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ABSTRACT

This study presents an account of position saliency in terms of children's ability to utilize graphic information, and in particular the serial encoding of information from letters in a graphic pattern. By varying the number and position of the letters distinguishing graphic patterns (positive condition) in a short-term recognition memory (STRM) task, the relative use of information from different parts of the graphic pattern can be determined. Under STRM, the subject must analyze, remember, and utilize the graphic information from the Target (T) stimulus, in judging whether or not the Comparison (C) stimulus is the same as the T stimulus. In Experiment one, Exposure Time (ET) of the T stimulus, Retention Interval (RI) between T and C stimuli, and the Positive condition were varied. The results indicated that both second semester prereading kindergarten children and first graders are more likely to detect a difference between the T and C stimuli in the initial letter position than at the middle or final position. Experiment two used a similar paradigm with a fixed ET and RI. The results revealed neither a position effect nor any indication that entering kindergarten children's performance changed during the study. (Author/TS)

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POSITION SALIENCY IN CHILDREN'S SHORT
TERM RECOGNITION MEMORY FOR GRAPHIC PATTERNS

by

Ronald Carl Leslie

Report from the Project on
Conditions of School Learning and Instructional Strategies

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ABSTRACT

Part of the conventional wisdom concerning children's learning to read is that word identification is often based upon only part of the graphic pattern. For over half a century descriptions of oral reading errors of beginning readers have noted (a) the use of limited graphic information in word identification, and (b) the saliency of the initial letter as such a cue. However, such conclusions are not justified solely on the basis of oral reading errors. Graphic, syntactic and semantic constraints as well as response availability and retrievability affect the choice of response. Furthermore, the relative importance of these constraints in reading may change with the child's reading proficiency.

This study presents an account of position saliency in terms of the child's ability to utilize graphic information, and in particular the serial encoding of information from letters in a graphic pattern. By varying

the number and position of the letters distinguishing graphic patterns (Pos condition) in a short-term recognition memory (STRM) task, the relative use of information from different parts of the graphic pattern can be determined. Under STRM, the subject must analyze, remember and utilize the graphic information from the Target (T) stimulus, in judging whether or not the Comparison (C) stimulus is the same as the T stimulus.

In Experiment 1 Exposure Time (ET) of the T stimulus, Retention Interval (RI) between T and C stimuli and the Pos condition were varied.

If the initial letter is salient, because it is usually the first of the letters encoded there should be an interaction of ETxPos condition. Detection of a difference between T and C stimuli should increase primarily in the middle and final letter position with an increase in ET. If position saliency is due to a differential forgetting rate as a function of letter position, an RIxPos condition interaction would be predicted with greater forgetting in the middle and final letter positions. The hypothesis that the saliency of the initial letter position is due to a phonic decoding strategy used by young readers may be examined by evaluating the performances of both readers and non-readers.

The results of Experiment 1 indicated that both second semester prereading kindergarten children and first graders

are more likely to detect a difference between the T and C stimuli in the initial letter position than at the middle or final letter position. Furthermore, the predicted ETxPos condition interaction was significant with increased ET primarily affecting detection of a difference at the middle and final letter positions. The RIxPos condition interaction was in the direction predicted to explain position saliency. The initial letter was more likely to be forgotten with increased RI than letters in other positions.

Experiment 2 used a similar paradigm with a fixed ET and RI to investigate the saliency of position for entering kindergarten children. The results indicated neither a position effect nor any indication that children's performance changed during the study.

The results of Experiment 1 are further described using a finite state model incorporating four psychological processes: encoding, forgetting, comparison of encoded T information with presented C stimulus, and a decision process. The model emphasizes the importance of evaluation of children's responses in terms of different decisional strategies which may be adopted.

These studies support the notion that the initial letter position becomes a salient cue in word identification. Furthermore, this position saliency can occur prior to reading instruction per se. Children

develop a left-to-right processing strategy which is revealed by varying the processing time. From the finite state model we can conclude that children's decisional processes vary with their information about the stimuli.

I

INTRODUCTION

Part of the conventional wisdom concerning children's learning to read is that the identification of words is often cued by only part of the word. Evidence for such cuing is found in a number of studies of children's oral reading errors (Bennett, 1942; Biemiller, 1970; Davidson, 1934; Weber, 1970). For over half a century, descriptions of the oral reading errors of beginning readers have noted (a) the use of only limited graphic information as cues to word identification, and (b) the saliency of the initial letter as a cue to word identification. These characteristics of word identification performance may be used to indicate the developmental progression of learning to encode information from a graphic pattern (i.e., to form an internal representation from the graphic pattern) and to utilize the encoded information in word recognition. A major change in the performance of the child as he learns to read is the increase in the graphic approximation of his oral reading to the printed word. As the child becomes a skilled reader, a word misread is increasingly likely to resemble the printed word in specifiable ways: the printed word and the word substituted for it have more letters in common, and they continue to be more likely to begin with the same letter. This developmental progression indicates

the increasing importance of graphic information in the identification process. However, it does not indicate why the child does not use more graphic information in the identification process initially, or why the initial letter is so often used as a major cue in word identification. These issues are examined in the present study by investigating the development of the ability of kindergarten and first grade students to utilize graphic information. Specifically, the role of letter position in that development will be examined.

One explanation of the use of limited graphic information and the growing saliency of the initial letter position argues that they are not due to the visual characteristics of the graphic pattern (Kolers, 1970). Kolers and Perkins (1969) reported adults' oral errors on pseudo-words presented in various visual transformations of normal print, e.g., mirror image. No relationship was found between the letter position and the probability of an error for pseudo-words of equal length. Kolers (1970) argues that this indicates that position saliency cannot be due to visual processing capabilities, but is due to cognitive or linguistic factors. One linguistic factor which has been proposed to account for position saliency is segmentation ability, that is, the child's ability to break

a word into its constituent phonemes (Shankweiler and Liberman, 1972). According to this hypothesis, the child must be able to segment the spoken representation of a word before he can use the individual sounds for the letters as a means of identifying the word in memory. It is argued that the ability to segment the initial sound occurs prior to the ability to segment succeeding sounds in a complete word. Thus, the child is able to decode the initial letter into its sound, then use this sound and whatever contextual information is available to identify the word. The information from the middle or final letters is allegedly not used because the child cannot segment those parts of the word. This lack of segmentation ability is said to prevent the child from using letter-sound information to generate a representation of spoken words in memory. While no data is given on the relationship of the segmentation abilities of readers and non-readers to word identification ability, the formulation does have certain clear implications. The saliency of the initial letter position and the use of limited graphic information are both due to the reader's word identification strategy, a strategy based upon using the letters as cues to sounds. If this is a tenable explanation of the phenomena, the phenomena should be restricted to the child who is unable to segment, but

who knows some letter-sound correspondences, *i.e.*, beginning readers. However, prereading five year olds have been shown to prefer the use of initial letter position in matching tasks involving both strings of letter-like forms (unpublished data from the Prereading Skills Program) and pseudo-words (Calfee, *et al.*, 1971). Thus this explanation as presently formulated does not appear tenable.

A more widely held explanation for the use of limited graphic information has been stated by Samuels (1970). According to him, "children select the easiest cue for recognition," and that cue is often a single letter of the word. While the term "easiest" is not further defined or operationalized in terms of a measurement procedure, it is clear that it is meant to convey that limited graphic information is utilized. Biemiller (1970) presents a similar view by suggesting that the child "avoids" using graphic information as much as possible, choosing instead to rely on other sources of identification information whenever possible, *e.g.*, semantic or syntactic contextual information. According to Samuels, the use of limited graphic information is due solely to the child's strategy of encoding only enough graphic information to distinguish the word from other words being learned. Samuels argues that the child will modify the strategy under conditions

which require the use of more graphic information (Samuels and Jeffrey, 1966). That is, the child has the ability to encode more than a very limited amount of graphic information but does not use it.

Using a learning paradigm with sets of four two-letter pseudo-words (e.g., DA, BE, MI, SO and SE, SA, ME, MA), Samuels and Jeffrey (1966) found that the group learning the list of words having no common letters (the graphically dissimilar list) used graphic information from a single letter as the cue for identification. The group learning the list of words which were graphically more similar used both letter positions as a source of identification. This data has been interpreted by Samuels as evidence for a difference in strategy of word identification. However, although both groups were tested after the same learning criterion was met, the group learning the list of graphically dissimilar words had reached the criterion after fewer trials than the group learning the graphically similar list. If the term strategy is to refer to differences in the encoded information resulting from the analysis and subsequent storage of graphic information, it is not clear that the two groups differed in word recognition strategies. Suppose both groups began by encoding a single letter to

identify the words: as soon as both groups reached this criterion, one group would be able to perform the identification task, and the other would not. Continued learning would be needed before the group learning graphically similar words could perform the task, because they would need graphic information from both letters. If the group learning graphically dissimilar words had continued to work on the task as much as the one learning graphically similar words, its members also might have had both letters encoded. Berry, et al. (1971) in fact reported that the amount of graphic information utilized may continue to increase after perfect performance has been reached. If Samuels and Jeffrey had tested a third group which had as much experience with the graphic patterns as the high similarity groups, there may have been no difference in the graphic information used in their identification performance. Such performance would not indicate changes in the initial encoding of graphic information as a function of the task. Rather, the term strategy would refer only to the fact that performance on an easier task might be accomplished with less information than that needed for a harder task and would not reflect any change in the child's processing of graphic patterns. Lacking such evidence, the issue of whether or not the

child modified the encoding of a graphic pattern as a function of the task remains unresolved.

I have examined two explanations of the use of limited graphic information and saliency of initial letter position. The first hypothesis, that the phenomena are not related to visual capabilities of the child, but are due instead to the way the beginning reader uses word-segmentation ability and letter-sound knowledge to identify a word is weak. It has neither the empirical data to justify the alleged connection between word-segmentation abilities and reading skill, nor the generality to explain why prereaders also use limited graphic information in visual tasks. The second hypothesis, that the child fails to use more graphic information because he encodes only enough graphic information to distinguish among the printed vocabulary, is not contradicted by available evidence. It was emphasized, however, that there is no data to justify the assertion that the encoding process changed as a function of the graphic requirements of the task. An equally plausible explanation is that the number of presentations necessary to encode sufficient information for identification varies directly as a function of the visual similarity of the set of graphic patterns to be identified. The encoding that occurs upon the initial

presentation of a graphic pattern might not vary when then the child knows that graphic information from each letter position will be necessary for identification.

The theoretical positions just cited on the use of limited graphic information and the saliency of the initial letter have not related the phenomena to visual processing capabilities. No attempt has been made to consider several relevant questions. First, can the limited use of graphic information be accounted for by the child's inability to process critical types of visual information, e.g., the sequence of the letters in a graphic pattern? Second, is the child limited in the amount of graphic information that he can store in a brief presentation of an unfamiliar graphic pattern? Finally, is there any evidence that would lead us to hypothesize that the child might have graphic information encoded which is not utilized in the decision process of selecting a response (cf. Gibson, 1969)? The first two of these questions concern graphic processing ability, while the third involves the decision process. All three questions will be addressed in the following sections.

GRAPHIC PROCESSING ABILITY

Two characteristics of the child's processing habits might change as he learns to read and might be related to his use of limited graphic information and position saliency: (1) critical types of visual information or the qualitatively different kinds of graphic information which the child can encode, e.g., sequence of letters (saw vs. was); and (2) limited capacity, or the quantitative capacity of the child to encode graphic information.

Critical types of information. A number of studies demonstrate that a child's ability to use critical types of graphic information increases dramatically during kindergarten and first grade (Calfee, et al., 1971; Chapman, 1971, a,b). Information is considered critical when its use is necessary for visual discrimination among individual graphemes or among words or letter-strings. To explain the early non-use of graphic information, Smith (1971, p. 224) has suggested that the child who is learning to read "does not know where to look for the distinctive features of letters; he knows how to look but not what to look for", and he must learn this. If this were the case, we might expect that oral reading errors were the result of a lack of ability to process letters visually. But there is evidence to the contrary. Not even

Prereading kindergarten children have trouble distinguishing among the letters of the alphabet, except those few that are distinguished by orientation (Gates et al., 1939). Therefore, it appears that the prereading child does know "what to look for" in order to distinguish individual letters; furthermore, he knows it prior to formal instruction.

On the other hand, the child's ability to discriminate among short letter-strings and the set of letters distinguished by orientation does change as he progresses through the first year of reading instruction. A kindergarten child often has trouble consistently discriminating between words like saw and was which differ only in the sequence of their letters and big and dig whose initial letters differ in their orientation. But this difficulty cannot account for the identification difficulties of the beginning reader. It is estimated that less than ten percent of oral reading errors are graphically distinguished from the printed word only by letter sequence or letter orientation (Bennett, 1942). In general, these two deficits in encoding and utilizing critical aspects of the graphic pattern are no longer evident by the end of the first grade. Therefore, it does not appear that the ability to encode the distinguishing

characteristics of a single letter or the sequence, information from letter-strings is a major problem in word identification.

There is, however, one type of graphic pattern whose processing is quite relevant to understanding substitution errors. Over eighty percent of oral reading errors begin or end with the same letters as that of the printed word. The precursor of those graphically similar errors is seen in the trouble kindergarten children have in discriminating words of three or more letters which differ by a single letter not in the initial letter position, e.g., cape and cape. While most kindergarten children can discriminate among such graphic patterns at better than chance performance, over half of the students are unable to perform the task consistently above eighty-five percent correct. (Chapman, 1971, a,b). When the number of different letters in the word is increased, discrimination performance rises. For example, Nodine and Hardt (1970) found that reversing the middle letters in a four-letter word was detectable in better than ninety percent of the cases by prereaders. Both the length of the graphic item and the position of the distinguishing letter affects performance (Chapman, 1971a).

That a child performs at better than chance accuracy on such tasks suggests that he is using some graphic information in making his responses, and that this information may be sufficient for making a correct response. However, discrimination ability in these particular studies was assessed with a matching to sample procedure which indicated the ability of the child to utilize graphic information. They do not indicate the amount of graphic information which the child had available for the following reasons: (1) The child might have used the position of the previous response as a factor in making a response. There was a tendency for the child to select the alternative next to the sample in a left to right progression (Chapman, 1971a). Since no child was told when he made an incorrect response, all responses might have been considered to be correct. In such a situation, a child might use either graphic information or position of the last "correct" response to decide on the next response. This would preclude our using the chosen alternative as an indicator of the graphic information utilized in the selection of the response. (2) Each trial consisted of several alternatives which the child might examine and choose. There is no means of determining which alternatives were actually examined. Therefore, we cannot

determine which of the alternatives are considered to be identical with the standard. Since all combinations of position differences between the standard and alternative did not occur in each alternative position, these studies do not provide sufficient data for drawing a conclusion as to the amount of graphic information utilized. Thus, we can conclude only that there are visual tasks for which only limited visual information is used, and for which letter position relates to or predicts the likelihood that graphic information from that letter will be utilized.

The graphic information from the letters in the middle or the end of a letter string does not appear as likely to be used in discrimination or identification tasks as graphic information from the initial letter position. One visual processing mechanism which might be postulated to help explain this unique problem of dealing with letter strings is an internal scanning mechanism. Ghent-Braine (1968) has used the concept of visual scanning to account for differential visual information following presentation of a visual form. She notes that both the starting point for the scan and the scanning direction are important in understanding pattern perception. Ghent-Braine (1968) states "Enhanced perception of a particular side of a pattern could occur as a result of scanning the pattern in

a particular direction." Selection of the point at which to begin the scan may change as a function of the experience with alphabetic materials which are ordered left-to-right. Either a left-most starting position or a left-to-right visual scan of a graphic pattern could account for the salience of the initial letter, especially if the scan is either incomplete or limited by the ability to "store encoded information. Such a scanning mechanism will be considered later as a possible explanation of initial letter saliency.

Limited capacity. Studies of short-term recognition memory for visual forms have suggested the possibility of a limited capacity to encode visual information. This limitation does not apply to the ability of the child to register visual information in a sensory storage system, but to the ability to encode and utilize more than one or two visual patterns. In studies concerned with the utilization of information from brief tachistoscopic exposure, prereading five-year olds have demonstrated a short-term visual storage system which is superior to that of adults. Using a partial report technique (Sperling, 1960; Averbach and Coriell, 1961), Sheingold (1971) found that prereaders' performance was superior to that of adults when the form to be reported was cued within 50 msec. of

the stimulus offset. Thus, there is no evidence of a limited ability to register graphic information.

Other studies indicate that the prereaders cannot utilize enough graphic information to report more than 1.6 individual patterns from an array of two, three, or four forms presented tachistoscopically (Haith, Morrison, Sheingold, and Mindes, 1969). This estimate is consistent with studies dealing with memory for individual letters (Hoffman, 1927 in Woodworth and Schlosberg, 1954). If the child treats each letter as a separate pattern to be analyzed and remembered, this memory limitation could explain the use of limited graphic information. On the other hand, if the graphic pattern as a whole has a unique character which can be the source of graphic information, such a memory limitation may not affect processing. Neisser (1967) notes that the child and the illiterate are reportedly more likely not to separate the individual graphic elements for encoding, and are more likely to deal with a larger unit. If this is true, the child may be able to encode a great deal of graphic information from the graphic pattern, and to demonstrate such encoding ability under some task conditions.

L
DECISION PROCESS VARIABILITY

Graphic information encoded from a visually presented pattern is not the sole determiner of a response in a visual task. The way the child utilizes the information in deciding upon the selection of a response may be equally important. While we should "never assume that any response implies more than the minimum of knowledge required to produce it" (Diack, 1961), it should be noted that responses may not reflect the available information. For example, Pillsbury (1897) investigated adults' encoding habits by presenting words with blurred letters, misspellings, or omitted letters for identification. Pillsbury recorded not only the word identifications but the reports of the character of the stimuli. He reported that under identical presentation conditions, subjects who knew the purpose of the experiment were more likely to report the blurred or incorrect letters. It seems likely that these subjects were willing to make such a report on the basis of their graphic information because they knew such stimuli were to be used. This information biased the report the "knowledgeable" subjects were willing to make on the basis of the graphic information.

