DOCTOR OF PHILOSOPHY

Functional analyses of reading and short-term memory in dyslexic children.

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In which the experimental stage is set - populations of fast and slow reading undergraduates, dyslexic undergraduates, dyslexic and control children are tested - it is shown that those subjects fast at processing 5 digits from single fixations are similarly fast at processing a wide range of visual information (reading for comprehension, reading for gist, reading with unhygenic typeface, visual search) - those fast at processing from the VIS tend to have a shorter post-exposure VIS duration - as speed of processing 5 digit arrays from a single fixation reliably differentiates the good and the poor readers tested, it is concluded that a profitable next step in experimentation is to investigate those functions involved in this task.

Introduction

It was argued in Chap.2 that a functional deficiency at any of many levels could result in reading retardation. Since, by definition, the dyslexic person's reading problems cannot be a result of intellectual impairment, and as his vocabulary and comprehension of spoken language appears within normal limits, it is probable that the proposed area of study can be delimited to be the early information processing stages of reading. Further evidence in support of this comes from the fact that the dyslexic's reading problem can be seen even at a single word level, where they find it difficult or impossible to make the overt speech equivalents of 'hard' written words. Thus it is considered promising that this study should concentrate on these early processes rather than those underlying the more complex reading skills involved in sentence analysis and the reading of words in context.

To substantiate this hypothesis it must be demonstrated that there are differences between good and poor readers at processing simple material from a single fixation. There exists some support for this proposition in the work of Gilbert, (1959 a,b) who investigated the differences between good and poor readers in the student population, and demonstrated that fast adult readers could process single words or simple prose material more rapidly and efficiently than slow readers when these stimuli were followed by a masking stimulus. Thus the fast readers could process this simple material in a shorter time (or stimulus onset asynchrony

(S.O.A.) between test stimulus (T.S.) onset and mask stimulus (M.S.) onset) than could the slow readers.

Unfortunately this study does not fully confirm the proposal for the following two reasons:

(i) undergraduates were used as subjects and there is no evidence that the same patterning of results would necessarily be found with younger subjects who are still improving their reading skills.

(ii) the simplest stimuli used were words. Word processing has been demonstrated to be subject to:

a) familiarity/frequency effects (see e.g. Howes and Soloman, 1951 and Tulving and Patkau, 1962).

b) set size effects (see e.g. Miller, Heise and Lichten, 1941, and Fraisse and Blanchetëau, 1962).

c) information content and the effects of sequential letter probabilities (see e.g. Miller, Bruner and Postman, 1954; Shannon and Weaver, 1949; and Salzinger, Portnoy and Feldman, 1962).

d) pronunciability effects (see e.g. Spoehr and Smith, 1973 and Baron and Thurston, 1973).

e) contextual effects (see e.g. Tulving and Patkau, 1962 and Treisman, 1965).

f) grammatical effects (see e.g. Gibson and Guinet, 1971 and Schlosberg, 1965).

g) meaningfulness effects, though this is a matter of current debate (see e.g. Gibson, Bishop, Schiff, and Smith, 1964 and Henderson, 1977).

h) concreteness/abstractness effects (see e.g. Riegel and Riegel, 1961 and Winnick and Kressel, 1965).

Thus the perception of a word is dependant upon its familiarity, its information content, its pronunciability, its degree of meaning, the context in which it is read, whether it is a noun in a verb, and if it is a noun, whether it is concrete or abstract. If, as in the Gilbert (1959 a) study, there is a differential between good and poor readers on word perception, any of these factors could play a causative role in that differential.

Whilst some of these factors, e.g. pronunceability, may be assumed to have their effect at the early stages of information processing, the semantic and syntactic factors may be effective at more central or deeper levels of processing yet might nevertheless have resulted in Gilbert's differential findings.

There is thus a need for direct evidence that that good and poor readers differ in their ability at processing information which, if not completely devoid of these higher level semantic or syntactic properties, contains them at a much reduced level.

There is also considerable evidence that good and poor readers differ in respect of almost all measures of eye movements. Taylor (1957) showed that 6 year old children with a measured average rate of comprehension of 75 words per minute (w.p.m.) had an average span of recognition of 0.42 words and an average duration of fixation of 0.33 sec. Span of recognition increases and duration of fixation decreases pari passu up to the levels of college adults who had an average rate of comprehension of 340 w.p.m., an average span of recognition of 1.33 words and an average duration of fixation of 0.23 sec. Similarly, Tinker (1965) demonstrated that the number of regressions decreases markedly from the first to fourth grades.

Anderson (1937) compared the eye movements of 50 good and 50 poor undergraduate readers. He found that there were differences between the groups on i) duration of fixation, ii) size of fixation, iii) mean extent of forward shift per saccade, iv) number of regressions per line, and v) reading rate. The good readers also showed a greater flexibility of eye movements in adjusting to increasingly difficult material.

The eye movements of dyslexic children have also been shown to differ markedly from those of normal readers. Lesèvre (1964) found that 22 dyslexics showed more ocular instability than her controls, slower oculomotor reaction time, a greater number of short pauses, and a greater number of 'mouvements oculaires inutiles' (see Critchley, 1970). Dossetor and Papaioannou (1975) similarly demonstrated that the saccadic reaction time of 6-15 year old dyslexic children was significantly longer than that of 10 age and sex matched control children. Finally of relevance here is the work of Pavlidis (1978) who demonstrated that the dyslexic's eyes move across the page in a fashion which is unpredictable from the norms of good readers. The eyes may regress to the beginning of the line at any time, or they may jump forwards a whole line.

