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ABSTRACT

Research on the role of visual memory and serial recall in dyslexia is reviewed. Findings touch on feature theory, which proposes that information is held in the form of "features," and that students for example learn to discriminate letters by marking certain identifiable aspects. Other studies are described which focus on speed of processing visual information, verbal encoding of the symbols, confusion from phonetic characteristics, serial recall, and temporal order recall in nonverbal tasks. Critiques of the studies' assumptions and methodologies are presented. It is concluded that good and poor readers' differences in memory span and sequential ordering can be explained by linguistic terms and traced to dyslexic readers' verbal inadequacies in labeling, rehearsal, or chunking. (CL)

Dyslexia: The Effects of Visual Memory and Serial Recall

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Dyslexia: The Effects of Visual Memory and Serial Recall

Many researchers provide evidence that visual memory is deficient in poor readers. Norman (1972), stated "visual memory can be retained indefinitely by active rehearsal of those images." Posner, Lewis, and Conrad (1972) support its importance by stating "visual form can be classified as a member of a complex subsystem without first activating its name." In other words, verbal encoding of material is not necessary. Thus, if poor readers differ from good readers on measures of visual memory, this would indicate a dysfunction at the short term memory level. Problems might occur which relate to recoding (chunking), rehearsal difficulties, or exceeding capacity limits. The assumption that reading difficulties might be due to visual memory problems does make intuitive sense in that reading requires vision, and the incorporation of a visual symbol system. Orton (1925), one of the more renowned advocates of this position, purported that orientation and directional problems often seen with poor readers were due to confusion of mirror images of letters or "engrams" in long term memory, one engram being present in each hemisphere. According to this view, the reversals surface when a child is a victim of mixed dominance, and the correct letter is not chosen.

Recent theory, however, expounded primarily by Gibson and colleagues (Gibson, Gibson, Pick, & Osser, 1962; Gibson, 1971; Gibson & Levin, 1975) state that information, including visual, is held in long term storage in the form of "features". The theory proposes that when a child first begins reading instruction, he or she learns to discriminate between letters. This is done by noticing certain aspects of the letter which identify it.

For example, an "A' has a horizontal straight line intersecting two upright oblique lines. These features remain constant under circumstances such as brightness, size, and perspective. Gibson, Gibson, Pick and Osser (1962) studied feature recognition in children aged four to eight years and found a developmental progression occurring. Devising a set of standardized letter-forms with 12 possible transformations (e.g., rotated, reversed, changed perspective), the task involved matching one of the possible choices with the given standard, while the transformations served as confounders. The following results were obtained:

1. Some transformations were more difficult to discriminate between than others,
2. Discrimination ability improves with increasing age, and
3. Improvement with age occurs at different rates for the various features (i.e., perspective transformations were difficult for all ages, rotations and reversals were more difficult for young children, but rapidly decreased in difficulty).

These results correlate highly (r = .87) with replication experiments involving real letters. It appears as if children learn the critical, or most important features of the letters first, and thus it follows that children would confuse letters with the least amount of distinctive features differentiating between them (e.g., b, d, p, g). When the graphemes become reasonably distinguishable from each other, the child will begin to learn to decode (associate graphic stimulus with its spoken response). This involves mere paired associate learning. The child could also learn to read via the sight word approach, however, that student would be unable to generalize reading rules in order to learn new words. In this vein, Gibson, Pick,

Osser and Hammond (1962) found that pronounceable words (those with a high spelling-to-sound correlation) were more recognizable than those with unusual spelling patterns. As the child progresses in reading, the size of the units used in decoding increase from letter by letter "sounding out" to units involving spelling patterns (clusters of graphemes which have invariant pronounciation according to proper English rules), or recognition of a known word on sight. This is supported by research by Dodge (1905), which demonstrated that perception occurs only during fixations, not during saccadic movements. A fast tachtiscopic presentation which allowed for only one fixation (Cattell, 1885) revealed that a skilled reader is able to perceive four unconnected letters, a long word (e.g., distinguish), or four or more words if they form a sentence. Even first graders can recognize three letter words exposed for only 40 msec. In a similar vein, more recent research, Kolers and Katzman (1963) indicated that letters presented sequentially in the same spot upon a screen are almost impossible to read as one word. It take more than two seconds to recognize a short, well-known word. It appears then that spelling patterns which have invariant relations to sound patterns, function as a unit, and facilitate the decoding process by being more efficient than letter by letter decoding.

Another study by Gibson, Osser and Pick (1963) studied the development of grapheme-to-phoneme correspondence. Comparing end-of-year first graders with end-of-year third graders, and using words, nonsense words, and trigrams (e.g., nar, rna, ran), the researchers found that the first graders spelled tachtiscopically presented words the best, with nonsense words following. Third graders spelled both equally well. The authors concluded that beginning readers read in short units, but have already generalized certain regularities

of spelling-to-sound correspondence. Older readers have internalized more rules, and thus are able to handle nonsense and longer words with greater ease.

