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ABSTRACT

The development of rapid word processing skills was investigated using a visual search task. Visual displays of varying orthographic structure (words, pseudowords, nonwords) were presented to college students and to kindergarten, second-grade, and fourth-grade children. Response latencies were measured as subjects indicated whether a previously presented single letter appeared in the display. A shift in processing strategy occurred between kindergarten and second grade. Kindergarten children responded identically to words, pseudowords, and nonwords. They apparently used a letter-by-letter encoding strategy terminating the search as soon as a match occurred. For older groups, words and pseudowords were encoded faster than nonwords. However, once encoded, an exhaustive strategy was used with all three display types. The means by which words could be processed rapidly appeared to be acquired before the end of the second grade, although rate of processing continued to improve. (Author/AA)

The Development of Rapid Word Processing Skills

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Reading is a complex cognitive process which involves many different subskills. The ability to recognize words rapidly, accurately and with as little attentional demands as possible is certainly one of the most important of these subskills. Previous research with skilled readers has shown that they have the ability to use the redundant orthographic information in the English language to facilitate the recognition of word and pronounceable pseudoword displays. Knowledge about the development of this skill has implications for both theories of reading and for methods of reading instruction.

We decided to investigate the development of rapid word recognition skills by using a visual search paradigm. Figure I shows the sequence of events that occurs in a visual search task. Within one experimental trial a verbal warning is followed 500msec later by the visual presentation of a target letter for 1500msec. This is followed by a 500msec exposure of a pattern visual mask. The pattern mask is then followed by a visual display of a string of letters which remains on until the subject responds. The subject's task is to respond either "yes" or "no" depending upon whether or not the initial target letter can be found in the visual string of letters. The primary dependent measure is the amount of time that the subject takes to make his response.

We chose this particular paradigm for the following three reasons. First by using additive factors logic it is possible to localize the facilitative effects of orthographic regularity into perceptual or decision stages of information processing. Figure number II presents the sequence of stages which occur in our model of visual search performance. Within this model there are four independent and successive stages of information processing. In stage I the visual display is encoded by being matched with long term memory representations of the letters. The target letter is then compared with the letters in the visual display until a match is found or until all comparisons have been made without finding a match. The subject then makes his decision and responds either "yes" or "no". A second reason for using the visual search task is that previous research with adult subjects using the visual search paradigm has found reliable differences in response times for word and nonword displays. This difference should increase in children as they learn to read. The third reason for using the visual search task is that it can easily be adapted for use with very young children with little or no reading skills. Thus, we have a simple task which can be used for both college students and kindergarten children alike.

In our experiment we had one between subjects variable; grade level. We used kindergarten, second, and fourth grade children as well as college students. Each group had 20 subjects, and they all participated in an identical search task. The displays searched were of three types: either common words, orthographically regular and pronounceable anagrams of these words (pseudowords) and unpronounceable anagrams of these words (nonwords). The visual displays were either three, four, or five letters in length. In addition, there were two types of response, the subject could respond either yes or no. Again the primary dependent measure was the amount of time it took the subject to make either a positive or negative decision.

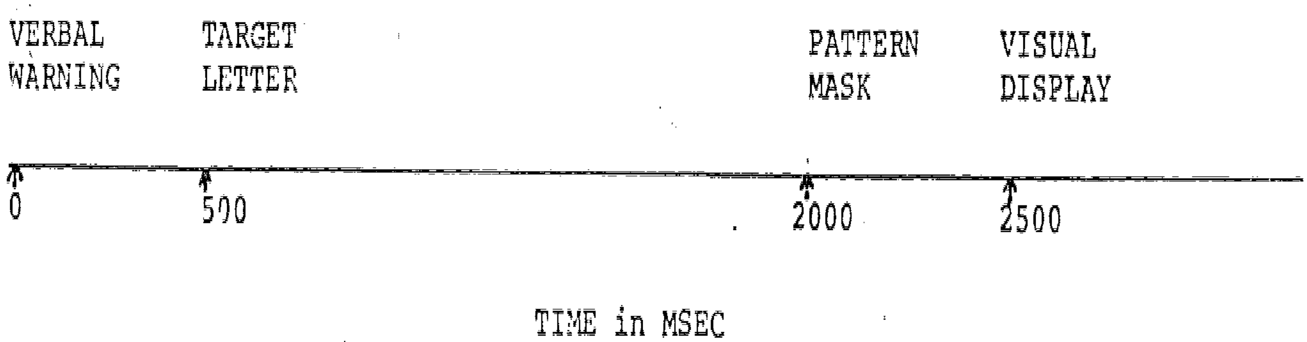
Table III shows mean response times for each type of visual display separately for each grade level. For kindergarten subjects there were no significant differences between any of the three display types. For fourth graders response times to word and pseudoword displays were equal and both were responded to faster than nonword displays. The response time data for the adults was identical to that of the second and fourth graders except that the difference in response times for pseudoword and nonword displays did not quite reach significance. Thus, by the middle of the second grade children have developed the ability to use redundant orthographic information to facilitate the processing of word and pseudoword displays. In addition, we can localize this difference in processing time into the initial encoding stage since the slopes of the best-fitting lines of response time plotted as a function of display size are equal for word, pseudoword, and nonword displays. It would therefore seem that once the visual display has been encoded, that the remaining stages of processing are identical for the three different display types.