There is thus a correlation between reading ability and efficient eye movements. This correlation is not enough, however, to justify the claim of Hildreth (1963) that 'reversals of letter sequence in perceiving certain words are due to faulty eye movements'. It is considered likely that the causality arrow lies not in the direction of 'faulty eye movements' resulting in poor reading but in the reverse direction: as the main differences between good and poor readers in respect of eye movements are that the good readers a) have a shorter duration of fixation, b) process more material from that fixation, and c) make fewer regressions (presumably because that information previously fixated has been efficiently processed, and there is thus no need to re-fixate) it seems plausible that the fast reader demonstrates these superior eye movements because he can process the information from one fixation both faster and more efficiently than the poor reader. Because these studies are essentially correlational in nature, the causality question has not been definitely answered. Thus to forestall any possible argument that differences in processing ability between good and poor readers are attributable to the poor readers having faulty eye movements or having a peripheral anatomical limitation, it is necessary to test that information processing in situations where eye movements do not play a large part.

Therefore, to delimit the area of study to be that of the early stages of visual information processing, it is necessary to directly demonstrate that good and poor readers differ at these stages. To fulfil this aim, information processing ability should be tested in situations where:

1) no eye movements are possible,

2) stimuli are used which would not be preferentially processed by subjects who were more efficient at the higher level analysis of word characteristics.

It is proposed that this is possible if random arrays of digits are used as stimuli. If these are presented tachistoscopically at short exposure times, no eye movements are possible.

Experiment 1a tested adult subjects for 5-digit processing time and investigates whether there are differences between 'fast processors' and 'slow processors' in respect of reading speed, speed of visual search, and the duration over which information is held in the VIS. Experiment 1b investigated whether dyslexic and control children differ in respect of the times they need to correctly process 5 random-digit arrays and the VIS duration of these subjects was again measured.

EXPERIMENT 1a

Abstract

50 students were presented tachistoscopically with arrays of 5 digits, followed by a masking stimulus. They were also tested for speed of reading, for speed of picking out a given digram (tg) from a passage of random letters, and for the duration over which material was held in the VIS. Similar tests were given to 4 students who had been diagnosed as dyslexic.

It was found that those students needing a longer time of digit presentation to respond correctly in the digit task were significantly slower both in the reading tasks and in the digram search tasks. The 4 dyslexic subjects were the slowest of all. The slower digit processors and readers showed a slightly longer mean VIS duration, but this result failed to reach the 5% level of significance.

It is argued that speed of processing from the VIS is one determinant of speed of reading. The results are also compatible with the thesis that dyslexic-type difficulties are a manifestation of some general limitation in processing ability.

Introduction

In this experiment the claim is tested that one determinant of speed of reading is 'speed of information processing'. Following the lead of Sperling (1963, 1967) it is assumed that, in any visual task, stimulus information is held for a limited time in a 'visual information store' (VIS) from which it is transferred in a suitable form to some more central mechanism. It is argued that a pure measure of 'speed of processing from the VIS' is the speed at which subjects can correctly identify tachistoscopically presented 5 digit sequences. The subjects were 50 students with no special history of difficulty over reading or spelling. 4 undergraduates who had been diagnosed as dyslexic were also tested, the intention being to confirm the hypothesis that dyslexic difficulties are the result of slowness at information processing (see Miles and Wheeler, 1974, 1977). Since Stanley and Hall (1973b) found that VIS duration was longer in the case of their dyslexic children than it was for a control group, figures for each of the present subjects in respect of VIS duration were also obtained.

The two main factors which this study investigates are thus:

1) the duration over which material was held in the VIS, and
2) the speed at which information was processed from the VIS.

The theoretical standpoint is that these processes are necessarily involved in reading. The experiment was designed to investigate to what extent each of these processes can determine efficiency at reading, and the part played by them in visual search.

1) The duration over which material is held in the VIS

The visual information store (VIS) is commonly understood to be the store in which incoming visual information is held before further processing takes place (see, for example, Sperling,1963, 1967).

In reading, the duration over which information is held in the VIS ('VIS duration') can be assumed to be determined by two components. The first, under conscious control, is the duration of the fixation pause; the second, which for any given stimulus illumination condition appears constant, is the rapidly decaying post-exposure duration. Eye movement studies have already shown that reading efficiency is related to the former. In contrast, however, the role of the latter in reading has so far not been demonstrated but only inferred from the results of single fixation tachistoscopic studies.

The VIS is assumed to hold visual information both while the stimulus is being fixated and for a brief period thereafter, perhaps around 200 ms. (see Sperling, 1967, and Haber, 1973). Readout processes, such as phonological encoding, visual encoding and semantic analysis, are thought to operate upon the information in the VIS (see Sperling,1967; Coltheart, 1972, and Allport, 1977). Since reading involves both the process of making articulate the printed or written symbols and the analysis of these symbols for meaning, it follows that the information in the VIS constitutes the 'data-base' upon which the reading process operates. VIS duration (i.e. the time during which the information is held in the VIS) must therefore be a relevant factor in the determination of the efficiency of reading: if it is too short the result will be incomplete information analysis; if post-fixation VIS duration is too long, there will be storage of already processed material (which is then effectively functioning as noise) and this material will forwards-mask the next input to the VIS. In other words, the readout processes will be operating on a store which contains new, to-be-analysed information masked by noise residual from the last fixation. It therefore seems likely, as Ellis and Miles (1978) suggest, that there may be a general relationship such that the faster a reader can process from the VIS, the shorter the VIS duration.

To the extent to which the VIS duration is under central control, this proposal has long been confirmed. The input to the VIS is determined by the eye movements which the reader makes, and the fixation pause in reading is the time during which the VIS is being loaded.