Along with the increasing complexity of graphic features, other aspects are involved in a more intricate model of the feature theory, all of which assist students in perceiving words. These features, listed in hierarchical order, are phonology, semantics, and syntax. Their use varies with the age of the reader and the task at hand. Younger children use a phonologically oriented approach, while older readers utilize more semantics and syntax in their reading. In general, readers give top priority to the most efficient strategy for a given task (e.g., using graphic features in searching for a name imbedded in an article). Confusion may result if presentation is very quick (may miss a lower order feature, thus affecting word identification), or if there are conflicting features such as the word "blue" written in red ink. When asked what color ink the word is written in, response time is slowed due to the written word serving as a confounder. Phonologic features have high priority for short term memory (e.g., verbal rehearsal involved in remembering a telephone number), while having a low priority for long term storage (semantics would be used to store information in long term memory). Within the immediate span of visual perception (fixation between saccadic movements) involved in reading, meaning is less effective in structuring written material than spelling-to-sound correspondence (Gibson, Bishop, Schiff & Smith, 1964). Meaning, however, can assist spelling patterns in that a pronounceable meaningful word is perceived best, but a pronounceable meaningless word is still perceived better than meaningful, non-pronounceable trigrams (e.g., IBM). The role of meaning increases as longer strings

of words are used, and meaning and syntax take on increased importance in sentence perception.

Lyle and Goyen (1968, 1971A, 1971B, 1973, 1975) performed studies attempting to identify visual memory as a major cause of dyslexia. They state that early reading stages involve letter discrimination and recognition and they relate this to Orton's (1925) engram theory. Goyen and Lyle's (1971) study was concerned with visual recognition of shapes. With 25 dyslexic and 24 normal readers divided into two age groups, two treatments were used; incentive (money and the verbal response "right") and non-incentive. Each treatment was administered to one-half of each age group. For seven year olds, normal readers were more accurate than poor readers on immediate recall for work-like shapes presented for 10 msec. No differences were found for the eight year old group. This replicated results of their earlier study (Lyle & Goyen, 1968). Similar results were found in later research (Lyle and Goyen, 1973). In another 1971 investigation, the authors found no differences in a six-seven year old age group. They suggest that the earlier results could have been a result of the brief presentations or were perhaps due to high similarity among items. Their most recent research (Lyle and Goyen, 1975) dealt with recognition of rectangular shapes at three different exposure durations (10 msec., 1 sec., 5 sec.). The dependent variable was recognition on a same/different basis. Normal readers performed more accurately on the 10 msec. and 1 sec. presentations, but not on the 5 sec. presentation. The researchers concluded that speed of processing visual information distinguished poor from good readers, not short term memory or form discrimination. They also suggested that a perceptual deficit associated with a maturational lag may result in a reading disability.

Vellutino (1980) criticized the Lyle and Goyen studies for obtaining conflicting results on measures of visual perception and memory, drawing unwarranted conclusions from the obtained results, and for methodological shortcomings (e.g., how does one identify a dyslexic child in first grade, and if possible, how can one be sure that the child will not learn the necessary reading skills as he matures?). Vellutino also criticizes most of the other research performed with respect to visual memory for not controlling for possible verbal encoding of items. Letter and digit tasks could have involved a verbal strategy for placement in memory. This is Vellutino's contention; that when reading, one works with verbal material and that the figures on the page are translated into verbal units, not visual, for storage. He and his associates conducted research which investigated visual memory, and later, in other studies, controlled for previous experience with letters and words.

Vellutino, Steger and Kandel (1972), and Vellutino, Smith, Stager, and Kaman (1975) studied poor and normal readers aged 7-14 years. They found poor readers performing better on visual reproduction (copying) of three to five letter words than on pronunciation of those words. Often, words were spelled graphically correct after those words were just mispronounced. Orientation, sequence, substitution, addition, and omission errors were found in the same frequency for both poor and normal readers. This equivalence to normals in visual memory is said to indicate that written reversal production is due to verbal labeling rather than being a visual organization problem. It appears as if poor readers are able to copy adequately from memory, but if required to write spontaneously, difficulties become apparent due to a lack of adequate verbal strategies.

Vellutino related his results back to Gibson's (1962) theory of word perception. Different tasks had required subjects to focus on either visual or verbal components of the words, thus prompting encoding into one or the other medium. The hierarchy of strategies that were used varied according to the task at hand, and attendance to one set of figures momentarily blocked out others. Vellutino then related his findings to the dual-memory storage model which purports interaction between the two systems, i.e., letter and word recognition involves integration of the visual and verbal (spelling-to-sound) storage systems. He suggested that poor readers have selective difficulties in grasping the verbal counterpart of written words.

