004	0.168	.683
Age × order	0.021	2	0.011	0.505	.605
HIGH Condition					
Age	0.393	2	0.196	9.187	.000
Order	0.007	1	0.007	0.336	.564
Age × order	0.189	2	0.095	4.426	.014

Table 7

Mean A' Scores for 5-year-olds, 8-year-olds and Adults and Total Sample in the Three Information Conditions

	LOW to HIGH	HIGH to LOW	Total
PAIR Condition			
5-year-olds	.650	.772	.711
8-year-olds	.857	.863	.860
Adults	.867	.872	.869
Total	.791	.836	
LOW Condition			
5-year-olds	.633	.589	.611
8-year-olds	.739	.729	.734
Adults	.740	.762	.751
Total	.704	.693	
HIGH Condition			
5-year-olds	.523*	.603	.563
8-year-olds	.702	.691	.697
Adults	.724	.609	.666
Total	.650	.634	

*Not significantly above chance at the .05 level of significance.

Table 8

Pair by Pair Comparisons of A' Scores for Age × Order Interaction Within Information Conditions

	PAIR Condition					
	5L-H .650	5H-L .772	8L-H .857	8H-L .863	ADL-H .867	ADH-L .872
5L-H .650		*	*	*	*	*
5H-L .772						*

LOW Condition

There was not a significant age × order interaction therefore no pair × pair comparisons were made.

	HIGH Condition					
	5L-H .523	5H-L .603	ADH-L .609	8L-H .691	8H-L .702	ADL-H .724
5L-H .523			*	*	*	*

Note. Starred comparisons are significant at the .05 level, Tukey HSD test.

CONTRASTS within the three Information conditions:

Five-year-olds performed significantly below 8-year-olds and adults in the PAIR and LOW conditions at the .001 level of significance, Scheffe test.

Five-year-olds performed significantly below 8-year-olds and adults in the HIGH condition at the .01 level of significance, Scheffe test.

Table 9

Comparisons of Mean A' Scores for One, Two and Three Sessions

	8-year-olds			Adults		
	2 sess.	3 sess.	p^a	1 sess.	2 sess.	p^a
LOW	71.75	75.20	N.S.	75.35	74.95	N.S.
HIGH	70.40	68.95	N.S.	70.50	62.90	N.S.
PAIR	86.45	85.90	N.S.	85.85	88.15	N.S.

[a]Probabilities reported are for t tests between number of sessions; $p > .05$.

Table 10

Comparisons Between Age Groups of the Mean Number of "Same" Responses in the Different Information Conditions

	MEANS			PROBABILITIES[a]		
	5-yr-olds	8-yr-olds	Adults	5-yr-olds vs. 8-yr-olds	8-yr-olds vs. Adults	5-yr-olds vs. Adults
PAIR	21.75	23.60	23.05	.255	.590	.433
LOW	21.42	21.20	19.92	.920	.451	.456
HIGH	19.62	25.90	23.00	.007	.062	.133

Note. Scores were converted to make "same" and "different" scores comparable. The maximum number correct is 24.

[a]Probabilities for t tests between age groups.

Table 11

Mean Number of "Same" Responses for 5-year-olds, 8-year-olds and Adults in the LOW and HIGH Conditions

	LOW	HIGH	*p*[a]
Whole sample	20.85	22.84	.02
5-year-olds	21.42	19.62	.309
Simple	20.35	19.25	.647
Medium	22.50	20.00	.352
8-year-olds	21.20	25.90	.001
Simple	21.80	26.40	.02
Medium	20.60	25.40	.025
Adults	19.92	23.00	.007
Medium	18.80	20.20	.346
Complex	21.05	25.80	.006

Note. Scores were converted to make "same" and "different" scores comparable. The maximum number correct is 24.

[a]Probabilities for t tests between LOW and HIGH scores.

Table 12

Mean Number of "Same" Responses for 5-year-olds at the Different ISIs

	5-year-old SIMPLE	5-year-old MEDIUM
50 msec.	4.95	5.1167
250 msec.	4.9667	5.9333
500 msec.	4.500	5.7667
1000 msec.	4.8167	5.5500

Note. Scores were converted to make possible a comparison of "same" and "different" responses. The maximum number correct at each ISI is 6.

None of the differences between means are significant at the .05 level (1-tail test).