The work of Taylor (1957) and of Tinker (1958) has shown that as reading ability developmentally improves so both the fixation span increases and the duration of fixation decreases. Similarly Anderson (1937) has shown that fast undergraduate readers had a larger fixation span and a shorter fixation pause than their peers who were slower at reading. There is thus a trend such that, as reading speed increases, so a larger amount of information is processed in a given fixation pause; this implies that the speed of processing from the VIS is faster. The mean fixation pause being shorter in the fast readers implies that the VIS duration is shorter for fast readers. In confirmation of this, Tinker (1965) has shown that the fixation pause for prose which can be processed easily is reliably shorter than that for harder material such as the prose in a scientific article (mean fixation pauses of 217 ms. and 243 ms. respectively). It follows, therefore, that in so far as VIS duration is under central control it is directly regulated by the speed at which the stored information is being processed.

In contrast there are no grounds for thinking that post-fixation VIS duration is under direct conscious control. After the offset of the stimulus, the VIS has a fast passive decay (Sperling, 1963; Coltheart, 1972) which is affected, not by the type of material being processed, but solely by the illumination levels of the stimulus and post-exposure fields. Post-fixation VIS duration seldom exceeds 300 ms.

While there is no evidence of within-subject control of VIS duration, there is clear evidence of individual differences in post-fixation VIS duration. Gummerman and Gray (1972) determined the time needed by 2nd, 4th and 6th grade students and college adults to process simple stimuli which were followed either by a homogenous white field or by a pattern masking stimulus. The groups performed equally well when the white field followed the stimulus,but the older subjects were more accurate than the 2nd and 4th graders when the pattern mask was used. From the premise that the white field simply degrades the stimuli, whilst the pattern mask stops processing of the VIS stimulus representation, Gummerman and Gray (1972) conclude that the young children's VIS duration is longer than that of older children and adults, but that the young children process the information from the VIS more slowly. In addition Stanley and Hall (1973), by means of a technique which involved the successive presentations of 2-part stimuli, found that the VIS duration was longer in the case of dyslexic poor readers than in the case of good readers. This finding was confirmed by Stanley (1975) when he used the same technique with both monocular and dichoptic presentations.

It should be noted, however, that in contrast to these results, when the VIS durations of dyslexics and controls was measured by Stanley and Molloy (1975) using a variant of the Haber and Nathanson (1968) retinal painting task, no significant difference was found between the 2 groups.

Two areas of the possible involvement of the role of post-fixation visual information storage in reading can be considered. At the end of each fixation the eye makes a saccadic movement to the next locus of fixation. These saccades last on average about 20 ms. which is the equivalent of 6-8% of reading time (Tinker, 1958). While it had been thought that the eye was blind during eye movements (cf. Ditchburn, 1955), some vision has been shown to be possible during saccades. Volkmann, Schick and Riggs (1968) investigated vision for a dot pattern during voluntary saccadic movements. They found that detection decreases to 50% for a flash occurring about 20 ms. before the onset of a 40 ms. saccade and reaches a minimum such that vision of the flash is almost completely absent when it occurs during the saccade. Detection then begins to improve, reaching the 50% point again for a flash occurring about 75 ms. after the onset of the eye movement. Volkmann et al. (1968), in reviewing the available literature on vision during eye movements suggest that there is partial central inhibition during saccades, and they speculate that this might be found to be a result of presynaptic inhibition at the geniculate level. The processing of the material over which the eye is moving is certainly inhibited. Whether this is a result of an inhibition of input to the VIS or readout from that store is unknown. However, it is possible that information in the VIS resulting from the previous fixation survives during the saccade and is thus available for further processing during this period. It is known from tachistoscopic studies, where no eye-movements are involved, that subjects do make use of the residual post-exposure information in the VIS (Sperling, 1963). It is therefore plausible that they will also make use of this information whilst reading; otherwise 6 - 8% of the processing time available in reading would be wastefully unemployed.

Be this the case or no, Haber (1973) holds another view of the importance of visual information storage in reading. He suggests that this mechanism ensures at least ¼ sec. of processing time, a figure which he argues to be the minimum sequential rate for any information processing task.

These possible roles for post fixation visual information storage in reading have not been definitively demonstrated; they are speculations resulting from the generalisation of findings from single-fixation tachistoscopic experiments. It is indeed difficult to imagine how they could be directly tested. If, however, it were possible to replicate the finding of Stanley and Hall (1973) that poor readers had longer VIS durations and if the same poor readers were also found to be slow at other tasks involving processing from the VIS, this would support the claim that the VIS is involved in an important way both in reading and in other processing tasks.

2) <u>The speed of processing from the VIS</u>

The reasons for investigating this have already been stated in the introduction to this chapter. To obtain estimates of speed of information processing it was decided to measure how quickly the subjects could correctly identify a 5-digit sequence from a single fixation. This procedure was adapted on the grounds that it would yield a relatively pure measure of speed of information processing; in particular the results would not be affected, as the reading of words is affected, by individual differences in speed of eye movements, by comprehension load, by familiarity with the material to be read (since all subjects could be assumed to be familiar with the Arabic digit notation), nor by chunkability.

Speed of processing, so defined, is thus the main independent variable in this study. The subject population is then split into fast and slow processers, whose ability in reading and visual search is then compared.

The design was influenced by the following considerations:
(i) Digit Processing Time. It was important to ensure that the results of this test could not simply be explained in terms of eye movements. Since eye movements are involved both in visual search and in reading, it could be argued, in the absence of any control procedure, that any correlation that occured between the two was the result of the ability of the fast readers to make quicker or more efficient eye movements. Now it is true that speed of eye movements bears some relationship to speed of reading, but the main differences between good and poor readers have been found to lie in duration of fixation and in the span of recognition (Anderson, 1937, Tinker, 1946, Gruber, 1962); and these functions are clearly of central origin. To forestall any possible argument, however, it was decided in the case of tachistoscopic presentation of digits to use exposure times which, at least in the case of most students, permitted only one fixation. In conditions designed to approximate to the eye movements of reading with no information uptake Walton, 1957 found that the mean reaction time of the eye for movements varied in the case of adult readers between 170 and 309 ms., with a group mean of 219 ms.; and as 90% of the subjects in the present experiment were responding correctly at exposure times of 100 ms. or less, it follows that the processing of the digits involved one fixation only, no eye movements being possible in this time.