Smith (1967) reports another example of response characteristics affecting a visual task. His data suggest

that subjects may effectively have a trade-off involving the need for graphic information and accuracy. The more accurate subject overall had more graphically constrained errors than the subject who was less accurate overall, but more willing to make a response with less information. If one assumes that the availability of graphic information varies as a function of the contrast levels (as determined by the intensity of the light source), then one can determine at what contrast levels subjects are willing to make a response. Smith (1967) reported that the subject who required a high level of illumination before making a response was not only more accurate, but had more graphically constrained error responses than a subject who made responses at a lower level of illumination. Since we must assume in this argument that the illumination level actually resulted in different levels of graphic information being available, the interpretation must be considered as tentative. In any case, for performance levels much less than perfect, we must consider the possibility of decision strategies influencing performance.

While the possibility of the child having strong response biases in identification or discrimination tasks has not been investigated, the possibility cannot be neglected. In any task in which the child's performance is

not consistently correct, the possibility of deciding upon the response on the basis of incomplete information or outright guessing must be assumed. Evaluation of the information available in such situations should take into account the possibility of biases operating in response selection.

CONSIDERATIONS IN INTERPRETING VISUAL TASKS

It has been pointed out that oral reading errors of beginning readers have been construed as an indication of the use of limited graphic information and a reliance on the initial letter as the primary source of this information. Both encoding/storage ability and decision processes could affect the utilization of graphic information: the first by limiting the nature or extent of the graphic pattern encoded and the latter by affecting the particular sources of information used to make the identification. Identification errors in oral reading cannot provide estimates of the amount of graphic information the child is able to encode for the following reasons: (1) The extent of the graphic information encoded and utilized in reading varies inversely with the amount of contextual information available in the identification task (Weber, 1970). When an oral reading error is consistent

with the syntactic and semantic constraints of prior context, the graphic approximation to the printed word is usually less than that found when the error is not so constrained. (2) The extent to which the availability of verbal labels, the strength of associative connections, and their retrievability affects the selection of responses is both unknown and uncontrolled. Therefore, other methods of assessing encoding must be found.

One method proposed for assessing the graphic information encoded relies on similarity judgments to provide an index of strength of graphic information. (Marchbanks and Levin, 1965; Williams, et al., 1970). In both studies, children were presented three or five-letter graphic patterns for a three-second examination period. Then they were asked to select from four graphic patterns the one which was most similar to the one they had just seen. None of the items for comparison was the same as the graphic pattern presented initially, but each was similar to the presented pattern in a specific way: the overall shape was the same without having any common letters, or the comparison items had one letter in common in any one of the letter positions. The percentage of times that one type of comparison item was chosen over the others was a measure of the relative strength of that type

of similarity as a visual cue. The results indicated that all subjects in the first grade preferred the comparison items with the same initial letter as the presented pattern. While Marchbanks and Levin (1965) also found similar results for kindergarten children, Williams, et al., (1970) failed to replicate these results with children of the same grade from a lower socio-economic community.

This experimental paradigm offers some advantages over other ways of measuring the utilization of graphic information. Primarily, it does not require association or response learning as a prerequisite. However, at best provides an indication of relative strength of the graphic information. If information from several letters is encoded, the child must choose which letter is to be used as the basis for determining similarity. But the experimental paradigm does not provide any estimate of the available graphic information. Furthermore, it is difficult to assess whether or not the children understood the directions for the task. Williams, et al., (1970) reported that all the comparison items were equally likely to be chosen by the kindergarten children. Does this indicate that all the sources of information were equally encoded or that the children had no idea what to do and

therefore chose randomly? Such information cannot be determined from the data. On the basis of the criticisms of previous studies, a methodology for studying the encoding and utilization of graphic information will be proposed below.

A MORE EFFECTIVE PARADIGM: SHORT-TERM RECOGNITION MEMORY

One of the major limitations noted with previous studies concerned with the processing of graphic information was that the information the subject had available might not be reflected in the response selection. Correct responses, especially to unique or unusual graphic patterns; may have been cued by only a small part of the graphic pattern. In studies involving similarity or discrimination judgments, incorrect responses were not used to estimate how much graphic information was utilized. Both correct and incorrect responses may have been based on a wide range of graphic information.

A methodological procedure which does not have the inherent limitations of previous studies is the short-term recognition memory paradigm. Successive presentation of target (T) and comparison (C) stimuli which must be judged as same or different provides a test for discrimination (Sorkin, 1962). Under successive presentation conditions,

the subject must analyze the graphic information of the T stimulus, remember the information resulting from the analysis for a short period of time, and use this information in judging whether or not the C stimulus is the same as the T stimulus. Unlike the simultaneous presentation of both T and C stimuli which permits the subject to check and re-check for specific differences between the stimuli, the analysis of the T stimulus must be completed before the presentation of the C stimulus. Furthermore, the decision may be based on the graphic characteristics of the pattern as a whole. The child does not need to identify isolated letters as part of the task requirement.

There are three other advantages of the successive presentation paradigm. First, manipulation of the number and position of the components of the graphic pattern which distinguish the T and C stimuli should result in stimuli pairs which vary in their discriminability. This permits us to examine performance over a wide range of discriminability.

Second, an analysis of subjects' incorrect responses serves as an index to the information which is being encoded and remembered. If a S's performance varies as a function of the letter position, some stimuli pairs should

be better discriminated than others. For example, if a consonant-vowel-consonant trigram (CVC) such as sec is presented as a T stimulus, possible comparison (C) stimuli which might be presented to a S would be sóc, ser, sor, med, moc, mer, and mor. These C stimuli are different from the T stimulus in the number and position of letters which distinguish the patterns. If S consistently encodes information from the initial (I) letter position, he will have to base subsequent judgments about the nature of the T stimulus on the information he has encoded about the characteristics of the initial letter. Comparison stimuli such as soc, ser, and sor should be judged by S as identical to the T stimulus sec, and mec, moc, mer, and mor judged as different.

Third and finally, the use of a forced-choice task provides us a better measure of the discriminability of graphic patterns. A child's likelihood of saying that two identical stimuli are different can be used to evaluate the information which is contained in the response "different" when the stimuli are, in fact, different.

Experimental rationale. Two experiments will be reported in this paper. Both employ a short-term recognition memory paradigm in which the number and

position of letters distinguishing the T and C stimuli are varied.

In Experiment 1 there are two Exposure Time (ET) conditions for the presentation of the T stimuli (.5 and 3 sec.). Three Retention Interval (RI) conditions are employed between the offset of the T stimuli and the onset of the C stimuli (0, 1 and 3 sec.). The propositions tested in Experiment 1 were:

(1) A limited utilization of graphic information implies that only part of the graphic pattern will be used in the recognition process. If true, the recognition of differences between T and C stimuli should vary as the number of possible differences which might be utilized to distinguish them varies. Therefore, recognition performance should vary as a function of the number and position of the distinguishing letters. Further, since, under this hypothesis incomplete information is used for judging two stimuli as the same, it would be reasonable to expect that responding to identical graphic stimuli would result in a number of errors even though there are no distinguishing letters.

(2) The saliency of the initial letter position should result in C stimuli being judged as different more often

when the initial letter is different than when any other letter distinguishes the T and C stimuli.

(3) The hypothesis that the initial letter position is salient because the child serially encodes the graphic information should result in an interaction of exposure time and letter position. Recognition of initial letter differences should not be greatly affected by the longer ET conditions if, in fact, the initial letter is the first one encoded. The increased ET should result in an increased probability of recognizing the middle and final letters.

(4) If the saliency of the initial position is due to a child's word identification strategy developed in learning to read, there should be no position saliency effect in the kindergarten group since they are not being taught to read.

(5) The saliency of the initial letter position might be due to a low likelihood of being forgotten. If this were the case, there should be an interaction of letter position and retention interval in which the probability of recognizing the middle or final letters decreases more with a longer RI than that associated with the initial letter.

In Experiment 2, beginning kindergarten children were tested at the short ET and medium RI of Experiment 1. The data were analyzed to decide two questions:

(1) Is the initial position salient before reading related instruction begins?

(2) Is there evidence that the child becomes better at using information from the whole word as he becomes familiar with the short-term recognition memory task?

II

EXPERIMENT 1

Method

Materials. There were two main concerns in selection of test materials: (1) the presence of a position effect should not be confounded by the specific letters used in those positions, and (2) first grade readers should be able to use any cognitive functions related to reading, such as pronunciation, to perform the task. It was decided to use pronounceable CVCs that are also pronounceable when the consonants are interchanged. This results in a confounding of specific letter positions with letter type, a consonant or a vowel, but permits the examination of an I or F letter position saliency.

Two hundred twenty-four CVCs from the 50-100 range of the Archer (1960) association list were chosen as stimuli. These were placed in 28 x 9 matrix which reflected the following restrictions (Table 1). The twenty-eight items in Column 1 were designated as T stimuli and were composed of fourteen anagram pairs (e.g., row 1 and 15). The seven C stimuli in columns 2-8 have the same general word shape as the T stimulus (where general word shape is defined as having ascending or descending letters in the same letter position of both stimuli) and do not contain orientation

reversals of letters (e.g., bas; das) or order reversals of the consonants (e.g., sec, ces). The set of seven C stimuli paired with a specific T stimulus was chosen to provide specific relationships between the T and C as to the number and position of the distinguishing letters. The T stimulus was also used as a C stimulus on trials in which the stimuli were to be judged to be the same. The eight ways in which the T stimulus may be related to the C stimulus constitute the Position-condition (Pos). The stimuli in columns 2-4 had different initial letter, middle letter and final letter from the T stimulus respectively. The stimuli in columns 5-7 had different letters in two positions and the stimuli in column 8 were completely different from the T stimuli. For any T stimulus, the set of C stimuli which had a letter different from it at a specific position were identical at that position. For example, for T stimulus sec, the C stimuli which differed from it in the initial letter (I, IM, IF, and IMF) had the identical initial letter, e.g., mec, moc, mer, and mor. Furthermore, the same letters were used to make the C stimuli for the T anagram.

This 28 x 9 matrix of stimuli was used to construct seven lists of Target-Comparison (TC) pairs. Each list consisted of 56 TC pairs. Each T stimulus was paired as a

C stimulus with itself and is here labeled a Same condition item (S-condition). All of the lists contained identical T stimuli and differed only in the particular C stimuli used to generate the various Pos conditions. One C stimulus from column 2-8 was chosen without replacement for each of the 28 T stimuli to form Different condition items (D-condition) with the following restrictions: (1) each of the seven D-condition occurred four times in the list; (2) for each D-condition item randomly chosen for a T stimulus, the D-condition item made by reversing the I and F letters and its T stimulus was included. Thus, if sec-ser formed a pair in the list, ces-res also was included in the list. This insures that the position changed is not confounded with the specific letter which is different in a list.

The items from each list were used for the six ET(2) x RI(3) conditions of the experiment for a set of 4 Ss. Since the experiment consisted of four sessions, the items in a list were randomized into four blocks of 14 trials each, with one of each D-condition and seven S-condition items in each block. Each block was then randomly assigned for presentation in one of the four sessions. This was repeated for each of the six ET x RI conditions resulting in six blocks of material assigned for each session. These

blocks were then randomly assigned a presentation order within each session.

Each CVC was initially strip printed in lower case letters from a film on strips of white paper. Each of the 28 T stimuli were then photographed with a 35 mm camera. The negatives were mounted for a 35 mm slide projector. The C stimuli differed from the T stimuli by having a vertical line approximately three letter spaces from each end of the CVC.

Apparatus. Two Kodak Carosel projectors equipped with Gerbrands tachistoscopic shutters controlled by a Psionix 1248A Timer projected the stimuli on a gray square rear projection screen from a Sawyer's Mirascreen. Two horizontal lines on the screen above and below the projection field served as a focusing guide. The projectors were focused to project a CVC with a visual angle of 2 degrees width when viewed from the subject's chair. Aperture mechanisms (set at 1 mm) were attached to the projectors to reduce the light intensity. A hand-held switch controlled by the S was used to initiate each trial. A reset button was controlled by E to prevent the inadvertent initiation of a trial before the time parameters for ET and RI were set, and to insure that the S responded before he started the next trial.

Subjects. Fifty-six children from two kindergarten (K) and three first grade (F) classes of a rural elementary school in Marshall, Wisconsin, were randomly selected to participate in the study. The kindergarten group had a mean chronological age of 72.5 months and the first grade groups mean age was almost exactly one year older, 84.3 months. Because the study was conducted during March and April, the kindergarten classes had received reading readiness instruction. None of the K children in the study were identified as already reading by their teacher.

Procedure. A T stimulus presented for a variable ET (0.5 sec. or 3.0 secs.) was followed after a variable RI (0, 1 or 3 secs.) by a C stimulus which remained visible for 3 secs. The S's task was to judge whether or not the T and C stimuli were the same or different and to indicate the judgment orally.

Twenty-eight Ss from each grade (kindergarten and first) were randomly assigned to seven groups, each containing four Ss. Each group received the same experimental conditions with different lists of stimulus material.

Each S was tested for four experimental sessions. Each session consisted of a warm-up or practice period followed by six ET x RI conditions whose presentation order

was randomized for each group and session. For each ET x RI condition in a session, E randomly presented seven trials with Same condition stimuli (S-condition) and one instance of each of the seven D-conditions.

The following is a synopsis of the E's introduction of the child to the task. E had familiarized himself with the children who were to participate in the experiment by attending their class for several days prior to the beginning of the experiment. The children had been told that E would ask them to help him study what they could see and remember. When a child was selected to begin the sequence of sessions, E explained that S was going to be shown some letters to see how well he could remember them. Then E took S to the experimental room and demonstrated the projection and response apparatus. S was shown how to initiate a trial by pressing a hand held switch. Next, he was given 10 practice trials at 3 sec. ET and 0 sec. RI. He was then given 4 practice trials at the ET x RI condition assigned to begin session 1. In each subsequent session there were 10 practice trials, at the first ET x RI condition for that session. Before each block of trials, E informed S whether the T stimuli then would be presented for a short or long duration, and how long they would have to remember it. Each S was told after each response whether or not he was correct.

Results and Discussion

Each S's probability of a correct response on S-condition trials and D-condition IMF trials collapsed over ET x RI conditions was evaluated using the cumulative probabilities of a binomial distribution. There was no evidence to suggest that any child was unable to respond correctly at better than chance ($p < .01$), therefore we may assume that Ss understood the task.

The analysis of the effects of ET, RI and Pos conditions was performed on each subject's probability of a correct response collapsed over judgment type. Each subject judged four D-condition and four S-condition stimulus pairs for each ET x RI x Pos condition. The four T stimuli in the S-condition and in the D-condition were identical. S's probability of a correct response on these eight trials was used as a measure of overall performance for the ET x RI x Pos condition (cf. Tables 2 and 3).

As expected, the first grade group's performance (89%) was higher (11%) than that of the kindergarten group ($F(1,54) = 20.5, p < .01$). The probability of a correct response shows a small (3%) but significant increase directly related to ET ($F(1,54) = 33.9, p < .001$) and a

correspondingly small (4%) but significant decrease inversely related to increasing RI ($F(2,108) = 23.2, p < .001$). There was no indication of an ET x RI interaction ($F(2,100) = 1.86$).

Limited utilization of graphic information. The effect of manipulating the number and position of the different letters in the stimuli pair is clear ($F(6,324) = 41.5, p < .01$). Recognition performance is affected by manipulating the number and position of the distinguishing letters. Examination of the probability that a child would respond correctly to S-condition pairs indicated that the kindergarten group judged them to be different 21% of the time and the first grade group 10% of the time. If we assume that a child does not respond "different" unless there is some graphic information from the C stimulus which he does not remember from the T stimulus, then we must accept the limited utilization of graphic information in order to be consistent with the data.

Saliency of initial letter position. It is clear from the data that the initial letter is more likely to be utilized in the recognition judgment than either the M or F letter. Post hoc Scheffe tests reveal that all pairwise comparisons among Pos-conditions are significant ($p < .05$). The ordering of the Pos-conditions from easiest to

hardest reveals a clear position saliency effect:

IMF-condition (90%); IF-condition (88%); IM-condition (87%); I-condition (86%); MF-condition (83%); F-condition (79%); and M-condition (73%). Furthermore, the single-letter I-condition produces better recognition of a difference than the two-letter MF-condition for both grade levels at each ET x RI condition. The saliency of the initial letter in the recognition task is clearly established by the data.

Serial encoding. The probability of recognition of differences varies as a function of the ET and Pos condition. As seen in Figure 1 the effect of increased ET is seen primarily in terms of the improvement of the Pos conditions involving the M and F letter positions with increased ET, and this ET x Pos condition interaction is significant ($F(6,324) = 4.53, p < .001$). This interaction is consistent with the serial encoding hypothesis. The performance under Pos conditions involving a difference in the I letter position is not affected by increasing ET while performance under Pos conditions involving M or F letter positions improves with an increase in ET.

Position saliency and encoding skills. There is no Grade x Position interaction. End of year kindergarten children behave much like first graders and have already

begun to selectively encode the graphic information from the initial position of the word.

Forgetting. There was no evidence that the initial letter position was salient due to its low likelihood of being forgotten. On the contrary, examination of the RI x Pos-condition interaction ($F(12,648) = 2.22, p < .01$) reveals that it is the information from the initial position which is most likely lost over the RI (Cf. Figure 2).