Table 13

Mean Number of Correct "Same," "Different" and Total Responses for 5-year-olds, 8-year-olds and Adults in the LOW and HIGH Conditions

	Total Correct			Correct Same			Correct Different			LOW: Correct Same vs. Correct Different	HIGH: Correct Same vs. Correct Different
	LOW	HIGH	p^a	LOW	HIGH	p^a	LOW	HIGH	p^a	p^a	p^a
Whole Sample	31.73	29.16	.00	14.30	14.18	.82	17.43	14.98	.00	.00	.342
5-year-olds	27.92	25.38*	.078	12.68*	11.02*	.14	15.25	14.35	.45	.15	.099
Simple	29.15	26.75	.18	12.75*	11.55*	.345	16.40	15.20	.534	.137	.224
Medium	26.70	24.00*	.248	12.60*	10.50†	.27	14.10	13.50	.688	.578	.285
8-year-olds	33.10	31.40	.154	15.15	16.65	.079	17.95	14.75	.001	.05	.101
Simple	32.80	31.80	.57	15.30	17.10	.110	17.50	14.70	.06	.110	.06
Medium	33.40	31.00	.149	15.0	16.2	.366	18.4	14.8	.009	.186	.479
Adults	34.18	30.70	.002	15.08	14.85	.82	19.10	15.85	.000	.000	.338
Medium	35.7	31.4	.003	15.3	13.8	.227	20.4	17.6	.000	.001	.026
Complex	32.65	30.00	.117	14.85	15.90	.439	17.8	14.1	.000	.033	.094

Note. Scores were converted to make "same" and "different" scores comparable. The maximum number correct is 24 for "same" and "different" separately, 48 for Total correct.

[a]Probabilities for t tests between LOW and HIGH scores and for same vs. different comparisons within conditions.

*Not significantly above chance at the .05 level of significance. †Significantly below chance.

Table 14

Percentage of "Same" Responses Which Are Correct

	LOW	HIGH	PAIR	Probabilities[a] LOW vs. HIGH	LOW vs. PAIR	HIGH vs. PAIR
Whole sample	71.55	63.22	78.46	.00	.00	.00
5-year-olds	62.78	57.95	71.10	.31	.01	.001
Simple	66.64	61.78	75.93	.44	.086	.004
Medium	58.92	54.13	66.28	.518	.078	.07
8-year-olds	75.00	65.33	81.30	.002	.02	.000
Simple	72.72	66.14	83.62	.154	.002	.000
Medium	77.27	64.51	78.98	.003	.664	.000
Adults	76.87	66.39	82.97	.000	.002	.000
Medium	82.93	70.66	87.05	.000	.116	.000
Complex	70.82	62.12	78.89	.023	.006	.000

[a]Probabilities for t tests between LOW, HIGH and PAIR conditions.

Table 15

Percentage of Blocks of Trials Where Only "Same" or Only "Different" Responses Were Given

	LOW	HIGH	PAIRS
5-year-olds	27%	29%	11%
8-year-olds	15%	6%	2%
Adults	7%	6%	1%

Table 16

Effect of Order on Response Bias

Comparison of Percentage of "Same" Responses in First and Second Sets of 4-Item Arrays (LOW and HIGH Conditions Combined)

	Set 1	Set 2	*p*
5-year-olds	47.97	37.55	< .010
8-year-olds	50.78	47.34	> .05
Adults	44.79	44.64	> .05

Comparison of Percentage of "Same" Responses in LOW to HIGH vs. HIGH to LOW condition in 5-year-olds

LOW to HIGH			HIGH to LOW		
LOW	HIGH	*p*	LOW	HIGH	*p*
49.38	35.21	.010	39.9	46.56	> .05 < .10

Table 17

Order Effects for 5-year-olds in Third Session:
Mean A' Scores for the 4 Blocks of Trials
in Order of Presentation

	1	2	3	4
LOW and HIGH Combined	.615	.507*	.553	.548
LOW	.649	.542*	.590	.573
HIGH	.582	.472*	.516*	.523*

*Not significantly above chance at the .05 level of significance.

Table 18

Percentage Correct on Redundant Stimuli and Comparisons Between Age Groups

Age Groups	Percentage Correct
5-year-olds	
LOW to HIGH	77.5
HIGH to LOW	73.8
8-year-olds	
LOW to HIGH	96.25
HIGH to LOW	91.25
Adults	
LOW to HIGH	92.5
HIGH to LOW	93.8

Comparisons on LOW and HIGH Combined

5-year-olds	8-year-olds	*p*	5-year-olds	Adults	*p*
75.625	93.75	$< .005$	75.625	93.125	$< .005$