One of the advantages of using digits as stimulus material is that, provided they are randomised, the subjects can do little by way of chunking; and with this source of learning overlay eliminated, the time taken to respond to digit arrays csn be taken to be a relatively pure or basic measure of speed of information processing in contrast with reading or visual search. Therefore the terms 'fast processer' and 'slow processer' (measured in terms of performance on the digit task) are proposed as operational definitions, and with these definitions it becomes an empirical question whether fast and slow processers are or are not fast and slow readers respectively.

A masking stimulus was introduced at various ISIs after presentation of the test stimulus. In the light of evidence supplied by Sperling (1963) it seems that, in the absence of the MS, one is studying what the subject can process in exposure time plus VIS time.

There is controversy about the level at which the MS acts, the two traditional theories being the integration theory (Kahneman, 1968 and Coltheart, 1972) and the interruption theory (Sperling, 1963, 1967). More recent work by Turvey (1973) has lead to the suggestion that the pattern mask interferes with a central decision maker whose role is to decide what information is being signalled by the more peripheral systems which deal with simple physical characteristics. The work of Marcel (1976) and Allport (1976) seems to accord with this idea of the mask interfering with a decision maker or comparator, and they suggest that the mask interferes with and limits the formation of a conscious percept whilst having no effect on unconscious dictionary access and linguistic/semantic analysis. However this controversy may be resolved, it is known that masking limits the processing of information, at least at the conscious level. It follows that if one determines the minimum SOA necessary for correct responding, one is thereby obtaining an indication of the speed at which the TS is being processed. Confidence in the reliability of this procedure is increased by the finding of Dember and Neiburg (1966) that individual differences in the susceptibility to backwards masking are highly reliable; their test-retest rank order correlations were found to be between 0.79 and 0.92.

(ii) Reading. It was decided to test speed of reading over different types of material and different typographies. The following conditions were therefore used:

Condition 1, light non-fiction, with reading for gist;

Condition 2, non-fiction, with reading for comprehension at normal textbook speed;

Condition 3a, light fiction with novel typeface;

Condition 3b, light fiction with novel typeface and 4 spaces between each word;

Condition 4, light fiction with very short (10 pica) line widths.

Conditions 3b and 4 were introduced to impose extra difficulty not through complexity of reading matter (as in Condition 2) but through typeface novelty and the necessary increase in the number of saccadic movements.

(iii) Visual Search Tasks. These were devised on the basis of procedures suggested by Neisser (1963, 1967) and Neisser and Beller (1965). The subjects were required to search for the digram 'tg' in passages of randomly generated lower case letters. 6 passages were used, in which there was systematic variation of a) typography and b) 'word length' (i.e. the number of letters appearing together without a space).

(iv) VIS Duration.. This was measured using a variant of procedures devised by: Eriksen and Collins (1968): Haber and Standing (1969); Haber and Nathanson (1968); Jackson and Dicks (1969); and Stanley and Hall (1973b). The subjects were presented with two distinguishable stimuli separated by very small time intervals, and were asked to say whether these two elements were perceptually continuous or discrete.

SUBJECTS

50 students took part in the experiment. 26 were Psychology undergraduates at U.C.N.W. and 24 were from the local Technical College. 27 were female and 23 male, the age range being 17-25 years.

The rate of reading of these subjects on a light fiction article (Condition 1) ranged from 146 w.p.m. to 613 w.p.m. The group mean was 310 w.p.m. with a standard deviation of 104.

4 male dyslexic students were also tested. All 4 had been assessed at the Dyslexia Unit attached to the University Psychology Department. They were of University standard intellectually but they still had considerable difficulty at spelling as well as demonstrating many of the other typical dyslexic symptoms described by Miles (1975). For these subjects the rate of reading in Condition 1 ranged from 127 to 202 w.p.m., with a group mean of 152 w.p.m. and a standard deviation of 35.

MATERIALS AND PROCEDURE

A. Digit Processing Time

Up to 30 different cards of 5 quasi-randomly generated digits (no digit could appear more than once on any card) were presented successively in an Electronic Developments 3-field tachistoscope. The digits were printed on white card with 28 point Helvetica light Letraset. Cards were presented at a distance of 508 mm. from the subjects' eyes, which gave an illumination at the eye of about 1 lux. Each trial was started with the word 'ready' followed by a fixation cross (illumination at the eye of about 0.15 lux) for 2 sec. The digits followed the fixation cross immediately. On the first trials, where T.S. exposure time was determined, the digits were followed by darkness. On later trials, where 5 digit processing time was determined, a pattern mask made up of a jumble of overlapping digit parts and with an illumination at the eye of approximately 3.0 lux, followed after a given ISI. The effectiveness of the mask was established by the fact that when both mask and digits were presented simultaneously for 2 sec. the digits could not be reported. The subjects were instructed beforehand to report as many of the digits as possible upon TS offset, or, in the case of the masking trials, immediately upon MS offset.

The criterion for correctness was one of identity only. No account was taken of the order of the items in the response array, i.e. the subjects had only to report the correct identity of the 5-item arrays. This decision was taken since it is known that dyslexic subjects,who were to be tested in both experiments 1a and 1b are known to suffer a Temporal Order Perception (TOP) deficit (see e.g. Bakker, 1972), and it was considered desirable at this stage of investigation to study item processing without this possible confounding source of variability.