Major factors in encoding and utilizing graphic information. The results of examining the relative influence of the significant factors by a point estimation technique (Myers, 1966) are presented in Table 4. As can be clearly seen, the estimate of the Pos-condition effect $\hat{\theta}_p^2$, is four times as great as the next largest effect due to grade level, $\hat{\theta}_g^2$, and twelve times as great as the effects of the interactions of Pos-condition with either ET or RI. Retention interval and ET effect are only 1/23 and 1/44 the magnitude of $\hat{\theta}_p^2$. The number and position of the different letters in the C stimulus is by far the strongest variable manipulated. Not even reading experience produces as a great an effect on performance as the position of the letters in the graphic pattern.

EXPERIMENT 2

There were two questions left unanswered by Experiment 1 and the subsequent analysis: (1) Has the attention to the initial letter position developed prior to entry into school? and (2) Is there any evidence that the children begin to look at more global aspects of the graphic pattern during the course of the experiment as they learn that a single letter fails to distinguish many stimuli? To test these hypotheses, Experiment 2 was performed with kindergarten children soon after the start of school using the short-term recognition memory paradigm of Experiment 1 with a constant ET and RI.

Method

Subjects. Twenty-eight kindergarten children from two classes in a Madison, Wisconsin school participated in the study. Their mean chronological age was 68.2 months. The study was conducted approximately one month after the opening of school. Although the Ss had been introduced to the concepts of "same" and "different" in the context of visual shapes and single letters, they had not been asked to make judgments about letter strings of two or more.

letters. The names of the letters of the alphabet were not being taught at this time.

Materials. Fourteen of the eight-item sets were chosen from the materials in Experiment 1. These were sets numbered 1-7 and 15-21 (cf. Table 1). The T stimuli were chosen such that their order reversals would also be T stimuli. A list was composed of the 98 D-condition items (14 instances of each D-condition) and an equal number of S-condition items.

Two randomized lists were created from these items with three restrictions: (1) no more than four trials of the same judgment could occur in a row, (2) the same T stimulus could not occur more than two times in a row and (3) an equal number of S-condition and types of D-condition items occurred in each half of the list. The lists were then counter-balanced by halves to produce 4 orderings of the same material.

Apparatus. A Kodak carousel slide projector with a Gerbrands tachistoscopic shutter was controlled by a series of Hunter timers. The rear projection screen described in Experiment 1 was used. A subject-held switch initiated the beginning of each trial.

Procedure. The procedure was similar to Experiment 1 with the ET set at .5 sec and the RI at 1 sec. There were two sessions of 98 trials each.

Results and Discussion

Development of Position Saliency. An analysis of variance was performed on the probability of a correct response collapsed over judgment type. The Pos-condition was significant ($F(6,162) = 32.8, p < .001$). There was no significance difference between I condition (72%) and F condition (71%), nor between IM condition (75%) and MF condition (73%). Comparable conditions at the end of the kindergarten year produced significant differences between I condition (78%) and F condition (73%) as well as between IM condition (83%) and MF condition (77%). This indicates that there is no evidence for a position saliency effect in young children who have not been exposed to reading readiness activities.

Experimental learning effects. There was no significant difference between performance from Session 1 (72%) to Session 2 (74%), ($F(1,27) = 3.4, p > .05$). There was, therefore, no indication that children began to process more graphic information as they learned it was necessary for accurate performance. Thus, we see that within the exposure time constraints of these experiments, neither the kindergarten nor the first grade child is

likely to encode and utilize graphic information from as many as three letter positions. There is, however, a major change in the saliency of the initial letter which occurs before the end of the kindergarten year. The hypothesis that the child learns to focus on the initial letter position appears the most consistent explanation for these results.

IV

A THEORETICAL ANALYSIS OF THE SHORT-TERM RECOGNITION MEMORY PERFORMANCE

The results of the two reported experiments indicate that the position of the letter in a graphic pattern is not a major factor in the utilization of graphic information by kindergarten children at the beginning of the school year. However, the position of the letter in a graphic pattern becomes a major factor in pattern recognition before the children finish their kindergarten year and begin formal reading instruction, and it continues to be an important factor for first grade subjects.

The evidence is consistent with the serial encoding hypothesis which attributes the effect of letter position to the order of encoding and with a limited encoding hypothesis which attributes incorrect recognition responses to a lack of encoded graphic information. According to these hypotheses, judgments of sameness or difference of the C stimuli are sometimes based on incomplete information as to the identity of the T stimulus. A priori, if S encodes one letter on each trial, on the average four of the seven (57%) D-condition trials should be correctly detected. If S encodes two letters, the a priori prediction is for an average of six of the seven (87%)

D-condition trials to be correctly detected. In Experiment 1, the kindergarten children displayed overall correct response probabilities for D-condition of 75% for .5 sec. ET and 80% for 3 sec. ET. This observed performance is less than the performance expected if the subjects consistently encoded as many as two letters on each trial. An analysis of S's performance should reflect the fact that response decisions are made even when the information available about the T stimulus is incomplete. Furthermore, it should also be noted that the amount of information a subject has available may affect his decision. For example, an S who knows that two of the letters in the C stimulus are in the T stimulus and is unsure of the third letter might be more likely to respond "same" than he would if he only knew that one of the letters in the C stimulus was the same and is unsure of the other two. The following finite state model is an attempt to analyze the children's short-term recognition memory performance in terms of four psychological processes. Three of these processes (encoding, forgetting, and comparison) result in the subject being in one of five possible information states about the relationship of the T and C stimuli, and a decision process relates the information states to a specific response.

The first task is to set out the performance which the model will attempt to describe. The event of presenting successively the T stimulus and the C stimulus will be represented as $S_{j,k}$ where $J=1,2,\dots,8$ and denotes the specific relationship of the letters in the stimuli ($j=1$, S-condition; $j=2$, D-condition I, i.e., initial letter distinguishes the T and C stimuli, $j=3$, D-condition M; $j=4$, D-condition F; $j=5$, D-condition IM; $j=6$, D-condition MF; $j=7$, D-condition IF; and $j=8$, D-condition IMF.) and $K=1,2,\dots,6$ and which denotes the ET x RI condition ($k=2$, .5 sec ET and 0 sec RI; $k=1$, .5 sec ET and 1 sec RI; $k=3$, .5 sec ET and 3 sec RI; $k=4$, 3 sec ET and 0 sec RI; $k=5$, 3 sec ET and 1 sec RI; $k=6$, 3 sec ET and 3 sec RI). To facilitate exposition, presentation of S-condition trials will be represented <SSS> with the letter S reflecting sameness of letters at the position it occurs. Specific D-condition trials will be denoted by the letter D at each letter position in which the C stimulus is different from the T stimulus. For example, a difference in the stimuli in the I letter position will be denoted <DSS>.

The subject's response will be represented as R_m , where $m = 1,2$ and denotes the responses "same" and "different" respectively. The dependent variable is the

probability of an R_m -response given a specific event $S_{j,k}$ where there are forty-eight events which can occur (8 stimuli x 6 conditions). The probabilities of the two response outcomes as a function of the stimulus event may be represented in the following performance matrix:

$$\begin{array}{c}
 S_{1,1} \\
 S_{2,1} \\
 \cdot \\
 \cdot \\
 \cdot \\
 S_{j,k}
 \end{array}
 \left[\begin{array}{cc}
 R_1 & R_2 \\
 P(R_1/S_{1,1}) & P(R_2/S_{1,1}) \\
 P(R_1/S_{2,1}) & P(R_2/S_{2,1}) \\
 \cdot & \cdot \\
 \cdot & \cdot \\
 \cdot & \cdot \\
 P(R_1/S_{j,k}) & P(R_2/S_{j,k})
 \end{array} \right]$$

for $j = 1, 2, \dots, 8$ and $k = 1, 2, \dots, 6$.

Since there are ninety-six entries and each row of the matrix must sum to one, there are forty-eight independent outcomes that the model must adequately describe.

The proposed model will postulate that three psychological processes are involved in the processing of the graphic patterns of the T and C stimuli to effect an

Information state (I_1) which reflects the subject's knowledge about the nature of the event. A decisional process subsequent to the Information state will result in the subject's response.

The subject's first task in the short-term recognition memory task is to encode sufficient information from the graphic pattern to distinguish it from other possible graphic patterns. A letter in the graphic pattern will be said to be encoded when sufficient information for distinguishing it from other possible letters in that serial position is processed. The fact that two or more letters may be said to be encoded does not imply that they are processed equally or that the amount of information from each is quantitatively or qualitatively equal.

Both exposure time and serial position of letters in the graphic pattern have been shown to affect overall performance in Experiment 1. Increased ET provides the subject with additional time to examine and encode information from the graphic pattern. And, as has already been noted, the effect of increased ET is to increase the subject's probability of encoding information from the M or F letter position. Therefore, it will be assumed that the probability of encoding information from a specific letter position in a graphic pattern will be a joint function of

ET and letter position. The probability of encoding a letter will be represented by $e_{p,t}$ where the subscript p refers to the serial position of the letter within the graphic pattern and t specifies the exposure time condition. Assuming that the probability of encoding any single letter is independent of the probability of the encoding of other letters in the graphic pattern, the probability of encoding two or more letters is the joint probability of encoding the individual letters. That is, a subject's performance when letters in two positions are changed is assumed to be predictable from information about the subject's likelihood of encoding letters at the different serial positions. Any new source of graphic information such as relational features between two letters would make this assumption untenable. If this assumption is wrong, parameter estimates for the individual letter positions will fail to model subjects' performance when more than one letter is changed in the C-stimuli.

There are eight different combinations of the letters at the three letter positions which may be encoded or not encoded during the presentation of the T stimulus. The initial of the letter at the specific position (I, M or F) will represent the encoding of information at that position, while a barred initial (e.g., \bar{I}) will be used to

represent the lack of information at that letter position. Encoding the I letter only would therefore be represented as I \bar{M} \bar{F} . The eight possible outcomes of encoding are represented as follows: $\bar{I}\bar{M}\bar{F}$; $I\bar{M}\bar{F}$; $\bar{I}M\bar{F}$; $\bar{I}\bar{M}F$; $I\bar{M}F$; $\bar{I}MF$; $I\bar{M}F$; IMF .

The information which results in a correctly encoded letter must be remembered if it is to be used as the basis for a later decision concerning the character of the C stimulus. The loss of information (forgetting) from a previously encoded stimulus may result in the information no longer being able to be used to differentiate among stimuli.

Under these conditions the item will be said to be forgotten. Forgetting may be due to interfering encoding processes, decay over the retention interval, or interference due to comparison of the remembered information with the C stimulus. These sources of forgetting will not be distinguished by the model. It will be assumed in the model that both serial position and retention interval will affect the memory and therefore the forgetting of encoded information. The probability of remembering a letter may then be represented as $r_{p,i}$ where p represents the serial position of the letter and i the

retention interval. Therefore, $1 - r_{p,i}$ equals the probability of forgetting the letter.

The information from letters encoded and remembered serve as the basis for the comparison process. It will be assumed in this analysis that if a child has information about the graphic pattern at any letter position, he will always note the similarities and differences between the T stimulus and the C stimulus at that position. The comparison process is assumed to be infallible whenever encoded information is available.

The result of encoding, remembering and comparing the stimuli is assumed to be one and only one of five information states (I_1, I_2, \dots, I_5). Information state I_1 corresponds to a subject's knowing that the T stimulus is identical to the C stimulus at all three letter positions. Information state I_2 corresponds to a subject's knowing that the T stimulus is different than the C stimulus at one or more letter positions. When the subject knows only that two of the letters in the T stimulus are identical to those in the C stimulus, he is assumed to be uncertain as to the nature of the stimuli and is in information state I_3 . Information state I_4 occurs when the subject knows only that one of the letter positions in the T and C stimuli is identical. Finally, when the subject

has no information as to the similarity of the stimuli, it will be assumed that he is in a pure guessing state, I_5 .

It is not assumed that the same information state necessarily occurs whenever a given stimulus is presented, but rather that the state is determined by a probabilistic process.

The probabilities for the outcomes of the various stimulus conditions are represented in the following stochastic matrix:

$$\begin{array}{c}
 S_{1,1} \\
 S_{2,1} \\
 \cdot \\
 \cdot \\
 \cdot \\
 S_{j,k}
 \end{array}
 \left[\begin{array}{ccccc}
 I_1 & I_2 & I_3 & I_4 & I_5 \\
 \sigma_{1,1}^{(1)} & \sigma_{1,1}^{(2)} & \sigma_{1,1}^{(3)} & \sigma_{1,1}^{(4)} & \sigma_{1,1}^{(5)} \\
 \sigma_{2,1}^{(1)} & \sigma_{2,1}^{(2)} & \sigma_{2,1}^{(3)} & \sigma_{2,1}^{(4)} & \sigma_{2,1}^{(5)} \\
 \cdot & \cdot & \cdot & \cdot & \cdot \\
 \cdot & \cdot & \cdot & \cdot & \cdot \\
 \cdot & \cdot & \cdot & \cdot & \cdot \\
 \sigma_{j,k}^{(1)} & \sigma_{j,k}^{(2)} & \sigma_{j,k}^{(3)} & \sigma_{j,k}^{(4)} & \sigma_{j,k}^{(5)}
 \end{array} \right]$$

where $\sigma_{j,k}^{(i)}$ denotes the probability of information state I_i given stimulus event $S_{j,k}$. Since information state I_1 can occur only for S-condition trials ($S_{1,1}, S_{1,2}, \dots$,

$S_{1,6}$), and information state I_2 cannot occur on these trials, these prior constraints may be made:

$$\sigma_{j,k}^{(i)} = \begin{cases} 0 & \text{when } i = 1 \text{ and } j \neq 1 \\ 0 & \text{when } i = 2 \text{ and } j = 1 \end{cases}$$

Furthermore, since information states I_3 and I_4 require that the subject knows that the T and C stimuli share two letters and one letter respectively, we can further state

$$\sigma_{j,k}^{(i)} = \begin{cases} 0 & \text{when } i = 3 \text{ and } j \geq 5 \\ 0 & \text{when } i = 4 \text{ and } j = 8 \end{cases}$$

since $S_{j,k}$ involves only one identical letter in the stimuli when $4 < j < 8$ (i.e., $\langle DDS \rangle$, $\langle SDD \rangle$, and $\langle DSD \rangle$) and $S_{j,k}$ involves no identical letters when $j = 8$ (e.g., $\langle DDD \rangle$). The value of $\sigma_{j,k}^{(i)}$ for the other entries in the matrix can be computed by ascertaining the probabilities of the encoding and remembering events which result in sufficient conditions for the five information states. The probability that S is in information state I_1 , following a S-condition trial, is the joint probability that all three letters are encoded and remembered under the particular ET x RI-condition.

$$\sigma_{j,k}^{(1)} = P(I_1, /S_{1,k}) = [P(\epsilon_{1,t})P(r_{1,i})] \cdot [P(\epsilon_{2,t})P(r_{2,i})] \cdot [P(\epsilon_{3,t})P(r_{3,i})]$$

The probability that the S is in information state I_2 following a D-condition trial is the probability that the S encodes and remembers at least one of the differentiating letters. For example the outcome of presenting $S_{5,k}$ (<DDS>) may be any of the eight different combinations of encoded information: $\bar{I}\bar{M}\bar{F}$; $\bar{I}\bar{M}F$; $\bar{I}M\bar{F}$; $\bar{I}MF$; $IM\bar{F}$; IMF ; $I\bar{M}\bar{F}$; and IMF . But the probability of any one of these outcomes is the sum of the probabilities of the several encoding-forgetting combinations which might produce it (cf. Figure 3). Therefore the probability that the S will be in information state I_2 following <DDS> will be equal to the sum of the following probabilities: (a) the probability the S encodes and remembers only the I letter or the M letter, (b) the probability the subject encodes both the I and M letter and remembers the I letter, the M letter or both, (c) the probability the subject encodes both the I and F letters and remembers the I letter or both, (d) the probability the subject encodes both the M and F letters and remembers the M letter or both, (e) the probability the subject encodes all three letters and remembers that I letter, M letter, both I and M letters or all three. Table 5 gives the equation for the estimated values for $\sigma_{j,k}$ in terms of $e_{p,t}$ and $r_{p,i}$.

The decision process which relates the five information states of the subject with the set of overt responses "same" (R_1) and "different" (R_2) is quite simple. If we assume that the subject responds "same" with a probability of 1 when in I_1 and "different" with a probability of 1 when in I_2 , we may represent the decision process with the following matrix:

$$\begin{array}{cc}
 & \begin{array}{cc} R_1 & R_2 \end{array} \\
 \begin{array}{c} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \end{array} & \left[\begin{array}{cc} \delta_1 & 1 - \delta_1 \\ \delta_2 & 1 - \delta_2 \\ \delta_3 & 1 - \delta_3 \\ \delta_4 & 1 - \delta_4 \\ \delta_5 & 1 - \delta_5 \end{array} \right]
 \end{array}$$

where I_1 is the probability of eliciting R_1 given information state I_1 and

$$\delta_i = \begin{cases} 1 & \text{when } i = 1 \\ 0 & \text{when } i = 2 \end{cases}$$

The probability of responding "same" on stimulus event $S_{j,k}$ is given in the following equation

$$R_1 = \delta_1 \sigma_{j,k}^{(1)} + \delta_2 \sigma_{j,k}^{(2)} + \delta_3 \sigma_{j,k}^{(3)} + \delta_4 \sigma_{j,k}^{(4)} + \delta_5 \sigma_{j,k}^{(5)}$$

The probability of responding "Different" is equal to $1 - P(R_1)$.