Since there were no significant interactions involving display type and display size, Figure IV shows mean response times averaged across words, pseudowords and nonwords for both positive and negative decisions plotted as a function of display size. The data are shown separately for each grade level. As can be seen, response time decreased with age and increased in a linear fashion as display size increased. In addition, positive decisions were faster than negative decisions. There was also a significant interaction involving grade level, response type, and display size. This interaction can be explained by the fact that there was a highly significant response type by display size interaction for the kindergarten subjects. This interaction was marginally significant for the fourth graders and did not approach significance for either the second graders or the college subjects. Examination of the kindergarten subjects data indicates that the slope of the best-fitting line for negative decisions was exactly twice the slope of the best-fitting line for positive decisions. For the older subjects however, the slopes of the best-fitting lines for positive and negative decisions were approximately equal. We interpret these results as indicating differences in the way that letters are compared between the kindergarten subjects and the older subjects. The pattern of results for the kindergarten subjects is consistent with a self-terminating search strategy. It would appear that kindergarten subjects compared the target letter with each letter in the visual display and responded as soon as a match was found with the target letter. A self-terminating strategy is consistent with the slope of the function for negative responses being exactly twice the slope of the function for positive responses. On the other hand, for the older subjects the fact that response times increased at the same rate for both positive and negative decisions as display size increased indicates that the search might be exhaustive in nature. In other words, it would appear that the older subjects compared the target letter with each letter in the visual display prior to making a response. Whether this search was conducted in a serial or a parallel fashion cannot be determined from our data. Thus, for kindergarten subjects our data are consistent witn an information processing model which involves a letter-by-letter encoding process and a letter-by-letter comparison process which terminates when a match is found. The data from the older subjects is consistent with a model for visual encoding that works with perceptual units which are larger than individual letters. Thus, our data support recognition models that operate on letter cluster or syllable units which are common to both word and pseudoword displays.

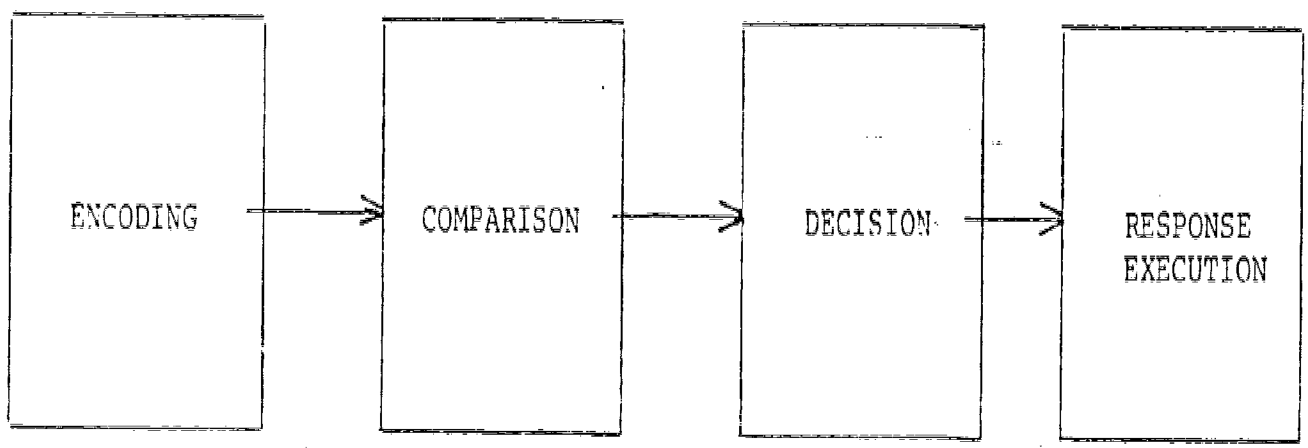
In conclusion, our results can be interpreted as showing developmental changes in both the ability to use the redundant orthographic information found in the English language and in the types of visual search strategies used. It would appear that as reading ability increases that subjects are able to use higher order orthographic information to facilitate the perception of regular letter strings. Recently, within our laboratory Mark

McCaughey has extended the above work to include first grade children. The preliminary results are highly consistent with the present data from our older subjects. However, for the first graders word displays were responded to faster than the pseudoword displays. There were no differences between pseudoword and nonword displays. This pattern of results can be interpreted as indicating that whole word units are being used in the initial encoding stage prior to the use of smaller regular units such as spelling patterns. In addition, as reading skills increase, it would appear that subjects begin to use these smaller perceptual units to facilitate the recognition of orthographically regular letter strings.