To determine TS exposure time the subjects, after a short practice, were tested with digit stimuli which were presented for 100 ms. with no following MS. If they were correct on 2 consecutive trials they were then presented with the TS at exposure times of 50 ms. If they were again correct on 2 successive trials at 50 ms. then TS exposure time would be 50 ms. throughout the remainder of the experiment, but if they were incorrect the exposure time would be set at

100 ms. If their responses were incorrect at the initial 100 ms. presentations, they were presented with the TS at exposure times increasing in 50 ms. steps (2 trials per step) until the criterion of 2 correct responses on consecutive trials was satisfied.

This procedure results in the TS exposure time being set at 50 ms. for 70% of the subjects, 100 ms. for 20% of the subjects, and for only 10% was it exposed for over 100 ms.

The procedure for determining the subjects 5 digit processing time was thereafter as follows: a masking stimulus was brought in after an ISI of 100 ms., the ISI then being either decreased in 10 ms. steps until there were 2 consecutive errors, or increased in the same sized steps until 2 consecutive answers were correct. When the results for all 50 subjects were pooled, the median SOA was 128 ms. This was made up of a 50 ms. exposure time, with an ISI of 78 ms. The durations ranged from 50:10 (SOA 60) to 800: 100 (SOA 900).

B Speed Of Reading Tests.

For measuring speed of reading over different types of material the following passages were used:

In Condition 1 the material was an adult level, light non-fiction article of 337 words. The subjects were instructed to read for gist at their normal reading speed.

In Condition 2 a more complex non-fiction article of

292 words was used, which discussed air pollution. The subjects were instructed to read at their normal speed for textbook material and were told to expect a comprehension test after completing the article. Any subject scoring less than 60% on the comprehension test was excluded from the study.

Both Conditions 1 and 2 were photocopies taken from popular paperback books, they were of common line length, typeface and leading.

For Condition 3 a passage from the Neale test of reading was retyped on an IBM electric typewriter with black carbon ribbon. The first half (Condition 3a) was typed with 1 space and 1 degree of leading, the second half (Condition 3b) with 4 spaces and 1 degree of leading. Conditions 1 and 3a were similar light reading material; and the correlation between these 2 tests was .84. This indicates a reliability sufficiently high to justify their use as group tests.

Another passage from the Neale test was used in condition 4, retyped with 1 space and 1 degree of leading, but with a maximum of 3 words per line: the maximum line length was 10 pica.

In all the conditions the first and last words were underlined and the subjects were instructed to read these words aloud so that their reading could be timed. On this basis, reading speeds, expressed in w.p.m., were calculated for each subject in each condition.

C. Digram Search Test

There were 6 conditions in the visual search experiment. Each subject was given a short practice session, which was followed by the 6 conditions in random order of presentation. They were instructed immediately after the command 'now' to search through the passage counting to themselves the number of 'tg's and to report how many there were as soon as they had reached the end. Search times were measured with a stopwatch.

The 6 conditions all contained 240 randomly generated letters, among which there were 10-15 target digrams. They differed in respect of 'word-length' of non-target letters among which the digrams were hidden, which ranged from 30-letter 'words' to 3-letter 'words', and typography.

Search times over all 6 conditions were calculated for each subject.

D Procedure for Obtaining Estimates of VIS Duration

Two part displays - either a cross and a square (Stanley and Hall, 1973b) or a man and a hat were presented in a tachistoscope. They were presented in different fields in such a way that, if both fields were on, the two parts of the pair produced a spatially composite percept, i.e. the cross was in the square or the hat was on the man.

For determining VIS duration, one of the pair was presented for 20 ms., illumination at the eye being approximately 1.5 lux. This was followed, after a period of darkness during the ISI, by the other member of the pair, which was presented at the same exposure time and the same intensity. This sequence took place in a continuous cycle. Initially the ISI was 10 ms., and at this exposure time, when the subjects were asked if the parts formed a composite (e.g. 'Is the cross in the square all the time now?'), they all reported 'yes'. When the ISI was then changed to 1000 ms. and the question repeated, all of them reported 'no'. An ISI of 100 ms. was then used. If the subjects answered 'no', it was decreased in 5 ms. steps, with an approximate interval of 3 sec. in between each step, the subjects being asked to report when the two parts became a composite. Once this had been reported, the ISI was then increased, the subject being asked to state when, for instance, 'the cross was no longer in the square all the time'. This latter procedure was repeated 3 times and an ISI mean taken over all 6 observations. If, when the ISI of 100 ms. was used, the subject answered 'yes', the ISI was increased in 5 ms. steps until he reported that the two parts were no longer composite. It was then decreased until the two parts again appeared composite. This was also repeated 3 times and the ISI mean taken over all 6 observations. The procedures used in obtaining this mean consitute the operational definition of 'VIS duration'.

This technique, which is a variation of the procedure adopted by Stanley and Hall (1973b), resulted in a mean duration, in the two conditions and for all 50 subject, of 70 ms., the range being from 27 to 140 ms. The correlation between the scores of the two conditions was 0.81.

All subjects were tested singly in 40 minute sessions, the tests being given in the following order: 1) 5 digit processing time, 2) reading speed, 3) digram search, 4) VIS duration.

RESULTS AND DISCUSSION

The reading speeds of the 50 subjects are given in table 1:1.