As indicated earlier, $\sigma_{j,k}^{(i)}$ represents the probability of the of the S's being in information state I_i following stimulus event $S_{j,k}$ under exposure time, retention interval conditions k and δ_i reflects decision parameters. By substituting the equivalent equation in terms of encoding and remembering parameters for $\sigma_{j,k}^{(i)}$ we can develop a series of linear equations in terms of $e_{p,t}$ (where $p = 1, 2, 3$ and $t = 1, 2$), $r_{p,i}$ where $p = 1, 2, 3$ and $i = 1, 2, 3$) and δ_m (when $m = 1, 2, \dots, 5$). Since the values of δ_m are fixed for $m = 1$ and 2 , we have a total of 18 parameters which must be estimated. The parameters may be estimated using the method of least squares (Atkinson, Bowers and

Crothers, 1965). The values of the parameters are selected so that they minimize the sum of the squared deviations between predicted and observed values of the performance matrix.

The subroutine Stepit (Chandler, 1965) was used to estimate the values of the eighteen variables in the model which result in the minimum deviation between the forty-eight observed and predicted functions. The only restrictions imposed on the possible values of the variables dealt with the forgetting parameter. The probability of remembering information and thus not having a correctly encoded item at time t was assumed to be equal to or greater than the probability at time $t + 1$. This assumes that there is no consolidation process during the retention interval affecting subjects performance.

Results and Discussion

The parameter estimates for the encoding, forgetting and decisional variables are presented in Tables 6-8 respectively. These parameters were used to generate the predicted probability of a correct response for each ET x RI x Pos-condition. An examination of the observed and predicted probabilities (Figures 4-15) shows that a close approximation has been achieved for both the kindergarten and first grade groups. The average deviation between the observed and predicted values was 4.6% and 3.6% for the kindergarten and first grade groups respectively.

The probability of Ss' correct response as a function of the major factors in the experiment were estimated from the model. The predicted values of a correct response as a function of ET collapsed over RI x Pos-conditions were within 1% of the observed values, while the predicted values of a correct response as a function of RI collapsed over ET x Pos conditions ranged from 1% to 4% from the observed values with a modal difference of 1% (cf. Tables 9 & 10). Pos-conditions were estimated within 3% of their observed values with an average deviation of .5% (cf. Table 11). Thus, the model can be seen to closely mirror the observed performance.

It may be assumed that the variance between the observed and predicted values is due to subject variability and the effects of any factors not adequately accounted for by the model. Using the within-cell variability of the highest order interaction from the analysis of variance as the best estimate of the random error attributable to subjects, the variance of the observed and predicted scores was evaluated as an F-ratio. The predicted values of the model were not significantly different from the observed values despite the power of the test ($F(60,648) = 1.137, p > .20$).

Having established that the model fits the observed performance reasonably well, the specific information from the model may now be examined. In the previous analysis of Experiment 1, the effect of ET was shown to interact with Pos-condition. The parameter estimates of the model indicate that the likelihood of encoding graphic information from the initial letter position does not increase with an increase in ET while the likelihood of encoding the middle and final letters does (10% and 9% for the middle and final letter positions respectively). This is consistent with the hypothesis that the initial letter is encoded prior to the other letters. Increased ET is used to encode information not previously encoded.

Further support of this view comes from the estimated probability that a subject will have 0-3 letters in memory at the time of the comparison process. These data are derivable from the parameter estimates and indicate that the increased ET results in an increased probability that subjects will have more information on which to make the comparison (Table 12). For example, in the kindergarten group the increased ET results in a 3% increase in the probability that two and three letters will be available for comparison, and a 2% and 8% decrease in the probability that zero and 1 letters will be available for comparison.

While these data are consistent with the serial encoding hypothesis, the absolute size of the ET effect is astonishingly small. The average number of letters available at the 0 sec. RI may be estimated from the estimates of Table 12. At the .5 sec ET, the kindergarten group is estimated to remember on the average 1.34 letters per trial. The increased ET results in an estimate of 1.46 letters per trial, an average increase of a little more than 1 letter every ten trials. The first grade group showed a similar increase in the average number of letters remembered with increased ET (2.19 to 2.3 letters per trial). The lack of a dramatic difference in the encoding as a function of ET may indicate that the encoding

processes are not greatly affected by the increased examination time because of possible limitations in memory capacity.

In the analysis of Experiment 1 a RI x Pos-condition interaction was noted. The parameter estimates of forgetting (cf. Table 8) indicate that forgetting is much more likely to occur with information from the initial letter position as a function of increasing RI (18% and 4% for the largest RI for the kindergarten and first grade groups respectively). Little or no forgetting occurs for the middle and final letter positions as a function of RI. If the graphic information from the middle and final letter positions is assumed to be encoded subsequent to that of the initial letter as in the serial encoding hypothesis, then their encoding may interfere with the storage of information from the initial letter position (Massaro, 1970). Since the comparison process is based on the encoded and remembered information, the estimated probabilities of encoding and remembering information from the various letter positions may be used to illustrate results of the encoding and remembering processes (cf. Table 13). Only information from the initial letter Pos is not noticeably affected by increasing the ET. Furthermore, the initial letter position is the only one which is

noticeably affected by increasing the RI. The probability of not having information from the initial letter position is 12.5% greater at the 3 sec. RI than at the 0 sec. RI for the kindergarten group and 2.5% greater for the first grade group. The encoding and remembering processes together indicate that the final letter position is more likely to be both encoded and remembered than the middle letter position (30% vs. 43% for the kindergarten group and 61% vs. 70% for the first grade) and the initial letter position is clearly superior to them both (61% and 90% for the kindergarten and first grade group respectively).

An examination of the parameter estimates of the decision process indicates that the amount of information a subject is assumed to have concerning the similarity of the stimuli does in fact affect the response probabilities (cf. Table 8). The estimated probability of responding "different" when two letters are known to be identical is dramatically less than the probability of responding "different" when no similarity information is available (2% vs. 88% for the kindergarten group and 20% vs. 57% for the first grade group). This is a clear indication that subjects do not just guess when they are unsure of the correctness of their responses.

In the model, the estimated probability of a correct response as a function of the total number of letters encoded is determined when the parameter estimates for the three information states I_3 , I_4 and I_5 are set. Table 14 presents the estimated probabilities of a correct response as a function of the number of letters remembered for both grade levels. The estimates are logical; the more letters which the subject remembers, the more likely the subject is to be correct. This may be attributed to two factors. The more letters a subject encodes, the more likely he will detect a difference in a D-condition trial. Furthermore, the likelihood of a correct response when the subject is in an uncertain information state reflects the amount of information he has (cf. Table 15). The more information available as to the similarity of the stimuli, the more likely the subject is to make the correct response. While the Ss decision strategies may not maximize their performance, the performance itself is reasonable. This is one reason why the decision bias of I_4 for the first grade group may not be higher than it is. A greater probability of responding "different" would have lead to better overall performance. But the children would be aware only of the fact that they are more likely to be right when they have more graphic information, and this is a reasonable expectation.

SUMMARY AND CONCLUSIONS

This study has demonstrated that the child entering kindergarten is unlikely to display a consistent patterning in processing a graphic pattern. There was no evidence that the initial letter was utilized more often than the final letter in a short-term recognition memory task. This result is consistent with Williams et al. (1970) who tested kindergarten children prior to letter recognition instruction and found no letter position bias in judging the similarity of graphic patterns sharing a letter.

There was no evidence that the kindergarten child was able to alter his method of processing the graphic patterns to improve his score. It has been pointed out by Calfee et al. (1972) that careful instructions and feedback often reduce the overall variability and improve children's performance on visual discrimination tasks. Despite continuous feedback, there was no improvement in performance from the first to the second day of Experiment II.

By the end of the kindergarten year the saliency of the initial letter position in the processing of a graphic pattern is demonstrated by the kindergarten group. The combined probability of a correct response from both same

trials and different trials in which the initial letter is changed (I condition) was .81 and from both same trials and different trials in which the final letter is changed (F condition) .73, a significant difference ($p < .01$).

Recognition of a change of both the middle and final letter (MF condition) did not occur as often as in I condition (.78 vs. .81), though the difference was not significant. That is, the child is as likely to notice the change in the initial letter as he is to notice the difference caused by changing the middle and final letters.

A number of the activities of the kindergarten class might be named as possible contributors to this result. There are two types of activities which I have observed in kindergarten classrooms which might influence the child's processing strategy: (1) activities which focus on the initial letter of a word such as searching for the words beginning with a specific letter on a work sheet or in a magazine; (2) activities which focus on the left-to-right progression of letters in a graphic pattern such as writing one's name or copying words. Both types of activities are intended to make the child aware of aspects of the concept of a word, *i.e.*, the beginning letter of a word and the importance of sequence in identifying and writing words.

The performance of the first grade group is interesting primarily for two reasons. First, the saliency of the initial letter is demonstrable at the end of the year after the children have been reading for some months. The effect is just as strong as in the kindergarten (I vs. F condition, 81% vs. 73% at the end of kindergarten and 92% vs. 85% at the end of the first grade). This result is not an artifact of averaging performance data over subjects. Only one first grade child made more errors on <DSS> trials than on <SSD> trials, and nine children were equally likely to make errors on each type of trial. Eight of these nine children were consistently correct in the recognition of a change at any letter position (85% correct or better). Therefore, these children may not be demonstrating an effect of letter position because of a ceiling effect: even if there are processing differences, with a ceiling effect error data no longer distinguish among possible levels of processing performance. It would be interesting to use a convergent measurement such as reaction time to determine whether there is a processing time difference associated with letter position.

Second, unlike many of the visual discrimination tasks which children are likely to have mastered by the end of the first grade, 50 per cent of the first grade group is

unable to consistently recognize a change of a single letter on a different trial (85% correct or better), and over 21 percent of the children in the first grade group did not recognize over 70 percent of such trials. While broad implications cannot be drawn from the performance of the children sampled from one school system, the data suggest that a significantly large population of children have trouble with this graphic processing task.

A post hoc analysis of the rank order correlation between an achievement test (Stanford Primary, Form X) administered by the school at the end of the first grade and children's overall recognition performance score resulted in a correlation of .62, suggesting that recognition skill of the type tested in these experiments might be important in understanding aspects of the overall reading performance.

A number of other areas of investigation are suggested as possible extensions of this study. If a child is limited in the amount of graphic information which can be utilized following a single presentation, then the role of repeated identification trials on the encoding of graphic patterns deserves further attention. It was noted earlier in the paper that Berry et al. (1971) reported an increase in the ability of a child to use graphic information from

all parts of a graphic pattern as a function of overlearning trials (trials subsequent to perfect performance). La Berge and Samuels (1974) have demonstrated that correct performance is often not a sensitive measurement of level of learning. There is a need for a clear demonstration of whether or not the task demands of more graphic information in order to recognize or identify a word change the rate or character of what is learned. That is, we need to see whether or not the probability of being able to utilize information from different letter positions during the course of learning is affected by the experimental manipulation of the graphic similarity of the set of items to be learned.

While the utilization of graphic information from the initial position has been established, the character of the information was not considered in this study. The graphic pattern is the source of the information used in the recognition tasks, but the information may be either the visual characteristics of the graphic pattern or the alphabetic names of the letters. A few children in the first grade overtly named the letters in the graphic pattern. However, if most of the children are using the physical characteristics of the pattern as the basis of recognition, our results should not be greatly disrupted in

a similar experiment, with letter-like forms like those used by Gibson et al. (1962). Since there had been some disagreement over the strength of the habit of processing the initial or left-most part of a pattern with non-alphabetic material (Ghent-Braine, 1968), these questions could be further clarified by examining the effect of position with non-alphabetic material.

A final area of investigation strongly suggested by this study is a child's decision strategy. A finite state model was proposed to describe the overall data in terms of psychological processes. An encoding process, a remembering-forgetting process, a comparison process and a decision process were postulated. The data was well described by the model in terms of the probability of encoding a letter as a function of its position and exposure time, the probability of forgetting an encoded letter as a function of position and retention interval, and the probability of making a response based upon the encoded and remembered information.

One aspect of the model which is not readily apparent from the traditional analysis is the comparison and decision processes. It is assumed that the encoded and remembered information from the T presentation is compared to the C stimulus. The results of the comparison are

described in terms of the child's knowledge about the nature of the event; the two stimuli are known to be the same if all of the letters are encoded and remembered from the T stimulus; the two stimuli are known to be different if any one letter which is remembered is different from the letter in the same position in the C stimulus; otherwise the child is uncertain. The model estimated the probabilities that the child will reply "different" if he knows that two, one, or none of the letters are common to both stimuli. According to the best fit of the model, the child is more likely to respond "different" if he knows none of the letters than if he knows that two of the letters are the same.

The use of such decision strategies by children is relatively unexplored. Since the use of partial graphic information seems to characterize much of the child's early reading performance, it certainly deserves attention.

Table 1
Target and Comparison Stimuli for Experiment 1

Target	Different Conditions							Same Condition
	INITIAL	MIDDLE	FINAL	INITIAL-MIDDLE	MIDDLE-FINAL	INITIAL-FINAL	INITIAL-MIDDLE-FINAL	
1. sec	mec	soc	ser	moc	sor	mer	mor	sec
2. cal	ral	cul	cad	rul	cud	rad	rud	cal
3. lok	fok	luk	lod	fuk	lud	fod	fud	lok
4. reg	seg	rog	rep	sog	rop	sep	sop	reg
5. nok	sok	nak	nol	sak	nal	sol	sal	nok
6. rel	sel	ril	rek	sil	rik	sek	sik	rel
7. kom	lom	kam	kor	lam	kar	lor	lar	kom
8. dic	lic	dec	dim	lec	dem	lim	lem	dic
9. tob	dob	tub	tok	dub	tuk	dok	duk	tob
10. rus	cus	ris	rum	cis	rim	cum	cim	rus
11. kad	fad	kid	kal	fid	kil	fal	fil	kad
12. fas	bas	fos	fac	bos	foc	bac	boc	fas
13. wof	sof	waf	wod	saf	wad	sod	sad	wof
14. von	won	van	vom	wan	vam	wom	wam	von

Table 1 (Continued)

Target	Different Conditions							Same Condition
	INITIAL	MIDDLE	FINAL	INITIAL-MIDDLE	MIDDLE-FINAL	INITIAL-FINAL	INITIAL-MIDDLE-FINAL	
15. ces	res	cos	cem	ros	com	rem	rom	ces
16. lac	dac	luc	lar	duc	lur	dar	dur	lac
17. kol	dol	kul	kof	dul	kuf	dof	duf	kol
18. ger	per	gor	ges	por	gos	pes	pos	ger
19. kon	lon	kan	kos	lan	kas	los	las	kon
20. ler	ker	lir	les	kir	lis	kes	kis	ler
21. mok	rok	mak	mol	rak	mal	rol	ral	mok
22. cid	mid	ced	cil	med	cel	mil	mel	cid
23. bot	kot	but	bod	kut	bud	kod	kud	bot
24. sur	mur	sir	suc	mir	sic	muc	mic	sur
25. dak	lak	dik	daf	lik	dif	laf	lif	dak
26. saf	caf	sof	sab	cof	sob	cab	cob	saf
27. fow	dow	faw	fos	daw	fas	dos	das	fow
28. nov	mov	nav	now	may	naw	mow	maw	nov

Table 2

The Probability of a Correct Response as a
Function of Exposure Time and Retention
Interval for Each Grade

Retention Interval (Seconds)	Exposure Time (Seconds)	
	.5	3.0
	Kindergarten	
0	.79	.82
1	.79	.80
3	.73	.77
	First	
0	.88	.91
1	.88	.91
3	.85	.90

Table 3

The Probability of a Correct Response as a
Function of Position Condition and Grade Level
in Experiment 1

Grade	Position						
	I	IM	F	IM	MF	IF	IMF
K	.81	.67	.73	.80	.78	.83	.88
F	.92	.79	.85	.93	.88	.93	.93

Table 4

Point Estimation of Significant Sources
of Variance in Experiment 1

Source	Estimated Size
Grade (G)	.334
Exposure Time (ET)	.031
Retention Interval (RI)	.060
Position (Pos)	1.372
ET x Pos	.109
RI x Pos	.101

Table 5

The Probability Equations for $\sigma_{J,K}^{(i)}$ in
Terms of the Probability of Encoding ($e_{p,t}$), and
Remembering ($r_{p,i}$) Graphic Information
For any ET x RI Condition K

Table 5

$$\sigma_{1,k}^{(1)} = [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(r_{3,i})]$$

$$\sigma_{1,k}^{(2)} = 0$$

$$\begin{aligned} \sigma_{1,k}^{(3)} = & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(r_{3,i})] \cdot [P(1-e_{1,t})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{3,t})P(r_{3,i})] \cdot [P(1-e_{2,t})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(1-r_{2,i})] \cdot [P(e_{3,t})P(r_{3,i})] + \\ & [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(r_{3,i})] \end{aligned}$$

$$\begin{aligned} \sigma_{1,k}^{(4)} = & [P(e_{1,t})P(r_{1,i})] \cdot [P(1-e_{2,t})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{2,t})P(r_{2,i})] \cdot [P(1-e_{1,t})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{3,t})P(r_{3,i})] \cdot [P(1-e_{1,t})] \cdot [P(1-e_{2,t})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(1-r_{2,i})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] \cdot [P(1-e_{2,t})] + \\ & [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{3,t})P(r_{3,i})] \cdot [P(1-e_{2,t})] + \\ & [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] \cdot [P(1-e_{1,t})] + \\ & [P(e_{2,t})P(1-r_{2,i})] \cdot [P(e_{3,t})P(r_{3,i})] \cdot [P(1-e_{1,t})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(1-r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] + \\ & [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] + \\ & [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{2,t})P(1-r_{2,i})] \cdot [P(e_{3,t})P(r_{3,i})] \end{aligned}$$