The two studies cited contained letters and words in the testing. To determine the effects of visual memory, Vellutino, Pruzak, Steger & Meshoulam (1973) conducted research involving the Hebrew orthography. In this study, the researchers used good and poor readers who were not familiar with Hebrew, and a third group of normal readers learning to read the Hebrew orthography. When requested to copy these words from visual memory, the two non-Hebrew reading groups scored equally and were worse on performance than the Hebrew readers. In another endeavor, Vellutino, Steger, DeSetto and Phillips (1975) again presented Hebrew words to good and poor readers, and compared them with a Hebrew reading group as a control. The groups were asked to demonstrate retention by recognizing randomly presented Hebrew letters under three temporal conditions: immediately, after 24 hours, and after six months. They found the non-Hebrew groups to be equivalent under all temporal conditions (equal on short and long term visual memory). They also found both non-Hebrew groups performing worse than the Hebrew group on the immediate and 24 hour conditions. This, they reported, provided

evidence that poor readers, in general, do not possess an inferiority in long or short term memory for visual forms. The authors also reported scanning differences with Hebrew readers scanning right to left, and non-Hebrew readers viewing left to right. This, according to Gibson (1962) is a culturally learned phenomenon. Regarding these consistent scanning patterns, the authors suggested that erratic or regressive scanning in some poor readers may be a result of, not a cause of, dyslexia. Lastly, no differences were discovered between good and poor readers on sequential or orientational errors as one would expect if subscribing to Orton's (1925, 1935) view. The authors concluded that poor readers are not deficient in visual memory for either long or short term memory, and that differences between Hebrew and non-Hebrew readers on Hebrew orthography can be explained by the Hebrew reader's knowledge of the language, familiarity with the figures, and verbal encoding of symbols.

Two other studies (Vellutino, Steger, and Pruzek, 1973; Vellutino, Phillips, and Steger, 1975), support the view that dyslexia is a visual-verbal problem rather than being strictly visual in nature. Vellutino, et al. (1973) found no difference between good and poor readers in grades 4, 5, and 6 on non-verbal association learning in both visual and auditory modalities. There was also no difference on visual-auditory inter-sensory learning tasks using non-verbal stimuli. The second study (Vellutino, et al., 1975) compared poor and normal readers in fourth, fifth, and sixth grades on visual-visual and visual-verbal learning tasks. Poor readers demonstrated inferior performance on visual-verbal, but not visual-visual tasks. The authors suggested, after a review of both studies, that a problem in visual-verbal learning may result in a reading disability.

Liberman and Shankweiler (1978) asked children to recall linguistic nonsense syllables, nonsense designs, and photographs of faces. Neither of the non-linguistic tasks differentiated between the good and poor reading groups. There were, however, significant differences on the linguistic task, with poor readers performing worse than good readers. It appears as if good readers encoded phonetically, which served as a more effieicnt strategy for holding items in short term storage.

Liberman, Shankweiler, Orlando, Harris and Berti (1971) found that sequence reversals (was for saw), and orientation errors (b for d) accounted for only 25% of the mistakes on a list of 60 easily reversible mono-syllable words. Moreover, some poor readers reversed while others didn't, and the error categories were not stable. Liberman and her associates found no correlation between sequential and orientational errors, contrary to what might be predicted by directional confusion theories such as Orton's (1925).

Shankweiler, Liberman, Mark, Fowler, and Fischer (197) found that superior second grade readers were more confused by phonetic characteristics than less able readers. In this experiment, superior readers, marginal readers (one-half year behind grade level) and poor readers (one year behind grade level) were presented with visual and auditory presentation of similar sounding letters in a letter string. Superior readers performed worse than the other groups in both sensory modalities, and a 15 second delay increased the difficulty for this group. The conclusion drawn was that good readers experienced more confusability due to their superior phonological coding ability.

Serial recall is another area involved with memory. It involves having a person remember a presented series of digits, letters or figures.

One sees such tasks on a variety of standardized tests. This inclusion on tests is not due to a belief that poor reading results from an inability to repeat digits, rather, these series are designed to test mental processes. When comparing good and poor readers on these tasks, the influence of verbal encoding skills again becomes apparent.

Serial recall is basic to reading. Consider that word recognition and sentence comprehension involve integration of units which are presented as serially organized input. Serial recall difficulties in children are evident in everyday life; phoneme reversals in speech (e.g., ephalent for elephant), sequence errors during alphabet recitation (e.g., A, B, D, C), and mistakes in ordering the days of the week.