The subjects were divided into 2 populations on the basis of digit processing time. The 20 subjects with the fastest digit processing time are referred to as 'fast processers', and the 20 subjects with the slowest digit processing time are referred to as 'slow processers'. For the purpose of this analysis the mid-range 20% of students were considered to fall clearly into neither of these categories and were therefore not included. Table 1:2 shows

TABLE 1:1

Reading Speed Data for the 50 Students on Different Passages

	Condition	Mean reading speed in w.p.m.	s.d.
1	Light non-fiction, reading for gist	310	104.2
2	Non-fiction, reading for comprehension	234	78.7
3a	Light fiction, reading for gist	229	77.2
3b	As 3a but with 4 spaces between words	199	49.7
4	Light fiction, 10 pica line width	238	61.8
	Mean over all conditions	241	65.3

Spearman's Rank correlations:

Condition 1 : Condition 2 $r_s = 0.77$

Condition 1 : Condition 3a $r_s = 0.84$

Condition 1 : Condition 3b $r_s = 0.81$

Condition 1 : Condition 4 $r_s = 0.83$

TABLE 1:2

Performance of fast and slow processers on 5-digit processing, reading, and digram search tasks, with figures for VIS duration

	Mean 5-digit processing time in ms.	Mean reading speed in w.p.m. (condition 1)	Mean reading speed in w.p.m. (all conditions)	Total digram search time in ms.	VIS duration in ms.
Fastest 40% **of** digit processers N = 20	$\bar{X}$ 82.35 s.d. 15.11	$\bar{X}$ 359.05 s.d. 117.78	$\bar{X}$ 274.95 s.d. 80.01	$\bar{X}$ 160.05 s.d. 16.75	$\bar{X}$ 64.00 s.d. 28.59
Slowest 40% digit processers N = 20	$\bar{X}$ 264.00 s.d. 167.12	$\bar{X}$ 260.00 s.d. 82.32	$\bar{X}$ 204.20 s.d. 50.15	$\bar{X}$ 188.40 s.d. 28.16	$\bar{X}$ 73.95 s.d. 22.92
Mean difference		99.05	70.75	38.35	9.95
t		3.083	3.351	3.603	1.557
p		$p < 0.005$	$p < 0.001$	$p < 0.005$	ns

Correlation between reading speed and digram search time: $r = 0.49$ ($p < 0.001$)

the reading speed in Condition 1, the overall reading speed, the digram search time and the VIS duration for both these fast and slow processer groups. In addition a correlational analysis was performed on the results of al, 50 students participating in this study; the results of this analysis can be seen in table 1:3.

From table 1:1 it can be seen that reading is fastest in the case of gist light non-fiction material (Condition 1), and that it becomes slower if one increases the 'load' with comprehension requirements (Condition 2) or if wasteful eye movements are incurred by the introduction of a 'non-hygenic' (Tinker, 1963) and novel typography (Conditions 3b and 4).

However, the inter-condition correlations range from 0.77 to 0.84. These high values suggest that a fast reader is in general a fast reader, whatever the materials to be read. The highest correlation, that of 0.84, is between conditions 1 and 3a - both light reading for gist. In addition correlations of 0.83 and 0.81 are found between conditions 1 and 4 and between conditions 1 and 3b respectively; these show that a fast reader relative to the general population is still fast, whatever the typography. The lowest correlation, 0.77, is between reading conditions 1 and 2 (reading for gist and reading for comprehension). This is not unexpected since reading for comprehension places a large cognitive demand on the subjects, and efficiency must depend on intelligence, familiarity with the material, etc. These demands are less present in reading for gist, and the 2 conditions can therefore be seen to

TABLE 1:3

Spearman Rank-Order Correlation Matrix for the performance of the 50 students on the various tasks.

A	1.00				
B	.47[a]	1.00			
C	.48[a]	.95[a]	1.00		
D	.64[a]	.47[a]	.49[a]	1.00	
E	.11[d]	.32[c]	.37[b]	.24[d]	1.00
	A	B	C	D	E

Tasks.

A: The time taken to process 5 digits
B: The time taken to read condition 1
C: The time taken to read all the conditions
D: Total digram search time
E: VIS duration

Significance levels.

a: significant correlation at the .001 level
b: significant correlation at the .01 level
c: significant correlation at the .05 level
d: Not significant correlation

tap different skills.

Table 1:2 shows that the results obtained by Stanley and Hall (1973a, b) can be roughly generalised to the adult non-dyslexic population, and that the results obtained by Gilbert (1959a,b) are a foundation for new work, in that not only are the fast processers fast at reading, but they are also fast at processing a wide range of stimuli. The top 40% of the subjects, as determined by speed of processing 5 digits, are significantly faster at both reading the condition 1 passage ($p < 0.005$) and at reading all the passages ($p < 0.005$) than are the 40% of the subjects who were the slower processers. They were also significantly faster at the digram target visual search task ($p < 0.0005$).

Although the trend is towards the faster processers having a shorter VIS duration than the slow processers (64 ms. on average, as compared with 74 ms.), this difference fails to reach the 5% level of significance; and the results, though in the same direction as those of Stanley and Hall, 1973b, must be regarded as inconclusive.

A similar picture is seen in the correlational analysis in table 1:3. There are generally high correlations between information processing ability, as measured by 5 digit processing time, and reading and digram search ability. Reading ability and visual search ability also correlate. Once again, however, VIS duration fails to correlate significantly with either digit processing time or digram search time, and only just reaches a significant correlation with reading performance.

It might be considered surprising, however, if further studies did not demonstrate an inverse correlation between VIS duration and 'speed of processing from the VIS'. This would be a compensation by nature whereby the slow processers could hold information in the VIS for a relatively longer period to allow their slower processing functions sufficient time to work on this information. Indeed, this is proposed as an explanation of the findings of Stanley and Hall (1973b). Also if this were not the case, then with the fast processers, there would be little advantage resulting from being fast at processing from the VIS, since new incoming visual information would be forwards masked by that still held in the store, even though the latter had already been processed.

A practical result follows from these findings. Since the differences between fast and slow readers are still found even in situations where no eye movements are possible, it follows that any policy of training subjects to make quicker eye movements appears to be misguided (cf. De Leeuw, 1965).