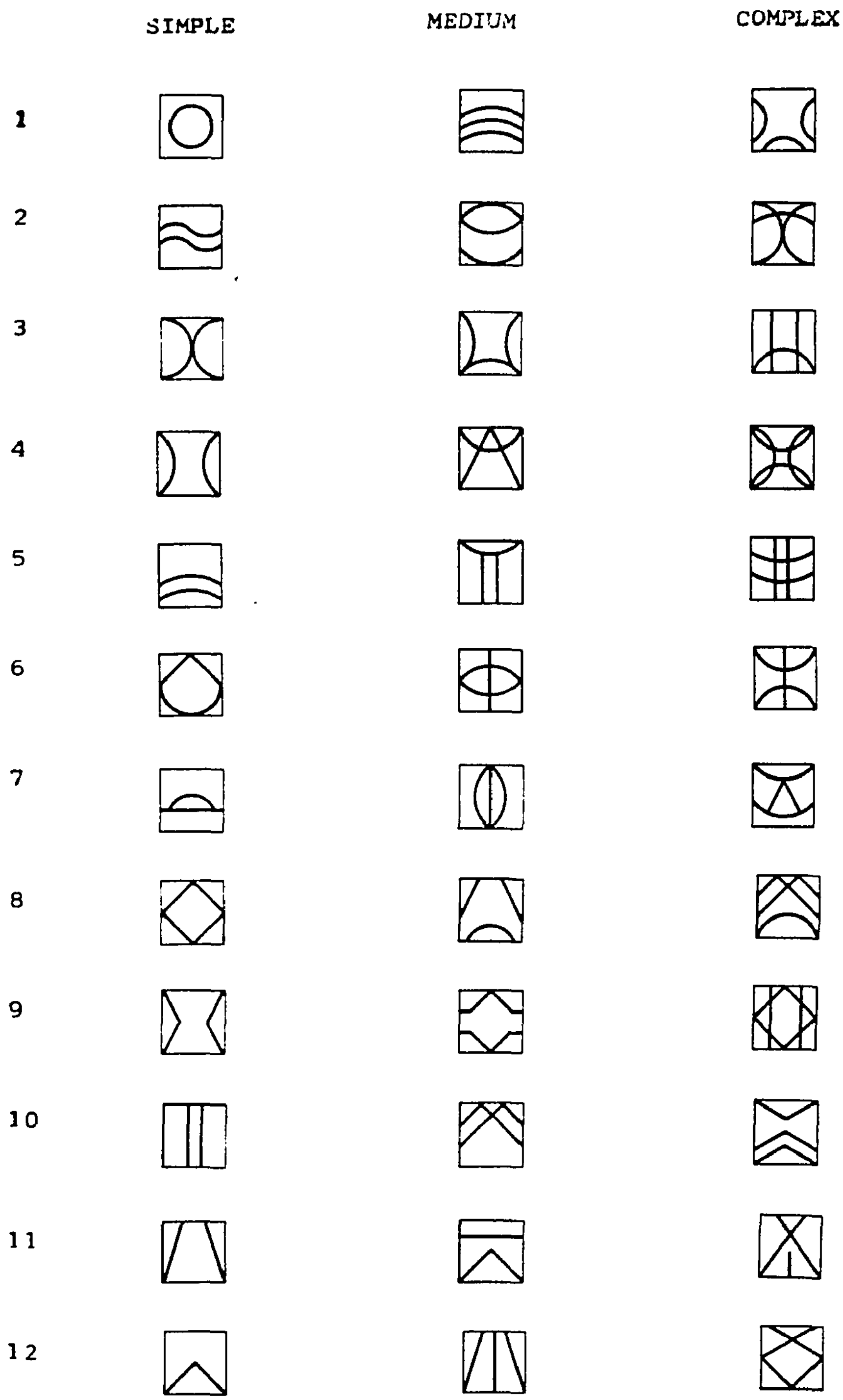

Fig. 1. Stimuli.

Appendix

CALCULATION OF A'

A' is calculated from the hit rate (H) and the false alarm rate (F) as follows:

For $H \geq F$, $A' = 1/2 + [(H - F)(1 + H - F)]/[4H(1 - F)]$;

For $H < F$, $A' = 1/2 - [(F - H)(1 + F - H)]/[4F(1 - H)]$.

Note. The limitations of A' may have "contaminated" the findings, that is, with d' greater significance may have been obtained in some of the comparisons. However, of the possible measures available for use, A' was felt to be most appropriate for the data in this study where the number of observations per subject is small.

SOURCE: J. G. Snodgrass, P. H. Burns, and G. V. Pirone, Pictures and words and space and time: In search of the elusive interaction, *Journal of Experimental Psychology: General*, 1978, *107*(2), 206-230.

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