Table 5

$$\begin{aligned}
\sigma_{1,1}^{(5)} = & [P(1-e_{1,t})] \cdot [P(1-e_{2,t})] \cdot [P(1-e_{3,t})] + \\
& [P(e_{1,t})P(1-r_{1,i})] \cdot [P(1-e_{2,t})] \cdot [P(1-e_{3,t})] + \\
& [P(e_{2,t})P(1-r_{2,i})] \cdot [P(1-e_{1,t})] \cdot [P(1-e_{3,t})] + \\
& [P(e_{3,t})P(1-r_{3,i})] \cdot [P(1-e_{1,t})] \cdot [P(1-e_{2,t})] + \\
& [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{2,t})P(1-r_{2,i})] \cdot [P(1-e_{3,t})] + \\
& [P(e_{2,t})P(1-r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] \cdot [P(1-e_{1,t})] + \\
& [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] \cdot [P(1-e_{2,t})] + \\
& [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{2,t})P(1-r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})]
\end{aligned}$$

Table 5

$$\sigma_{J,K}^{(1)} = 0$$

$$\begin{aligned} \sigma_{J,K}^{(2)} = & [P(e_{1,t})P(r_{1,i})] \cdot [P(1-e_{2,t})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(1-r_{2,i})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{3,t})P(r_{3,i})] \cdot [P(1-e_{2,t})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] \cdot [P(1-e_{2,t})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(r_{3,i})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(1-r_{2,i})] \cdot [P(e_{3,t})P(r_{3,i})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(1-r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] \end{aligned}$$

$$\begin{aligned} \sigma_{J,K}^{(3)} = & [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(r_{3,i})] \cdot [P(1-e_{1,t})] + \\ & [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(r_{3,i})] \end{aligned}$$

$$\begin{aligned} \sigma_{J,K}^{(4)} = & [P(e_{2,t})P(r_{2,i})] \cdot [P(1-e_{1,t})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{3,t})P(r_{3,i})] \cdot [P(1-e_{1,t})] \cdot [P(1-e_{2,t})] + \\ & [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{3,t})P(r_{3,i})] \cdot [P(1-e_{2,t})] + \\ & [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] \cdot [P(1-e_{1,t})] + \\ & [P(e_{2,t})P(1-r_{2,i})] \cdot [P(e_{3,t})P(r_{3,i})] \cdot [P(1-e_{1,t})] + \\ & [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] + \\ & [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{2,t})P(1-r_{2,i})] \cdot [P(e_{3,t})P(r_{3,i})] \end{aligned}$$

Table 5

$$\sigma_{J,K}^{(5)} = \sigma_{1,1}^{(5)}$$

Where $J = 2, 3, 4$

Table 5

$$\sigma_{J,K}^{(1)} = 0$$

$$\begin{aligned} \sigma_{J,K}^{(2)} = & [P(e_{1,t})P(r_{1,i})] \cdot [P(1-e_{2,t})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{2,t})P(r_{2,i})] \cdot [P(1-e_{1,t})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(1-r_{2,i})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{3,t})P(r_{3,i})] \cdot [P(1-e_{2,t})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] \cdot [P(1-e_{2,t})] + \\ & [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(r_{3,i})] \cdot [P(1-e_{1,t})] + \\ & [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] \cdot [P(1-e_{3,t})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(r_{3,i})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(1-r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] + \\ & [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] + \\ & [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{2,t})P(r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] + \\ & [P(e_{1,t})P(r_{1,i})] \cdot [P(e_{2,t})P(1-r_{2,i})] \cdot [P(e_{3,t})P(1-r_{3,i})] \end{aligned}$$

$$\sigma_{J,K}^{(3)} = 0$$

$$\begin{aligned} \sigma_{J,K}^{(4)} = & [P(e_{3,t})P(r_{3,i})] \cdot [P(1-e_{1,t})] \cdot [P(1-e_{2,t})] + \\ & [P(e_{3,t})P(r_{3,i})] \cdot [P(e_{1,t})P(1-r_{1,i})] \cdot [P(1-e_{2,t})] + \\ & [P(e_{3,t})P(r_{3,i})] \cdot [P(e_{2,t})P(1-r_{2,i})] \cdot [P(1-e_{1,t})] + \\ & [P(e_{3,t})P(r_{3,i})] \cdot [P(e_{1,t})P(1-r_{1,i})] \cdot [P(e_{2,t})P(1-r_{2,i})] \end{aligned}$$

Table 5

$$\sigma_{J,K}^{(5)} = \sigma_{1,1}^{(5)}$$

Where $J = 5, 6, 7$

$$\sigma_{J,K}^{(1)} = 0$$

$$\sigma_{J,K}^{(2)} = 1 - \sigma_{8,1}^{(5)}$$

$$\sigma_{J,K}^{(3)} = 0$$

$$\sigma_{J,K}^{(4)} = 0$$

$$\sigma_{J,K}^{(5)} = \sigma_{1,1}^{(5)}$$

Where $J = 8$

Table 6

Parameter Estimates of Enclosing Graphic
Information as a Function of Position
and Exposure Time for each Grade Level
in Experiment 1

Exposure Time (Seconds)	Position of Letter		
	Initial	Middle	Final
	Kindergarten Group		
.5	.708	.404	.389
3.0	.655	.554	.464
	First Grade Group		
.5	.919	.661	.760
3.0	.907	.707	.855

Table 7
 Parameter Estimates of the Probability of
 Forgetting Initial, Middle, and Final
 Letters as a Function of Retention
 Intervals for both Grade Levels in Experiment 1

Retention Interval (Seconds)	Position of Letter		
	Initial	Middle	Final
	Kindergarten Group		
0	.018	.356	0.000
1	.090	.356	0.000
3	.202	.356	.159
	First Grade Group		
0	.001	.118	.095
1	.012	.118	.095
3	.039	.118	.095

Table 8

Parameter Estimate of the Probability of
Responding "Different" as a Function of
Information State for Kindergarten and First
Grade Groups in Experiment 1

Information State	Grade Level	
	Kindergarten	First
I_1^a	.000	.000
I_2	1.000	1.000
I_3	.020	.213
I_4	.172	.076
I_5	.884	.571

^aThese values are set by the assumptions of the model

Table 9

The Estimated and Observed Probability of a Correct Response as a Function of Exposure Time for each Grade Level in Experiment 1.

Exposure Time (Seconds)	Grade Level	
	Kindergarten Group	
	Observed	Predicted
.5	.77	.76
3.0	.80	.80
	First Grade Group	
	Observed	Predicted
.5	.87	.86
3.0	.91	.91

Table 10

The Estimated and Observed Probability of a Correct Response as a Function of Retention Interval for each Grade Level in Experiment 1

Retention Interval (Seconds)	Grade Level	
	Kindergarten Group	
	Observed	Predicted
0	.81	.79
1	.80	.78
3	.76	.76
	First Grade Group	
	Observed	Predicted
0	.90	.89
1	.90	.89
3	.87	.88

Table 11

The Estimated and Observed Probability of a
 Correct Response as a Function of
 Pos-condition for each Grade Level in Experiment 1

Pos	Kindergarten Group	
	Observed	Predicted
<SSS>	.79	.80
<DSS>	.80	.80
<SDS>	.53	.53
<SSD>	.62	.62
<DDS>	.83	.82
<SDD>	.76	.75
<DSD>	.93	.92
<DDD>	.94	.97
	First Grade Group	
<SSS>	.90	.90
<DSS>	.94	.94
<SDS>	.70	.70
<SSD>	.80	.80
<DDS>	.95	.95
<SDD>	.87	.87
<DSD>	.96	.96
<DDD>	.97	.97

Table 12

Probability of Number of Letters Estimated in
Memory for Comparison as a Function of Exposure
Time x Retention Interval Condition for each
Grade in Experiment 1

Number of Letters	ET x RI (Seconds)					
	.5,0	.5,1	.5,3	3,0	3,1	3,3
Kindergarten Group						
3	.07	.07	.05	.11	.10	.07
2	.34	.32	.27	.37	.36	.31
1	.45	.45	.46	.40	.40	.43
0	.14	.16	.22	.12	.14	.19
First Grade Group						
3	.37	.36	.35	.44	.43	.42
2	.46	.46	.46	.44	.44	.44
1	.16	.16	.17	.12	.12	.13
0	.01	.02	.02	.01	.01	.01

Table 13

Estimated Probabilities of Encoding and Remembering a Letter as a Function of Exposure Time x Retention Interval Condition for each Grade Level in Experiment 1

		Letter Position			
ET x RI (Seconds)		Initial	Middle	Final	None
Kindergarten Group					
.5	0.	.695	.260	.389	.138
.5	1.	.644	.260	.389	.161
.5	3.	.565	.260	.389	.217
3.0	0.	.643	.357	.464	.123
3.0	1.	.596	.357	.464	.140
3.0	3.	.522	.357	.464	.187
First Grade Group					
.5	0.	.919	.583	.686	.011
.5	1.	.908	.583	.686	.013
.5	3.	.885	.583	.686	.013
3.0	0.	.907	.624	.724	.008
3.0	1.	.897	.624	.724	.010
3.0	3.	.874	.624	.724	.011

Table 14

Estimated Probability of a Correct Response
as a Function of Letters Encoded and
Remembered for each Grade Level in Experiment 1

Number of Letters	Grade Level
	Kindergarten Group
3	1.000*
2	.920
1	.740
0	.500
	First Grade Group
3	1.000*
2	.837
1	.765
0	.500

*assumption of model

Table 15

Estimated Probability of a Correct Response as
a Function of Number of Letters Encoded and
Remembered for each Grade Level in Experiment 1

Information State	Grade Level	
	Kindergarten	First
I ₁	1.0*	1.0*
I ₂	1.0*	1.0*
I ₃	.860	.715
I ₄	.618	.653
I ₅	.500	.500

* assumption of model

Figure 1

Percentage of correct responses collapsed over judgment type for Position (Pos) conditions as a function of Exposure Time for Experiment 1.

Each data point is the arithmetic mean of 56
 $Ss \times 24$ items = 1344 observations.

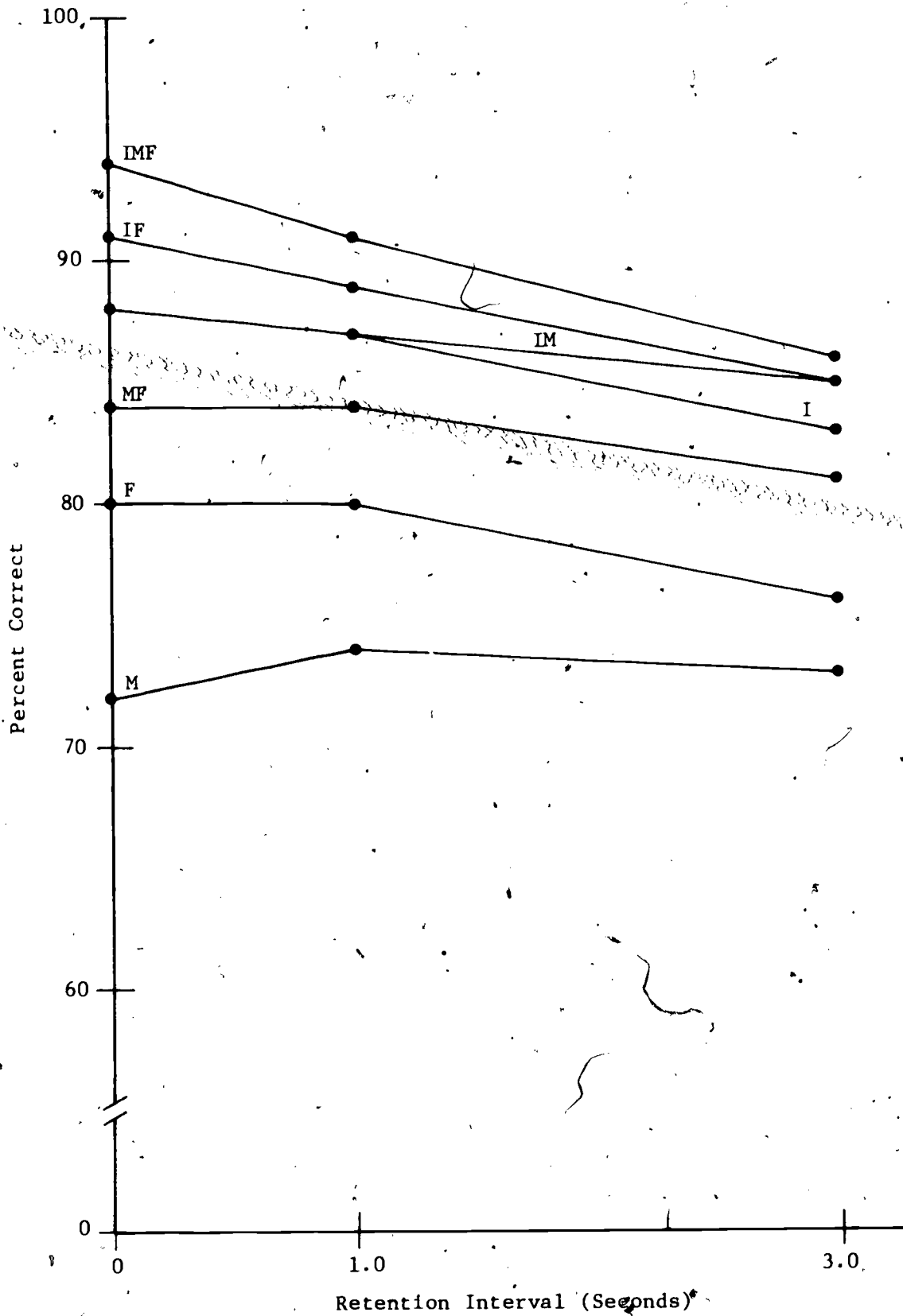


Figure 2

Percentage of correct responses collapsed over judgment type for Pos conditions as a function of Retention Interval for Experiment 1.

Each data point is the arithmetic mean of 56
Ss x 16 items = 896 observations.

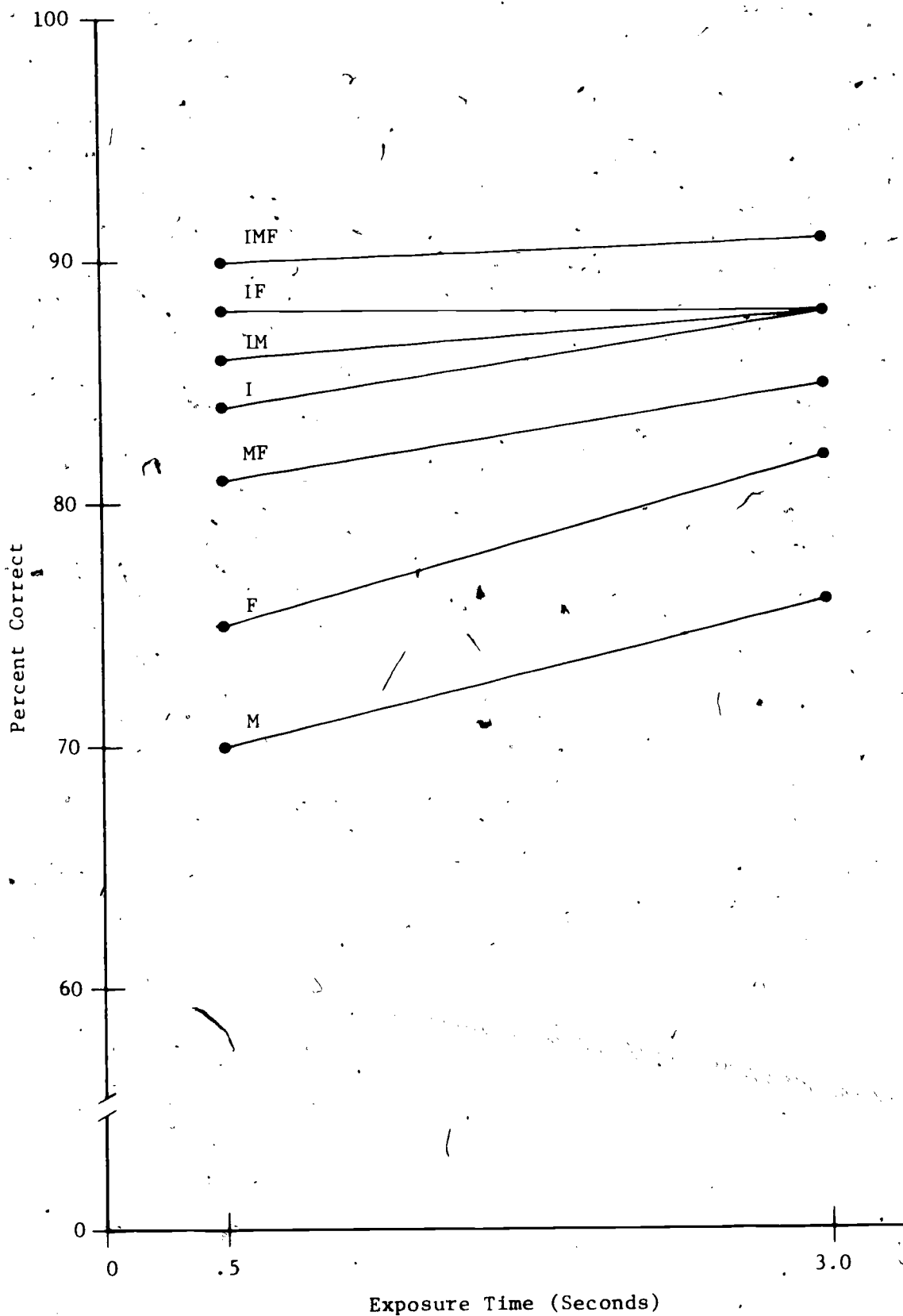


Figure 3

Possible events in encoding and remembering
a three letter stimulus in the short-term
recognition memory model.