In table 1:4 the performance of the slowest 40% of the digit processers is compared with that of the dyslexics. Although the latter sample was small (since relatively few dyslexic sufferers reach university) clear cut differences are nevertheless seen. The slow processers are significantly

TABLE 1:4

Performance of slow processers and dyslexic students on 5-digit processing, reading, and digram search tasks, with figures for VIS duration.

	Mean 5-digit processing time in ms.	Reading speed (condition 1) in w.p.m.	Reading speed (all conditions) in w.p.m.	Total digram search time in w.p.m.	VIS durati in ms.
Slowest 40% of digit processers N = 20	$\bar{X}$ 264.00 s.d. 167.12	$\bar{X}$ 260.00 s.d. 82.32	$\bar{X}$ 204.20 s.d. 50.15	$\bar{X}$ 198.40 s.d. 28.16	$\bar{X}$ 73.95 s.d. 22.92
Dyslexic students N = 4	$\bar{X}$ 450.00 s.d. 100.00	$\bar{X}$ 151.50 s.d. 34.56	$\bar{X}$ 123.80 s.d. 39.85	$\bar{X}$ 250.50 s.d. 15.78	$\bar{X}$ 75.00 s.d. 22.92
Mean difference	186.00	108.50	80.40	52.10	1.05
t*	2.128	2.554	3.00	3.55	
p	$p < 0.025$	$p < 0.01$	$p < 0.001$	$p < 0.001$	ns

* A variance ratio test showed that the homogeneity of variance assumption was upheld in all four conditions.

faster than the dyslexic subjects at 5 digit processing ($p < 0.025$), reading in Condition 1 ($p < 0.01$), reading over all conditions ($p < 0.005$), and visual search ($p < 0.001$). VIS duration is slightly longer for the dyslexic subjects than for the slow processers, but this difference once again fails to reach an acceptable level of significance.

The results given in tables 1:2 and 1:3 are compatible with the hypothesis that one determinant of reading speed is speed of processing from the VIS. If this conclusion were based solely on the existence of significant correlations it would, of course, be invalid. Reading ability, however, is clearly the affect of many different subcomponents, and whereas there can be no reading without processing from the VIS, efficient processing from the VIS does not necessarily result in ability to read. Since speed of processing from the VIS correlates significantly with speed of reading, and as the former is necessarily a component of the latter, it is plausible that speed of processing from the VIS is one of the factors which imposes a limit on speed of reading.

The results shown in table 1:4 are compatible with the hypothesis that dyslexic subjects are handicapped by some special limitations in the speed at which they can process simple information from a single fixation. This being the case, it follows that, to investigate the processes underlying individual differences in reading ability, one profitable area of study can be delimited to be those processes involved in the simple information processing task used in this experiment, viz digit array processing from a single fixation.

EXPERIMENT 1b

Abstract

41 dyslexic boys between 10.4 and 14.4 years old and 41 chronological age and intelligence matched control boys were tested for the speed at which they could correctly report 5 digit arrays which were presented tachistoscopically under backwards masking. The duration over which material was held in the VIS was also determined for these subjects

The dyslexic children needed over 4 times the SOA of the control children to correctly process the 5 digit test stimuli (dyslexic mean SOA 1331 ms., control mean SOA 289 ms.; $t = 11.02$; d.f. 80; $p < .001$). In confirmation of the results of Stanley and Hall (1973b), VIS duration was found to be significantly longer for the dyslexic children (dyslexic mean VIS duration 98.6 ms., control mean VIS duration 81.4 ms.; $t = 3.48$; d.f. 80; $p < .001$).

It is argued that dyslexia involves some special limitation in the ability to process information, and that the longer VIS duration found in dyslexic subjects might be a compensatory mechanism, holding the information in the VIS for a longer period to allow the less efficient read-out mechanisms more time to operate.

Introduction

For the reasons of homogeneity of sample already detailed, the majority of experiments constituting this thesis are to use dyslexic children as a group of reading retardates.

Whilst it might be expected that the findings of Expt. 1a may be generalised to the child dyslexic population, one flaw of Expt. 1a is its unfortunately small dyslexic sample. The findings of this experiment must therefore be confirmed in the dyslexic child population before it can be concluded that in this sample the most profitable area of study is also these functions underlying digit array processing.

Dyslexic children and chronological age matched controls were therefore tested on the 5 digit processing tasks and VIS duration tasks used in Expt. 1a.

Subjects

41 children who had fulfilled all the criteria of dyslexia were tested. These were boys, between the chronological ages (C.A.) of 10.4 and 14.4 years (mean CA: 12.35, s.d. 1.22), with mean RA (Schonell R1) of 9.38 years and mean SA (Schonnel S1) of 8.36 years. They all attended a private school which specialised in the teaching of children with dyslexic handicaps. A control group of children of normal reading ability consisted of 41 boys also attending private schools. These children, matched for CA with the dyslexic sample, were of mean CA 12.30 years (s.d. 1.22), mean RA 12.33 years and mean SA 12.08 years. The children in the two groups showed similar ranges of intelligence,

and no child in either group had an intelligence score of less than 90 as determined using a recognised intelligence scale (in the majority of cases the WISC was used).

Materials and Procedure

For the determination of digit processing time, the procedure of Expt. 1a was unchanged except for the following modification: in the phase where TS exposure time was determined, since these children needed considerably longer than the adults of Expt. 1a to process the 5 digit arrays, if the subjects were still unable to correctly identify the arrays at the 300 ms. TS exposure time, the exposure time was thenceforth increased in 100 ms. steps rather than the 50 ms. increments used in Expt. 1a.

The procedure and materials for the determination of VIS duration was identical to that previously used in Expt. 1a.