Research in the area of serial recall almost invariably indicates poor performance by dyslexics on both gross recall of items, and sequential ordering. A number of researchers have attempted to identify the variables which effect serial recall. Spitzer (1976) attempted to research a variety of aspects with normal readers aged five to eleven years. Four to seven items were presented sequentially. The children were presented with pictures (visual modality), or picture names (auditory modality), and were asked to press a button which corresponded to the position of the item instructed to be recalled. Results showed that visual presentation promoted better recall. This is at variance with other studies (cited in Spitzer, 1976), but those studies usually asked for a verbal rather than a motor response. Recency and primacy effects were also noted. Spitzer explains that the earlier items received additional rehearsal time, placing them in long term memory, while the last items presented were still in short term storage. The middle items were lost in the confusion. Atkinson and Shiffrin (1968)

also found that recall performance varies with serial position in adults, but found no primacy effect in children. They insist that this is due to the children's ineffective rehearsal strategies. The last items would still be in short term memory, but the earlier items were lost due to poor rehearsal. Spitzer (1976) also found a similar developmental change, that better recall for early and middle items appeared with increasing chronological age. Time differences in recall were also noted, with quicker response to later items (still in short term storage) and more delayed response to earlier items, presumably due to the child's having to search through his/her memory. This last point is supported by McCauley (1976), who states that when matching a stimulus to a previously presented set, the person must encode the stimulus into the form in which the set is already encoded. The person serially reviews that set and as it becomes longer, the search time lengthens. Kavanagh (1977) states that 250 msec. is required to scan all information in short term memory, but when dealing with long term storage, a longer search period is necessary.

In one study, Tarver, et al. (1976) found normal readers performing better than dyslexics in recalling items in the primacy positions. This, said the researchers, showed the superiority of verbal mediation used by the normal readers. They also found older dyslexics performing better than younger dyslexics, thus demonstrating a developmental increase in effectiveness of their verbal strategy.

In a second study, Spring and Capp (1976) measured the elapsed time required for normal readers and dyslexics to name a sequence of digits and concrete objects. Normal readers had superior performance on both tasks. Dyslexics and normal readers were similar on recency items, yet

there was a significant difference on primacy items. The authors concluded that long term memory is impaired in poor readers. They reported that long term memory is correlated with slow speed of encoding, with this slow encoding limiting rehearsal, or blocking it completely by requiring the dyslexic reader to spend too much time on attempting to label an item.

Only one researcher dealing with serial memory has attempted to relate a sequencing problem to dyslexia. Bakker (1972) purports that "temporal order perception" difficulties are a major cause of dyslexia...these difficulties being an inability to place items in the order in which they were presented in time (e.g., the production of "ephelant" for "elephant"). His theory is based on the work of Hirsh (1959, 1961) who demonstrated that a certain time interval (20 msec.) is needed to distinguish between two tones. Hirsh felt that problems in speech perception could be due to a dysfunction in the speed of processing acoustic stimuli (not having encoded an item by the time that the next one is presented). The left hemisphere being dominant for language, Bakker theorized that reading problems are caused by a left hemisphere dysfunction which results in a deficiency in temporal order perception. The emphasis here was on the relationship between time and the verbal code.

Earlier in his career, Bakker (1967) believed that temporal order difficulties were due to verbal encoding problems as he found dyslexics making more errors than normal readers on sequencing verbal material (i.e., meaningful figures and letters), but performing well on non-verbal tasks. In 1972, he changed his orientation. In one study (Bakker, 1972A), Bakker found an age difference on visual-auditory tasks (naming in order items visually presented in a sequence). There was a strong correlation between

scores on the visual-auditory tasks and the visual-visual tasks, and later reading achievement. He concluded that preschool temporal order scores could be used to predict future reading ability. Vellutino (1980), however, reveals that when I.Q. scores are compensated for, there is almost no relationship between temporal order scores and a child's future reading achievement.

In a second study, Bakker (1972B) presented sets of letters via haptic, visual and auditory modes to children who were asked to identify where two of the three letters in the set were located. He found age differences, and girls performing better than boys at the younger ages. Poor readers as a group were also found to be less proficient than normal readers on the tasks. Bakker then compared 14 poor readers with the same number of normal readers, and found the good readers to be better on temporal recall. This finding, along with the lack of relationship between temporal recall and reading ability in the girls' group, led him to conclude that there is a "critical period" for this relationship, and that girls pass through this phase earlier due to their advanced maturity. Vellutino (1980) found these conclusions to be based on weak evidence and variable results. He believes that the temporal order recall difficulties may be due to letter naming problems that are evident in poor readers, and which reflect a deficient verbal encoding strategy.

Zurif and Carson (1970) did claim that they found a correlation between reading achievement and temporal order recall. Non-verbal (auditory tapping, visual light flashing, and auditory-visual) and rhythm matching tasks were used. The authors used non-significant results to support their conclusions, however.