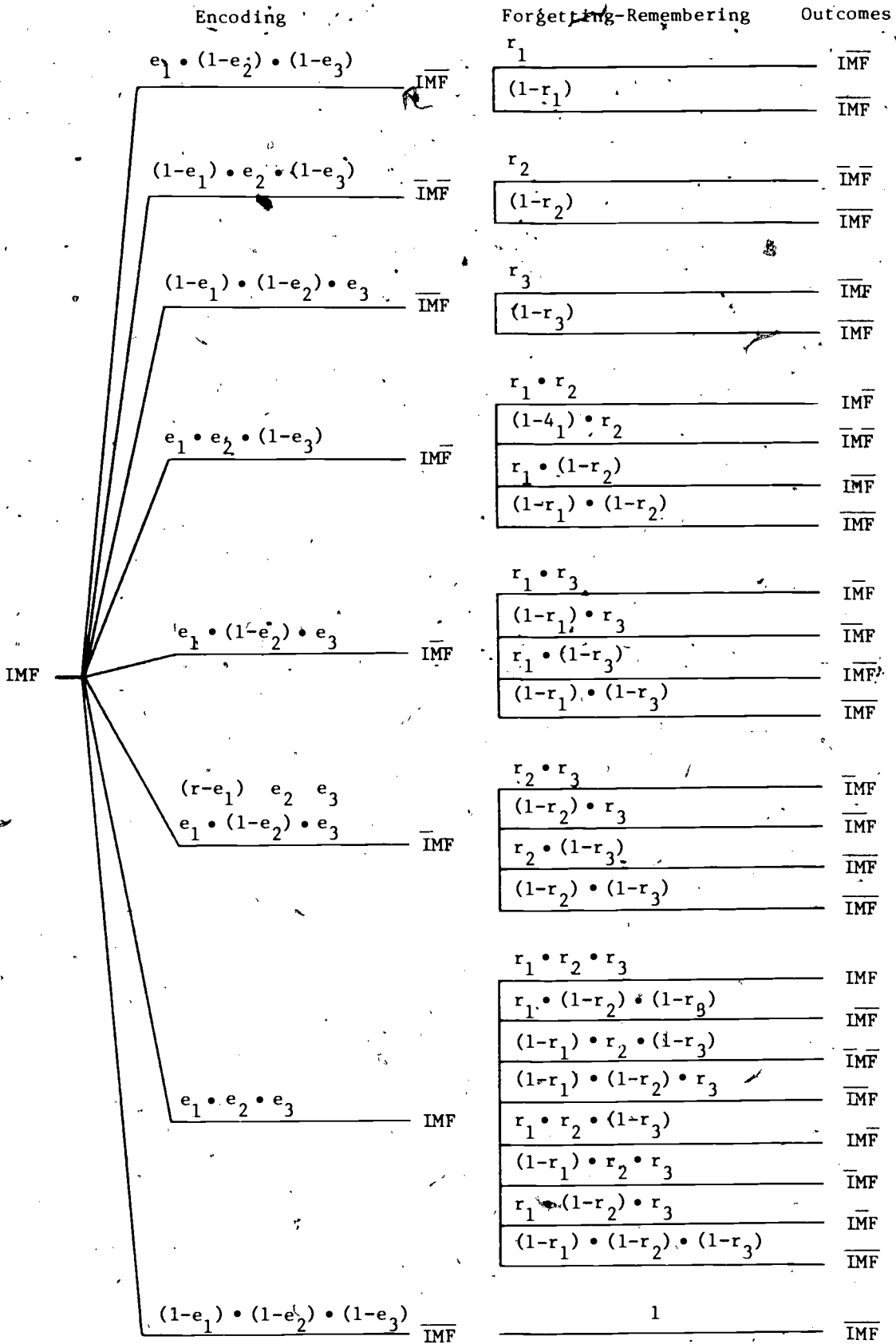


Figure 4

Predicted and observed correct response probabilities for Same-condition and Different-conditions at .5 sec. Exposure Time and 0 sec. Retention Interval for the Kindergarten Group in Experiment 1.

Each observed data point under condition <SSS> is the arithmetic mean of 28 Ss x 28 items = 784 observations; all other observed data points are the arithmetic means of 28 Ss x 4 items = 112 observations.

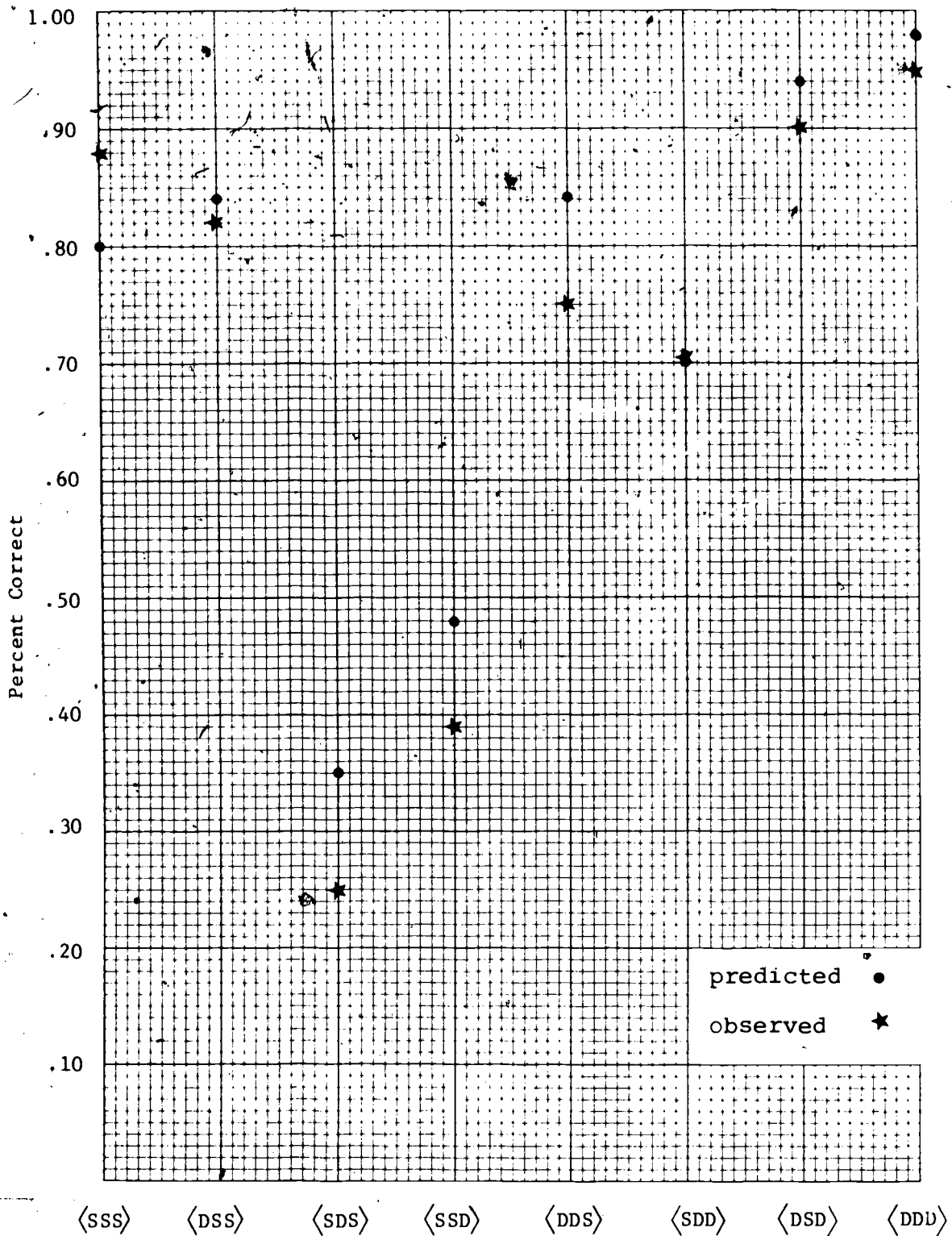


Figure 5

Predicted and observed correct response probabilities for Same-condition and Different-conditions at .5 sec. Exposure Time and 1 sec. Retention Interval for the Kindergarten Group in Experiment 1.

Each observed data point under condition <SSS> is the arithmetic mean of 28 Ss x 28 items = 784 observations; all other observed data points are the arithmetic means of 28 Ss x 4 items = 112 observations.

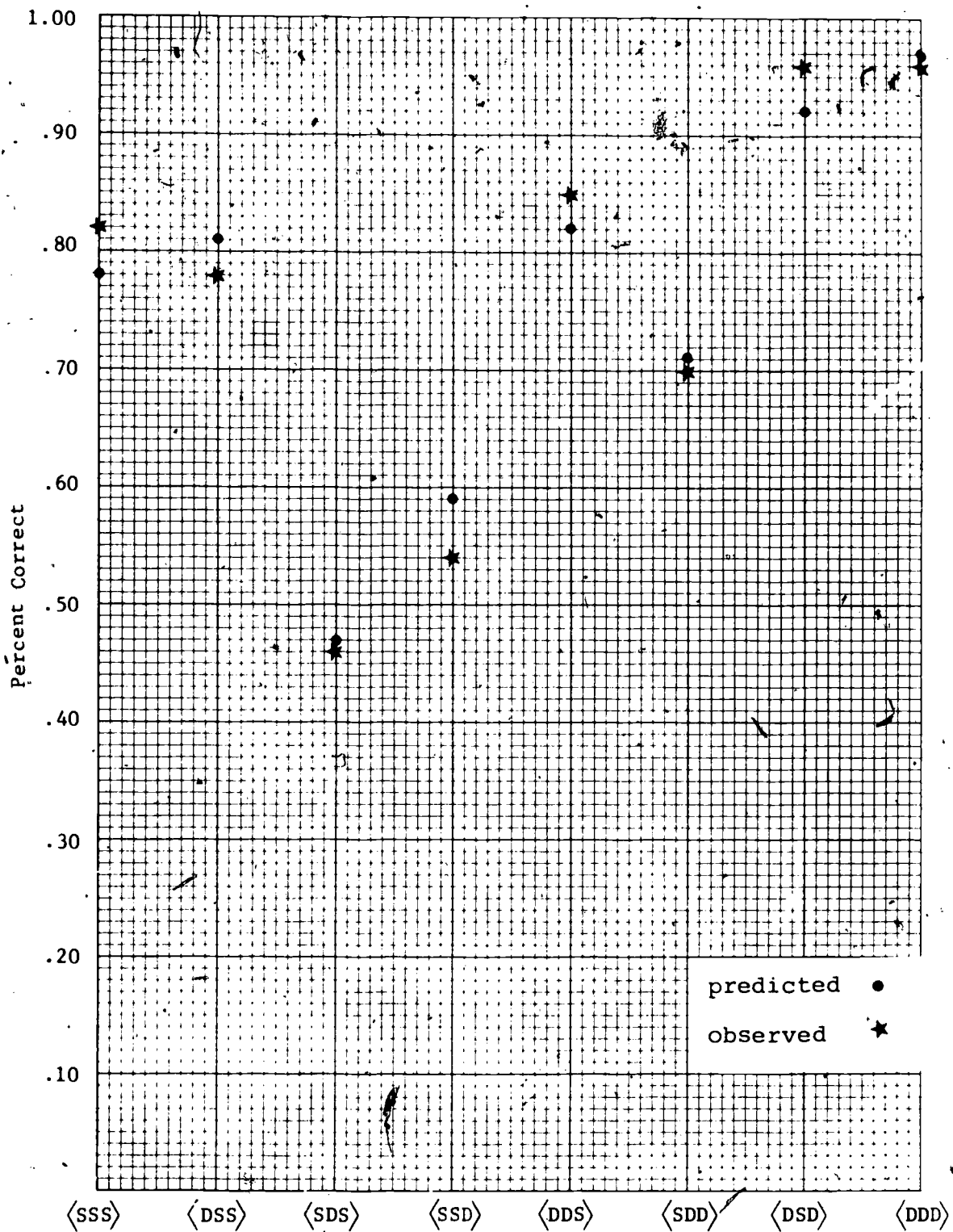


Figure 6

Predicted and observed correct response probabilities for Same-condition and Different-conditions at .5 sec. Exposure Time and 3 sec. Retention Interval for the Kindergarten Group in Experiment 1.

Each observed data point under condition <SSS> is the arithmetic mean of 28 Ss x 28 items = 784 observations; all other observed data points are the arithmetic means of 28 Ss x 4 items = 112 observations.

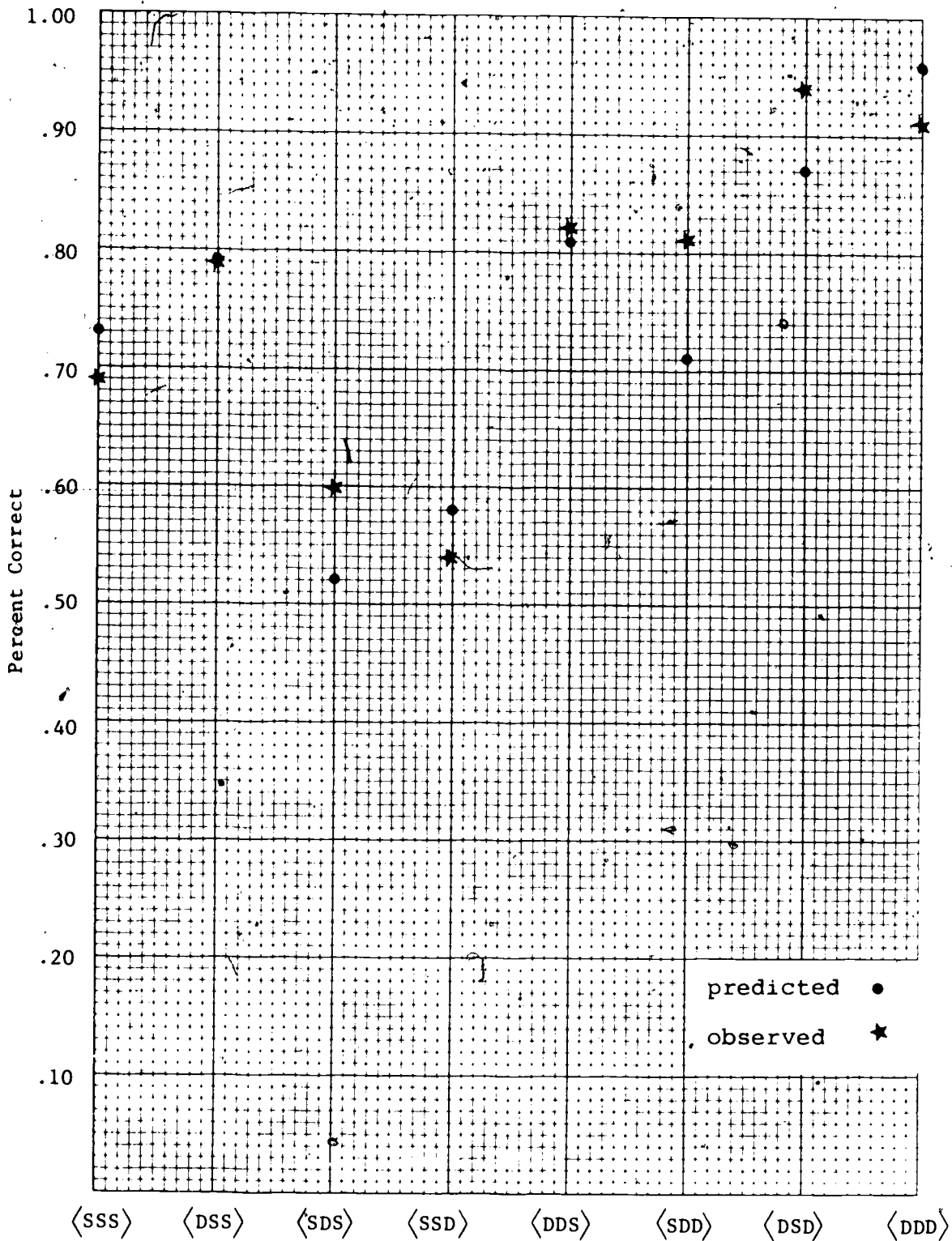


Figure 7

Predicted and observed correct response probabilities for Same-condition and Different-conditions at 3.0 sec. Exposure Time and 0 Sec. Retention Interval for the Kindergarten Group in Experiment 1.

Each observed data point under condition <SSS> is the arithmetic mean of 28 Ss x 28 items = 784 observations; all other observed data points are the arithmetic means of 28 Ss x 4 items = 112 observations.