EXPERIMENTAL TASK SEQUENCE

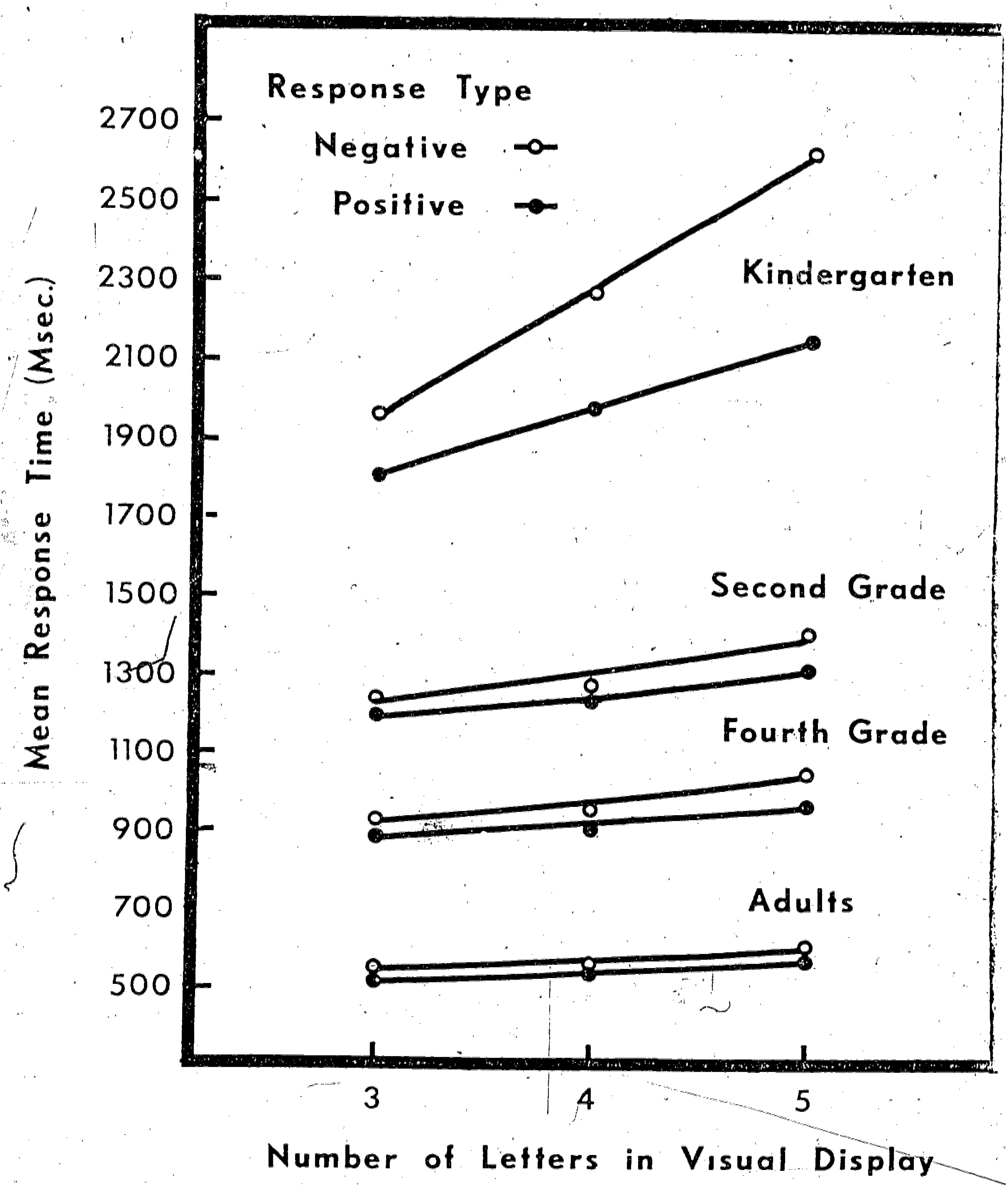


MODEL FOR VISUAL SEARCH PARADIGM



Mean response times in msec for word, pseudoword, and nonword displays for each grade level.

Grade Level	Display Type: Words	Pseudowords	Nonwords
Kindergarten	2128	2112	2104
Second grade	1258	1266	1301
Fourth grade	933	945	967
College	543	553	568



Response Type
Negative
Positive
Kindergarten
Second Grade
Fourth Grade
Adults
Mean Response Time (Msec.)
2700
2500
2300
2100
1900
1700
1500
1300
1100
900
700
500
3
4
5
Number of Letters in Visual Display