Senf and Freundl (1971), in testing visual and auditory digit span recall, found more gross errors for dyslexics than normal readers, but found no sequential errors in either modality, which is at odds with Bakker's theory. They believe that temporal order recall is processed in the same short term memory as item recall, but perhaps processed differently. Davis and Bray (1975) employed a variation of this study, and did find sequential error differences. Their study, however, contained a number of methodological flaws which may effect the validity of the results.

Corkin (1974), using the Knox Cube Test which required a child to reproduce a sequence tapped on blocks (immediate recall and six second delay), found that good and poor readers were different on the delayed recall task, and the good readers were also superior on sequencing of a string of three to nine digits which were presented aurally. Corkin suggested that these differences might be due to the mnemonic strategies used by the students. The author supports generalized deficiencies for serial processing in dyslexic readers. Vellutino (1980), however, criticized this research due to the poor methodology used (poor readers were chosen by teachers and no I.Q. test was given to the subjects).

Kastner and Richards (1974) tapped blocks with either familiar or novel stimuli drawn on them, and asked children to repeat that tapping order. They found no difference between good and poor readers on familiar stimuli (drawings of flags, moons, owls), but did obtain differences with novel stimuli (line drawings). The authors watched for verbal rehearsal strategies they had used. They found normal readers using verbal strategies, while poor readers used the visual mode to memorize novel stimuli. They concluded that poor readers were unable to use a consistent verbal encoding strategy, and thus switched to visual maneuvers for new stimuli. The study

can be criticized however, for failing to employ an I.Q. control, for use of a questionable reading measure, and for asking the children about the strategies used.

After finding no differences between good and poor readers on serial recall for English and Hebrew words, numbers, or geometric designs, with the exception of when the number of items in a given stimulus exceeded the upper limits of short term memory, Vellutino (1980) proposed that item and order difficulties might possibly occur when incoming items which tax memory are not coded and chunked into more economical units for short term memory storage. Senf and Freundl (1972) agree with this viewpoint and can extend their findings to the auditory as well as the visual modality.

Bakker's contention that poor readers possess a deficiency in temporal order processing, or a general disorder in sequential ability, can also be criticized by recent work in the area of information processing. Rather than order and gross recall structures constituting separate entities in the central nervous system, as Bakker (1972) believes, Conrad (1971, 1972) states that order and item are not distinguishable. In a vein similar to Gibson's (1962) feature theory, he contended that order errors were due to item features decaying in short term memory. Items, according to Conrad, are stored in short term storage in the order in which they are perceived, and would be recalled in that order if they hadn't decayed and been mistaken for, and sequentially transposed with, a similar item. Conrad found that visually presented letters which sounded alike were more often transposed upon being written down than letters which were not phonologically similar. He found that white noise made similar sounding letters more phonologically alike by erasing features. Conrad compared this with the result of decay

in memory. He also found that in immediate recall for six letter sequences, 83% of the transposed letters were acoustically similar. Positions four and five were most often confused, indicating primacy and recency effects. Conrad concludes that serial order and item recall are interdependent functions.

A number of studies would disagree with Conrad, asserting that item and order information are separable components of short term memory, and that using one component interferes with the other, thus causing errors. Vellutino (1980) suggested that the issue is still open, and suggests that perhaps a variety of cognitive functions are employed in storing and retrieving information. Healy (1975) provided evidence for the viewpoint that different coding strategies are used for different tasks: phonemic coding for temporal order recall, temporal-spatial patterns for spatial order recall, a combination of the two for many complex tasks, and use of alternative strategies to encode if necessary. Upon reviewing this and other information, Vellutino (1980) stated that any theory which has identified a certain deficient with a certain problem is questionable.

Bakker's (1972A, 1972B) views can also be questioned on other grounds. Hirsh's (1959, 1961) theory, to which Bakker related his findings, stated that elements of an acoustic signal are processed separately. Liberman, Cooper, Shankweiler and Studdert-Kennedy (1967), however, found that speech perception was a detection of larger patterns. Vellutino's (1980) analysis of the existing information lead him to criticize general deficient hypotheses as being too general, and modality specific deficiencies in serial order recall as being too specific and complicated.

To summarize, there are differences in memory span and sequential ordering between good and poor readers. These findings were explained

in linguistic terms and can be traced to the dyslexic readers' verbal inadequacies, either in labeling, rehearsal, or chunking.

References

Arabie, P. Multidimensional scaling study of visual memory of five year olds and adults. Journal of Experimental Child Psychology, 1975, 19, 327-345.

Atkinson, R. C., & Shiffrin, R. M. Human memory: A proposed system and its control processes. In K. W. Spence and J. T. Spence (Eds.), The psychology of learning and motivation (Vol. II). New York: Academic Press, 1968, 89-195.

Bakker, D. J. Temporal order, meaningfulness, and reading ability. Perceptual and Motor Skills, 1967, 24, 1027-1030.