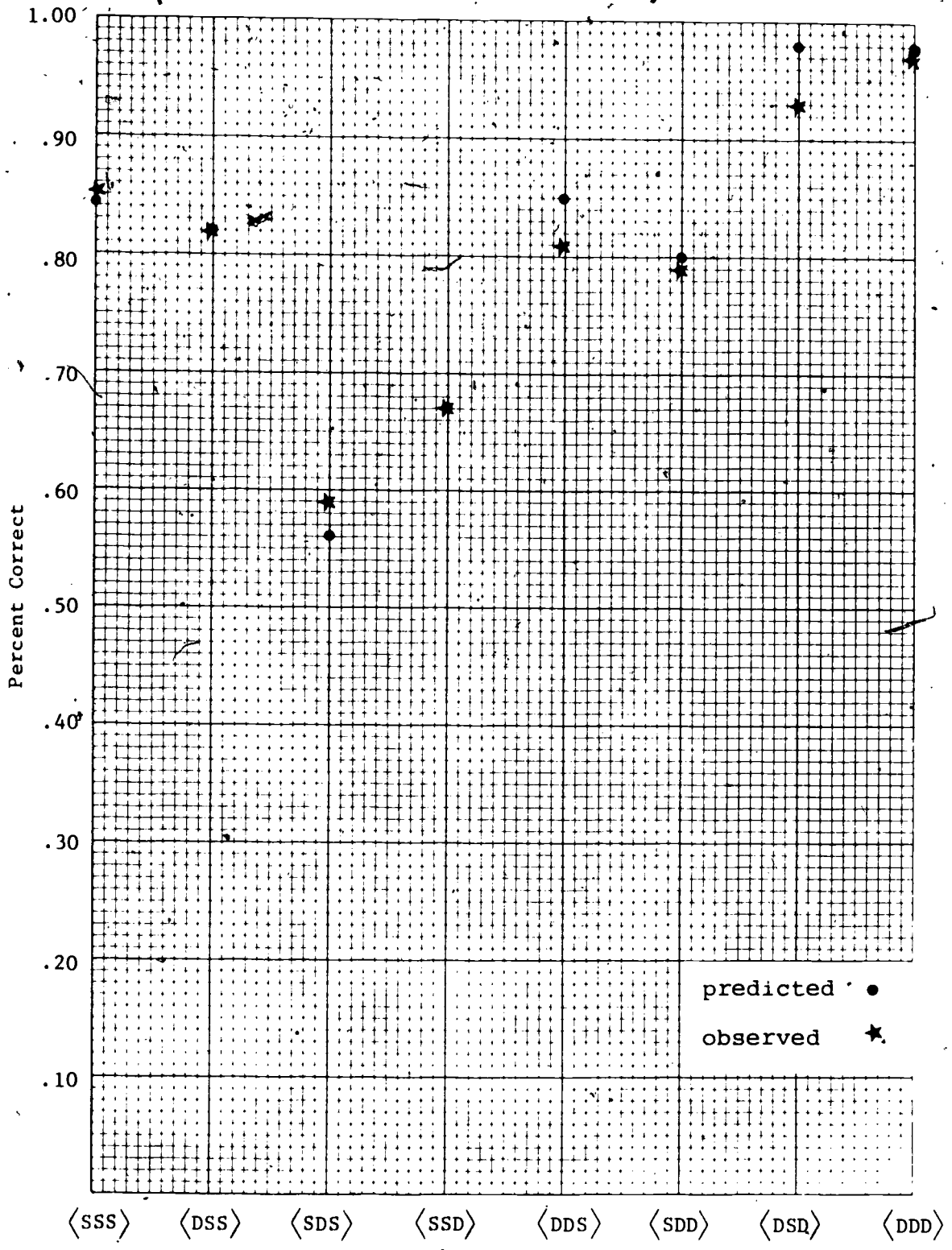


Figure 8

Predicted and observed correct response probabilities for Same-condition and Different-conditions at 3.0 sec. Exposure Time and 1 sec. Retention Interval for the Kindergarten Group in Experiment 1.

Each observed data point under condition <SSS> is the arithmetic mean of 28 Ss x 28 items = 784 observations; all other observed data points are the arithmetic means of 28 Ss x 4 items = 112 observations.

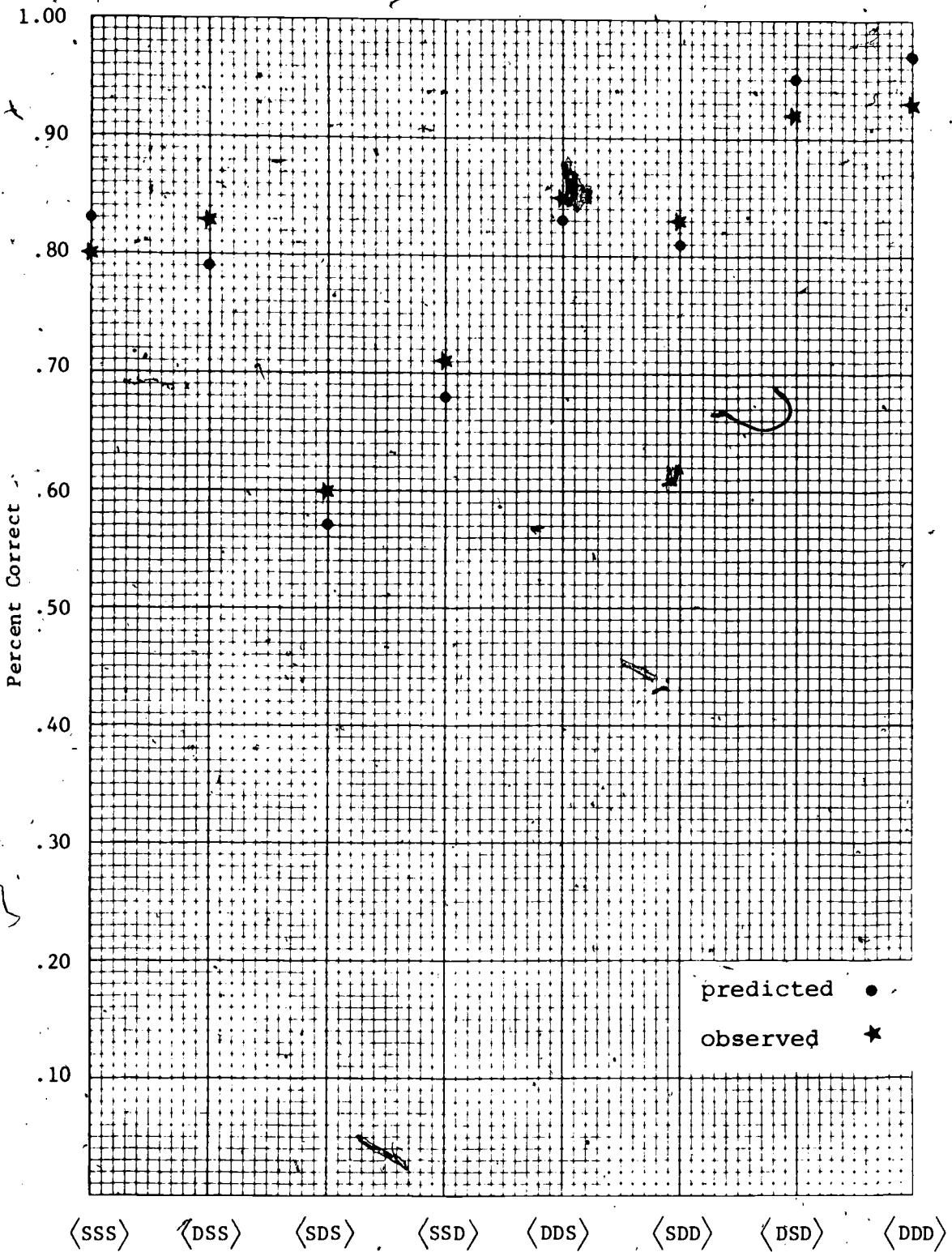


Figure 9

Predicted and observed correct response probabilities for Same-condition and Different-conditions at 3.0 sec. Exposure Time and 3.0 sec Retention Interval for the Kindergarten Group in Experiment 1.

Each observed data point under condition <SSS> is the arithmetic mean of 28 Ss x 28 items = 784 observations; all other observed data points are the arithmetic means of 28 Ss x 4 items = 112 observations.

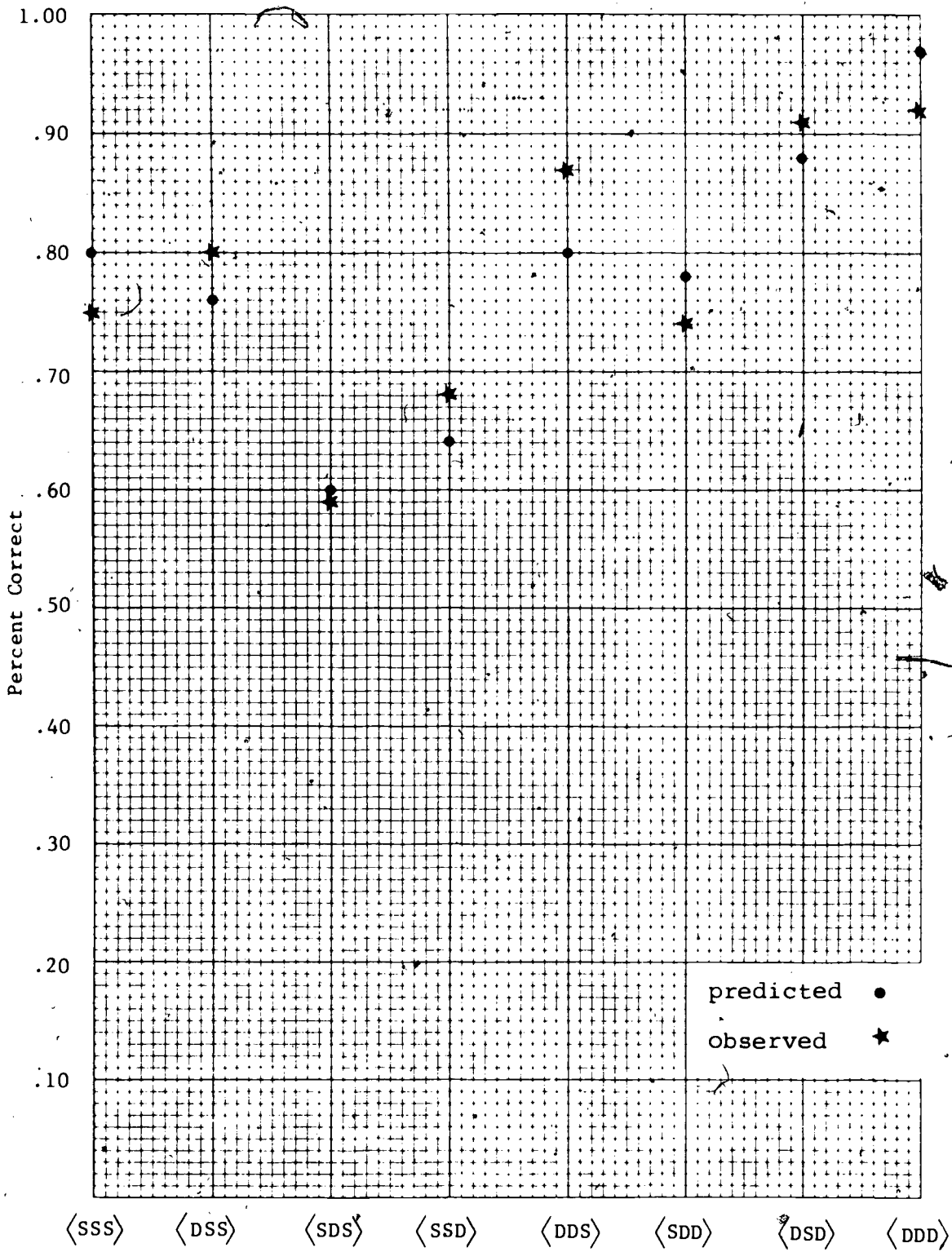


Figure 10

Predicted and observed correct response probabilities for Same-condition and Different-condition at .5 sec. Exposure Time and 0 sec. Retention Interval for the First Grade Group in Experiment 1.

Each observed data point under condition <SSS> is the arithmetic mean of 28 Ss x 28 items = 784 observations; all other observed data points are the arithmetic means of 28 Ss x 4 items = 112 observations.

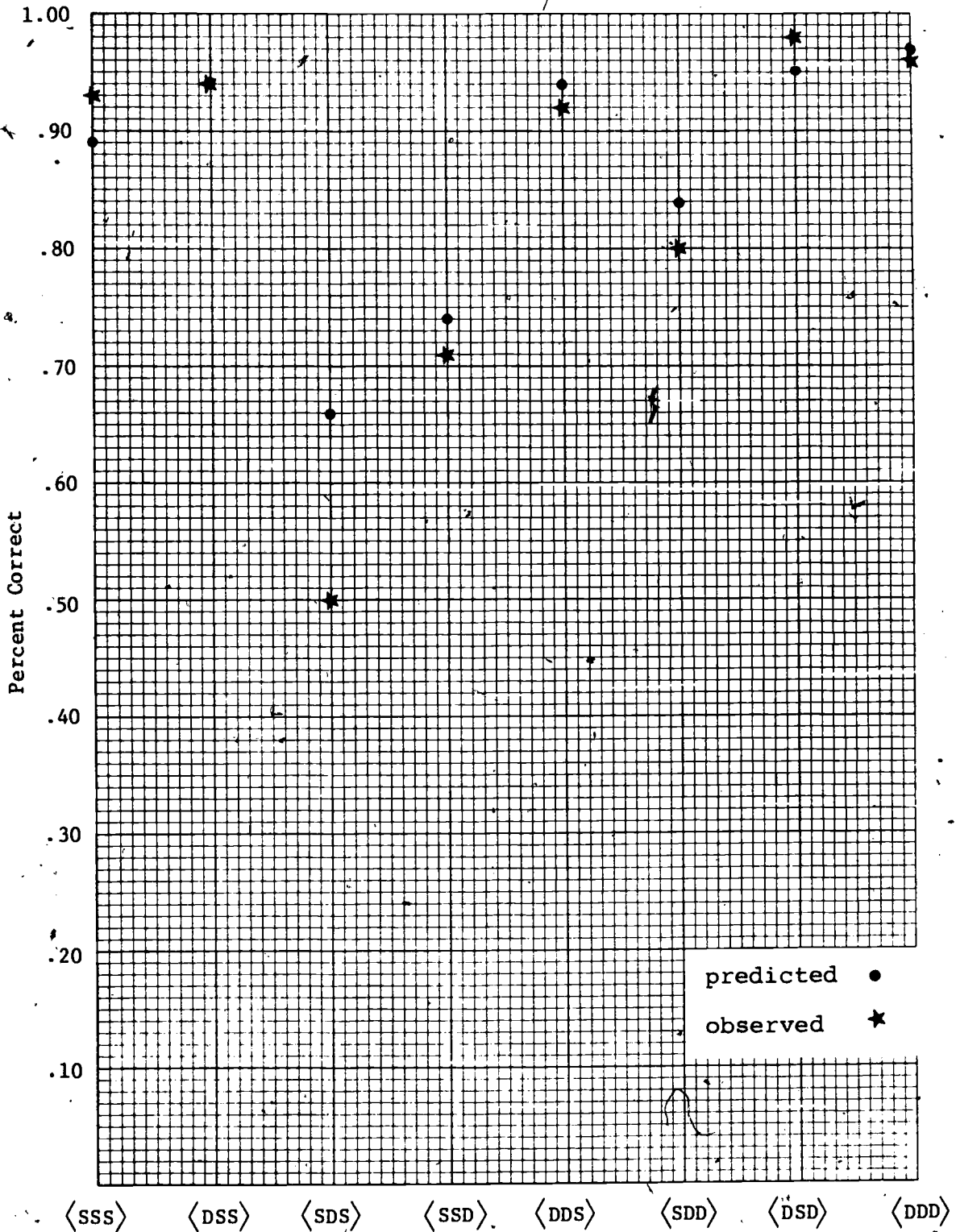


Figure 11

Predicted and observed correct response probabilities for Same-condition and Different-condition at .5 sec. Exposure Time and 1 sec. Retention Interval for the First Grade Group in Experiment 1.

Each observed data point under condition <SSS> is the arithmetic mean of 28 Ss x 28 items = 784 observations; all other observed data points are the arithmetic means of 28 Ss of 4 items = 112 observations.

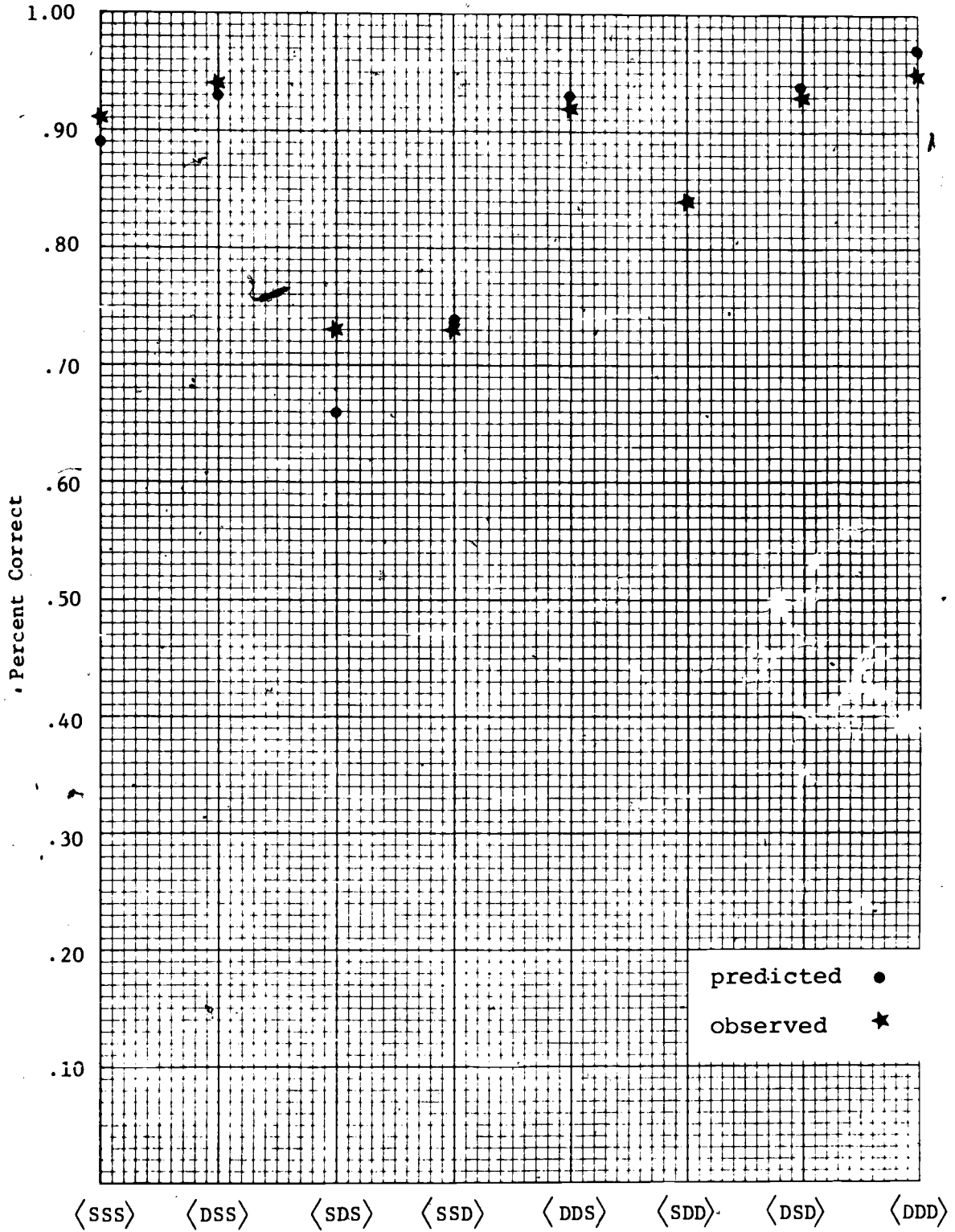


Figure 12

Predicted and observed correct response probabilities for Same-condition and Different-conditions at .5 sec. Exposure Time and 3 sec. Retention Interval for the First Grade Group in Experiment 1.