Bakker, D. J. Temporal order perception and reading retardation. In D. J. Bakker and P. Satz (Eds.), Specific reading disability: Advances in theory and method. Rotterdam: Rotterdam University Press, 1970, 81-96.

Bakker, D. J. Temporal order in disturbed reading, developmental and neuropsychological aspects in normal and reading-retarded children. Rotterdam: Rotterdam University Press, 1972.

Baumeister, A., & Maisto, A. Memory scanning by children: Meaningfulness and mediation. Journal of Experimental Child Psychology, 1977, 24, 97-107.

Bernbach, H. A. The effects of labels on short-term memory for colors with nursery school children. Psychonomic Science, 1967, 7, 149-150.

Berry, M. F. Language disorders of children. Englewood Cliffs, NJ: Prentice Hall, 1969.

Bruner, J. S., Oliver, R. R., & Greenfield, P. M. Studies in cognitive growth. New York: Wiley, 1966.

Bryan, T., & Bryan, J. Understanding learning disabilities. New York: Alfred, 1975.

Camp, B. W., & Pahlem, N. W. Paired associate and serial learning in retarded readers. Journal of Educational Psychology, 1975, 67, 385-90.

Cattell, J. M. Ueber die zeit der erkennung und benennung von schriftzeichen bildern un farben. Philosophische Studien, 1885, 2, 635-650.

Christal, R. E. Factor analytic study of visual memory. Psychological Monographs (Vol. 72), 1958, 13, 1-24.

Conrad, C. Cognitive economy in semantic memory. Journal of Experimental Psychology, 1972, 92, 149-154.

Conrad, R. The effect of vocalizing on comprehension in the profoundly deaf. British Journal of Psychology, 1971, 62, 147-150.

Corballis, M. C., & Zallik, M. C. Why do children confuse mirror image obliques? Journal of Experimental Child Psychology, 1977, 24, 516-523.

Corkin, S. Serial-ordering deficits in inferior readers. Neuropsychologia, 1974, 12, 347-354.

Dirks, J., & Neisser, V. Memory for objects in real scenes. Journal of Experimental Child Psychology, 1977, 23, 315-328.

Davis, S. M., & Bray, N. W. Bisensory memory in normal and reading disability children. Bulletin of the Psychonomic Society, 1975, 6, 572-574.

Dodge, R. The illusion of clear vision during eye movement. Psychological Bulletin, 1905, 2, 193-199.

Eccles, J. C. The neurophysiological basis of mind. Oxford: Clarendon Press, 1953.

Flavell, J., Beach, D., & Chinsky, J. Spontaneous verbal rehearsal in a memory task as a function of age. Child Development, 1966, 37, 283-299.

Flavell, J., & Wohlwill, J. F. Formal and functional aspects of cognitive development. In D. Elkind and J. M. Flavell (Eds.), Studies in cognitive development. New York: Oxford University Press, 1969.

Gibson, E. J. Principles of perceptual learning and development. New York: Appleton-Century-Crofts, 1969.

Gibson, E. J. Perceptual learning and the theory of word perception. Cognitive Psychology, 1971, 2, 351-368.

Gibson, E. J. Reading for some purpose. In J. F. Kavanagh and I.G. Mattingly (Eds.), Language by ear and by eye. Cambridge, Mass: MIT Press, 1972.

Gibson, E. J., Bishop, C. H., Schiff, W., and Smith, J. Comparison of meaningfulness and pronounceability as grouping principles in the perception and retention of verbal material. Journal of Experimental Psychology, 1964, 67, 173-182.

Gibson, E. J., Farber, J., & Shepela, S. Test of a learning set procedure for the abstraction of spelling patterns. Project Literacy Reports, 1967, 8, 21-30.

Gibson, E. J., Gibson, J. J., Pick, A. D., & Osser, H. A developmental study of the discrimination of letter-like forms. Journal of Comparative and Physiological Psychology, 1962, 55(b), 897-906.

Gibson, E. J., & Levin, H. The psychology of reading. Cambridge, Mass: MIT Press, 1975.

Gibson, E. J., Osser, H., & Pick, A. D. A study of the development of grapheme-phoneme correspondences. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 142-146.

Gibson, E. J., Pick, A., Osser, H., & Hammond, M. The role of grapheme-phoneme correspondence in the perception of words. American Journal of Psychology, 1962, 75, 554-570.

Glanzer, M., & Clark, W. H. Accuracy of perceptual recall: An analysis of organization. Journal of Verbal Learning and Verbal Behavior, 1963, 1, 289-299.

Goyen, J. D., & Lyle, J. Effect of incentives and age on the visual recognition of retarded readers. Journal of Experimental Child Psychology, 1971, 11(a), 266-273.

Goyen, J. D., & Lyle, J. Effect of incentives upon retarded and normal readers on a visual-associate learning task. Journal of Experimental Child Psychology, 1971, 11(b), 274-280.

Goyen, J. D., & Lyle, J. Short-term memory and visual discrimination in retarded readers. Perceptual and Motor Skills, 1973, 36(2), 403-408.

Grimmett, S. A. Enooding and decoding in memory. Viewpoints, 1975, 51, 82-92.

Hagen, J. W., Jongeward, R. H., & Kail, R. V. Cognitive perspectives on the development of memory. In H. W. Reese (Ed.), Advances in child development and behavior (Vol. 10). New York: Academic Press, 1975, 57-101.

Hayes, D. S., & Schidze, S. A. Visual encoding in preschoolers' serial retention. Child Development, 1977, 48, 1066-1070.

Healy, A. F. Coding of temporal-spatial patterns in short-term memory. Journal of Verbal Learning and Verbal Behavior, 1975, 14(a), 481-495.

Healy, A. F. Short-term retention of temporal and spatial order. Bulletin of the Psychonomic Society, 1975, 5(1b), 57-58.

Hirsh, I. J. Auditory perception of temporal order. The Journal of the Acoustical Society of America, 1959, 31, 759-767.

Kastner, S. B., & Rickards, C. Mediated memory with novel and familiar stimuli in good and poor readers. The Journal of Genetic Psychology, 1974, 124, 105-113.

Kavanagh, J. F., & Mattingly, I. G. Language by ear and by eye. Cambridge, Mass: MIT Press, 1977.

Kee, D. W., & White, B. R. Childrens' noun-pair learning. Child Development, 1977, 48, 674-677.

Kirby, R., & Dos, J. P. Information processing and human abilities. Journal of Education Psychology, 1978, 70, 58-66.

Kintsch, W. Learning, memory and conceptual processes. New York: John Wiley & Sons, 1977.

Kolers, P. A., & Katzman, M. T. Naming sequentially presented letters and words. Language and Speech, 1966, 9, 84-95.

Koppitz, E. M. Bender Gestalt test, visual aural digit span test and reading achievement. Journal of Learning Disabilities, 1975, 8, 154-157.

Kosslyn, S. M. Childrens' drawings as data about internal representations. Journal of Experimental Child Psychology, 1977, 23, 191-211.

Levie, W. H., & Levie, D. Pictorial memory processes. AV Communication Review, 1975, 23, 81-97.

Liberman, A. M., Cooper, F. S., Shankweiler, D., & Studdert-Kennedy, M. Perception of the speech code. Psychological Review, 1967, 74, 431-461.

Liberman, I. Y., & Shankweiler, D. Speech, the alphabet and teaching to read. In L. Resnick & P. Weaver (Eds.), Theory and practice of early reading. New York: John Wiley & Sons, 1978.

Liberman, I. Y., Shankweiler, D., Fischer, F. W., & Carter, B. Explicit syllable and phoneme segmentation in the young child. Journal of Experimental Child Psychology, 1974, 18, 201-212.

Liberman, I. Y., Shankweiler, D., Liberman, A. M., Fowler, C., & Fischer, F. W. Phonetic segmentation and recoding in the beginning reader. In A. S. Reber and D. Scarborough (Eds.), Toward a psychology of reading - The proceedings of the CUNY conferences. Hillsdale, NJ: Lawrence Erlbaum Associates, 1977.

Liberman, I. Y., Shankweiler, D., Orlando, C., Harris, K. S., and Berti, F. B. Letter confusion and reversals of sequence in the beginning reader: Implications for Orton's theory of developmental dyslexia. Cortex, 1971, 7, 127-142.

Luria, A. R. The role of speech in the regulation of normal and abnormal behavior. Oxford: Pergamon Press, 1961.

Lyle, J. G., & Goyen, J. Visual recognition, developmental lag, and strephosymbolia in reading retardation. Journal of Abnormal Psychology, 1968, 73(1), 25-29.

Lyle, J. G., & Goyen, J. D. Effect of speed of exposure and difficulty of discrimination on visual recognition of retarded readers. Journal of Abnormal Psychology, 1975, 8(6), 673-676.

McCauley, C. Effects of serial rehearsal training on memory search. Educational Psychology, 1976, 68, 474-481.

McNiff, S. A. Art activities for evaluating visual memory. Academic Therapy, 1976, 11, 283-296.

McSpadden, J. W., & Strain, P. S. Memory thresholds and overload effects between L.D. and achieving students. Exceptional Children, 1977, 44, 35-37.

Murray, D. L. Visual recall probe of cognitive structure. Science Education, 1978, 62, 39-40.

Murray, D. J., & Newman, F. M. Visual and verbal coding in short-term memory. Journal of Experimental Psychology, 1973, 100, 58-62.