Each observed data point under condition <SSS> is the arithmetic mean of 28 Ss x 28 items = 784 observations; all other observed data points are the arithmetic means of 28 Ss of 4 items = 112 observations.

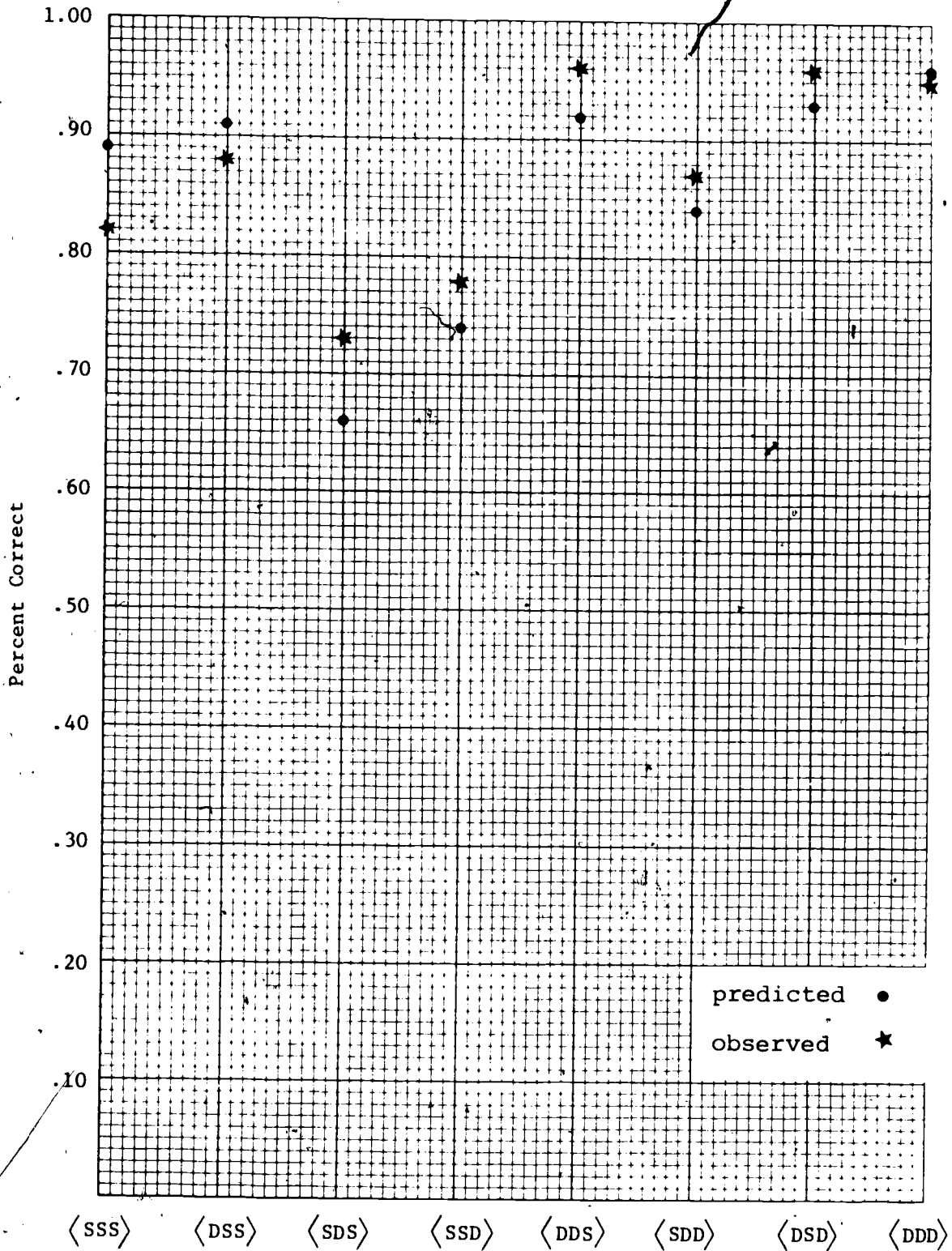


Figure 13

Predicted and observed correct response probabilities for Same-condition and Different-conditions at 3.0 sec. Exposure Time and 0 sec. Retention Interval for the First Grade Group in Experiment 1.

Each observed data point under condition <SSS> is the arithmetic mean of 28 ss x 28 items = 784 observations; all other observed data points are the arithmetic means of 28 ss of 4 items = 112 observations.

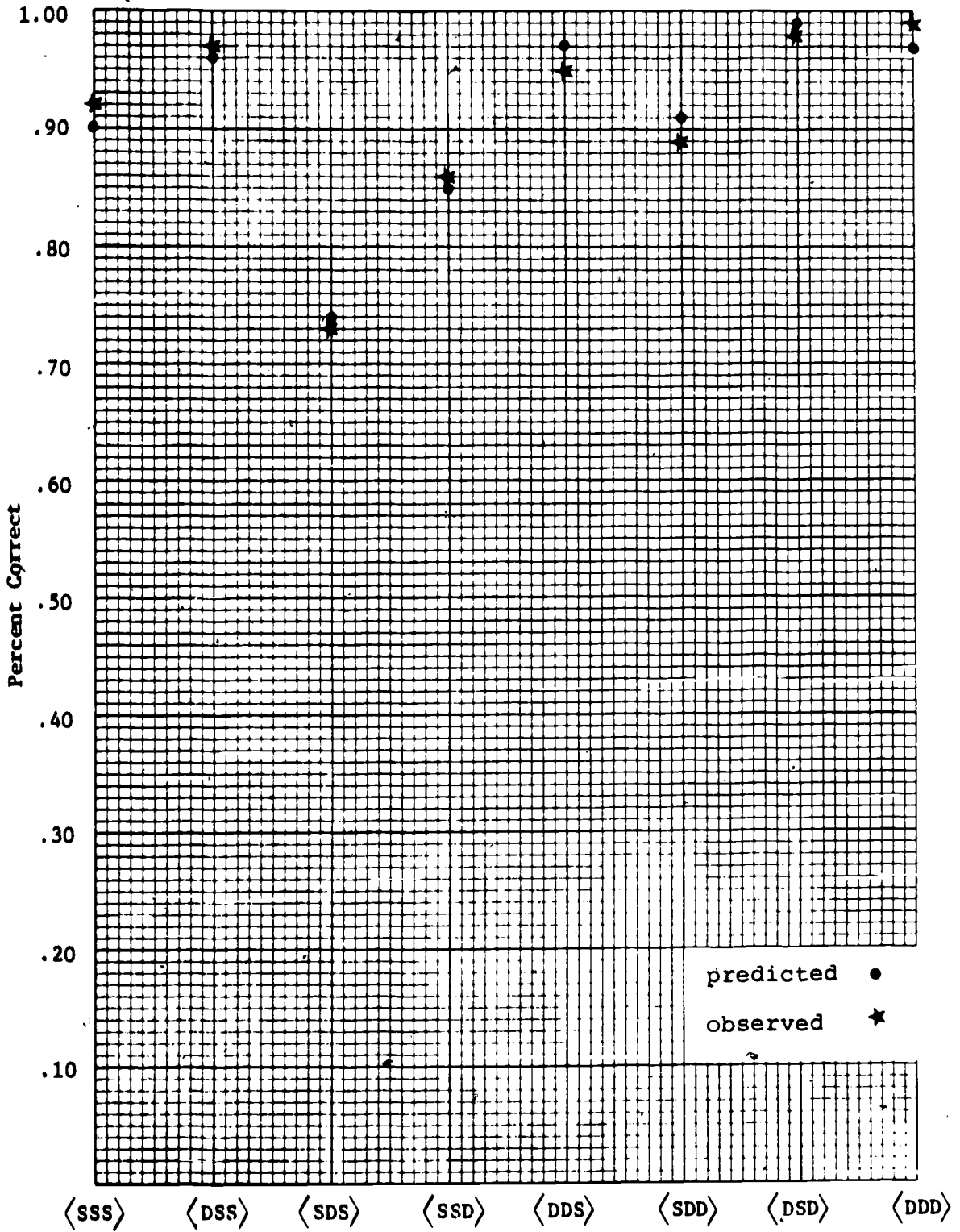


Figure 14

Predicted and observed correct response probabilities for Same-condition and Different-conditions at 3.0 sec. Exposure Time and 1 sec. Retention Interval for the First Grade Group in Experiment 1.

Each observed data point under condition <SSS> is the arithmetic mean of 28 \underline{S} s x 28 items = 784 observations; all other observed data points are the arithmetic means of 28 \underline{S} s of 4 items = 112 observations.

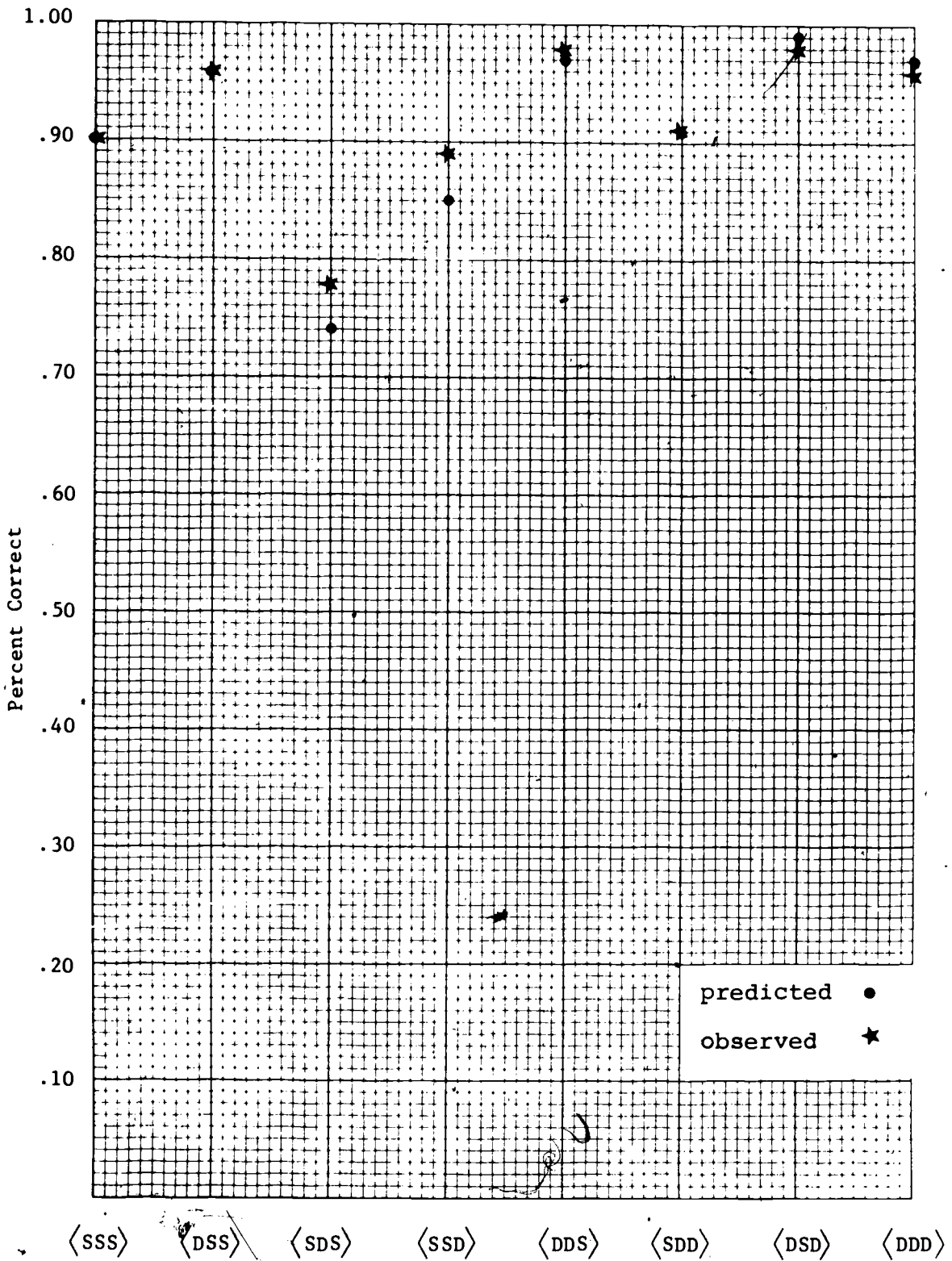
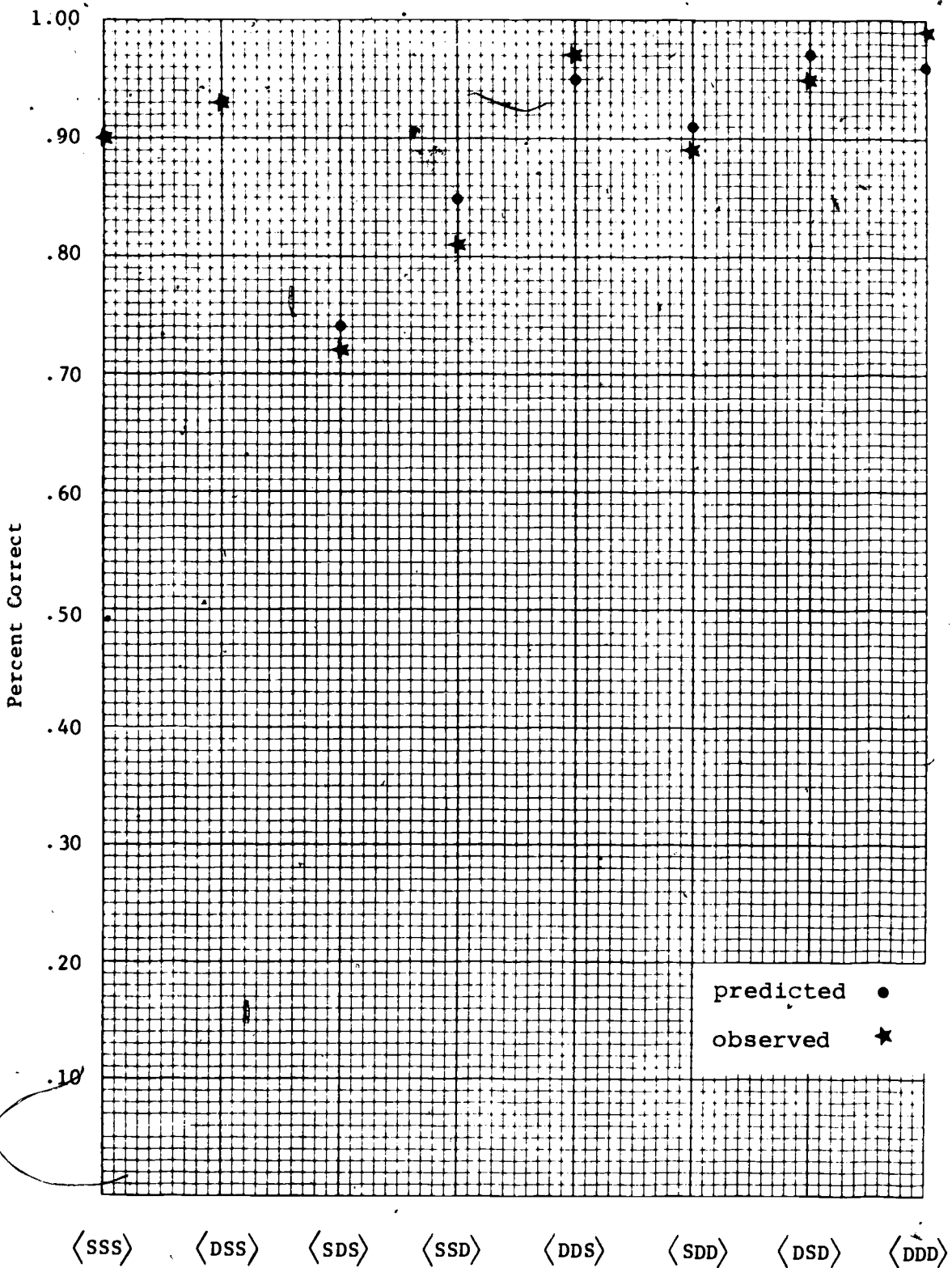


Figure 15

Predicted and observed correct response probabilities for Same-condition and Different-conditions at 3.0 sec. Exposure Time and 3.0 sec. Retention Interval for the First Grade Group in Experiment 1.

Each observed data point under condition <SSS> is the arithmetic mean of 26 Ss x 28 items = 784 observations; all other observed data points are the arithmetic means of 28 Ss of 4 items = 112 observations.



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