Norman, D. A. The role of memory in the understanding of language. In J. F. Kavanagh and I. G. Mattingly (Eds.), Language by ear and by eye: The relationships between speech and reading. Cambridge, Mass: MIT Press, 1972.

Orton, S. T. "Word-blindness" in school children. Archives of Neurology and Psychiatry, 1925, 14, 581-615.

Penfield, W., & Roberts, L. Speech and brain mechanisms. Princeton: Princeton University Press, 1974.

Posner, M. I., Lewis, J. L., & Conrad, C. Component processes in reading: A performance analysis. In J. F. Kavanagh and I. G. Mattingly (Eds.), Language by ear and by eye: The relationships between speech and reading. Cambridge, Mass: MIT Press, 1972.

Richie, D. J., & Aten, J. L. Auditory retention of non-verbal and verbal sequential stimuli in children with reading disabilities. Journal of Learning Disabilities, 1976, 9, 312-318.

Riding, N. J., & Pugh, J. C. Iconic memory and reading performance in nine year old children. British Journal of Educational Psychology, 1977, 47, 132-137.

Shankweiler, D., & Liberman, I. Y. Misreading: A search for causes. In J. F. Kavanagh and I. G. Mattingly (Eds.), Language by ear and by eye. Cambridge, Mass: MIT Press, 1972.

Senf, G. M., & Freundl, P. C. Memory and attention factors in specific learning disabilities. Journal of Learning Disabilities, 1971, 4, 94-106.

Sperling, G. The information available in brief visual presentation. Psychological Monographs, 1974, 11 (whole No. 498).

Spitzer, T. M. Development of visual and auditory recall. Child Development, 1976, 47, 767-778.

Spitzer, T. M. Visual and auditory recall as a function of presentation, modality, position, and series size. Child Development, 1976, 47, 767-778.

Spring, C. & Capp, L. Encoding speed and memory span in dyslexic children. Journal of Special Education, 1976, 10, 35-40.

Strauss, A., & Kephart, N. Psychopathology and education of the brain-injured child (Vol. II). New York: Grune & Stratton, 1955.

Swift, J. Visual memory training: A brief history and postscript. Art Education, 1977, 30, 24-27.

Torgesen, J. K., & Goldman, T. Verbal rehearsal and short term memory in reading-disabled children. Child Development, 1977, 48(1), 56-60.

Torgesen, J. K. Performance of reading disabled children on serial memory tasks: A selective review of recent research. Read, 1979, 1, 57-87.

Vellutino, F. R. Toward an understanding of dyslexia: Psychological factors in specific reading disability. In A. Benton and D. Pearl (Eds.), Dyslexia: An appraisal of current knowledge. New York: Oxford University Press, 1978.

Vellutino, F. R., Harding, C. J., Phillips, F., & Steger, J. A. Differential transfer in poor and normal readers. Journal of Genetic Psychology, 1975, 126, 3-18.

Vellutino, F. R., Pruzek, R., Steger, J. A., & Meshoulam, U. Immediate visual recall in poor and normal readers as a function of orthographic-linguistic familiarity. Cortex, 1973, 9, 368-384.

Vellutino, F. R., Smith, H., Steger, J. A., & Kaman, M. Reading disability: Age differences and the perceptual deficit hypothesis. Child Development, 1975, 46(2), 487-493.

Vellutino, F. R., Steger, J. A., DeSetto, L., & Phillips, F. Immediate and delayed recognition of visual stimuli in poor and normal readers. Journal of Experimental Child Psychology, 1975, 19, 223-232.

Vellutino, F. R., Steger, J. A., Harding, C., & Phillips, F. Verbal vs non-verbal paired-associates learning in poor and normal readers. Neuropsychologia, 1975, 13, 75-82.

Vellutino, F. R., Steger, J. A., Kaman, M., & DeSetto, L. Visual form perception in deficient and normal readers as a function of age and orthographic linguistic familiarity. Cortex, 1975, 11, 22-30.

Vellutino, F. R., Steger, J. A., & Kandel, G. Reading disability: An investigation of the perceptual deficit hypothesis. Cortex, 1972, 8, 106-118.

Vellutino, F. R., Steger, B. M., Moyer, S. C., Harding, C. J., & Niles, J. A. Has the perceptual deficit hypothesis led us astray? Journal of Learning Disabilities, 1977, 10(6), 375-385.

Whisler, N. G. Visual memory training in first grade: Effects on visual discrimination and reading ability. Elementary School Journal, 1974, 75, 50-54.

Wooldridge, D. E. The machinery of the brain. Hightstown, NJ: McGraw-Hill, 1963.

Zurif, E. B., & Carson, G. Dyslexia in relation to cerebral dominance and temporal analysis. Neuropsychologia, 1970, 8, 351-361.