Results and Discussion

A) Digit Processing Time

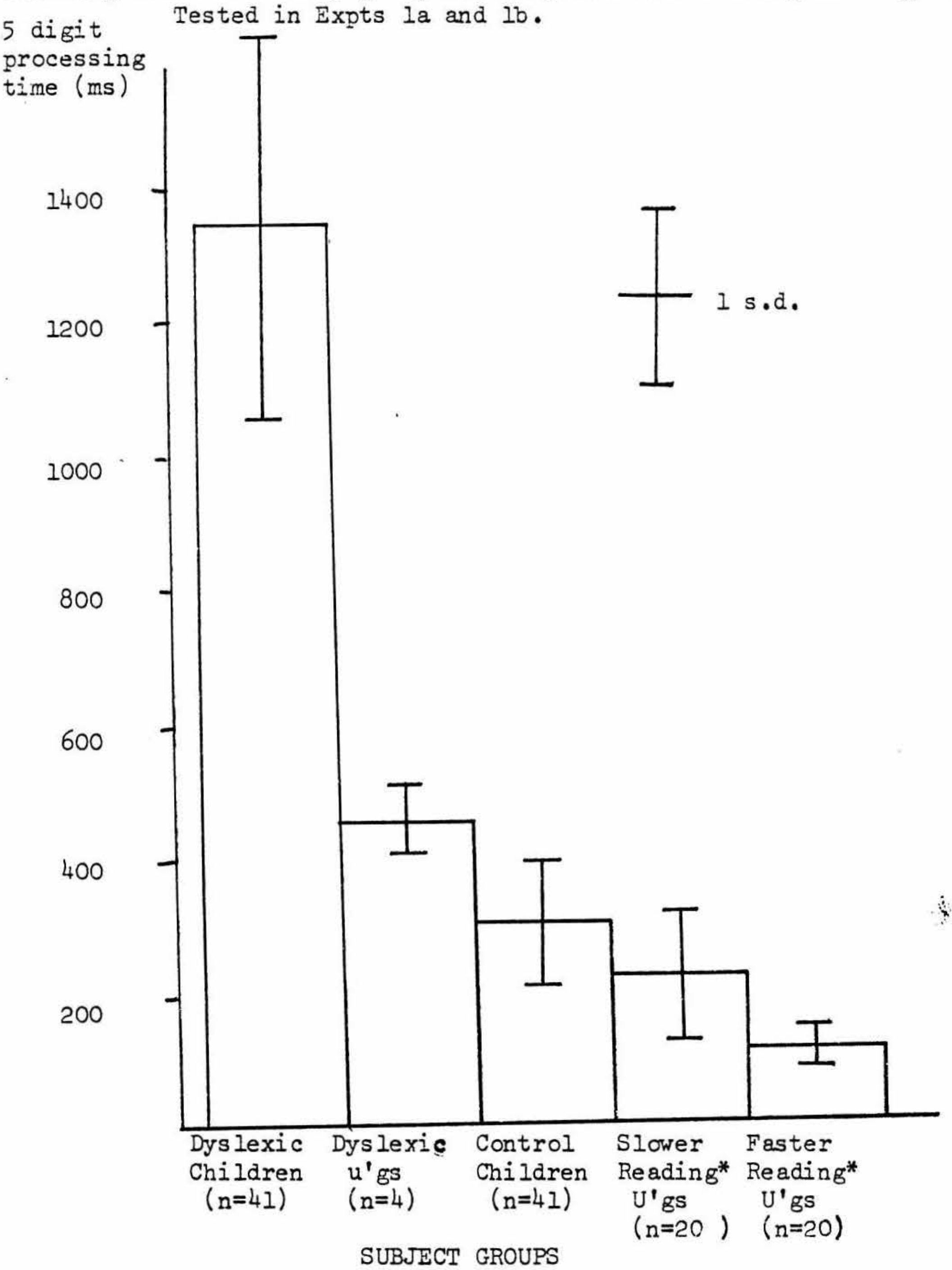
Highly significant ($t = 11.05$, d.f. 80, $p < .001$) group differences resulted: the dyslexic children (mean SOA 1331 ms., s.d. 585) needed over 4 times the SOA of the control children (mean SOA 289 ms., s.d. 156) to process the 5 digit arrays. This difference is mainly attributable to TS exposure time. Mean TS exposure time was 815 ms. for the dyslexics (s.d. 605) and 118 ms. for the control children (s.d. 111), $t = 7.26$, d.f. 80, $p < .001$.

This also demonstrates that the control children were processing the arrays from one fixation. Adult readers, as shown by Walton (1957), have a mean reaction time for the eye for saccadic movement of 219 ms. (range 170-309) and this figure is probably an underestimate for children. As the TS exposure time for the control children was 118 ms., there was therefore no time for these children to make saccadic movements. The dyslexic children in contrast, with their mean TS exposure time of 815 ms., can be assumed to be processing the arrays from more than one fixation.

Whilst the procedure used in ascertaining 5 digit processing time differs slightly between Expts. 1a and 1b, it is interesting to compare those SOAs which the different subject populations required to process those arrays. These figures can be seen in Figure 1:1.

The finding that dyslexic adults process the arrays much faster than the dyslexic children supports the notion of a maturational lag in dyslexia. It should however be noted that the dyslexic UNDERGRADUATES still need more time to process the arrays than the non-dyslexic CHILDREN. It does appear from Fig. 1:1 that there is an inverse correlation between reading ability and 5 digit processing time, and this further supports the idea that those information processing subsystems involved in the latter task (in preference to those higher level functions involved in word or prose

Figure 1:1
Digit Processing Times for the 5 groups of Subjects of differing Reading Ability Tested in Expts 1a and 1b.



* (for the purpose of this analysis, the 50 non-dyslexic adults tested in Expt 1a were divided into 2 groups, the faster 20 readers and the slower 20 readers, on the basis of reading speed over all Conditions.)

processing) should be further investigated to learn more of the information processing deficits underlying reading disability.

B) VIS Duration

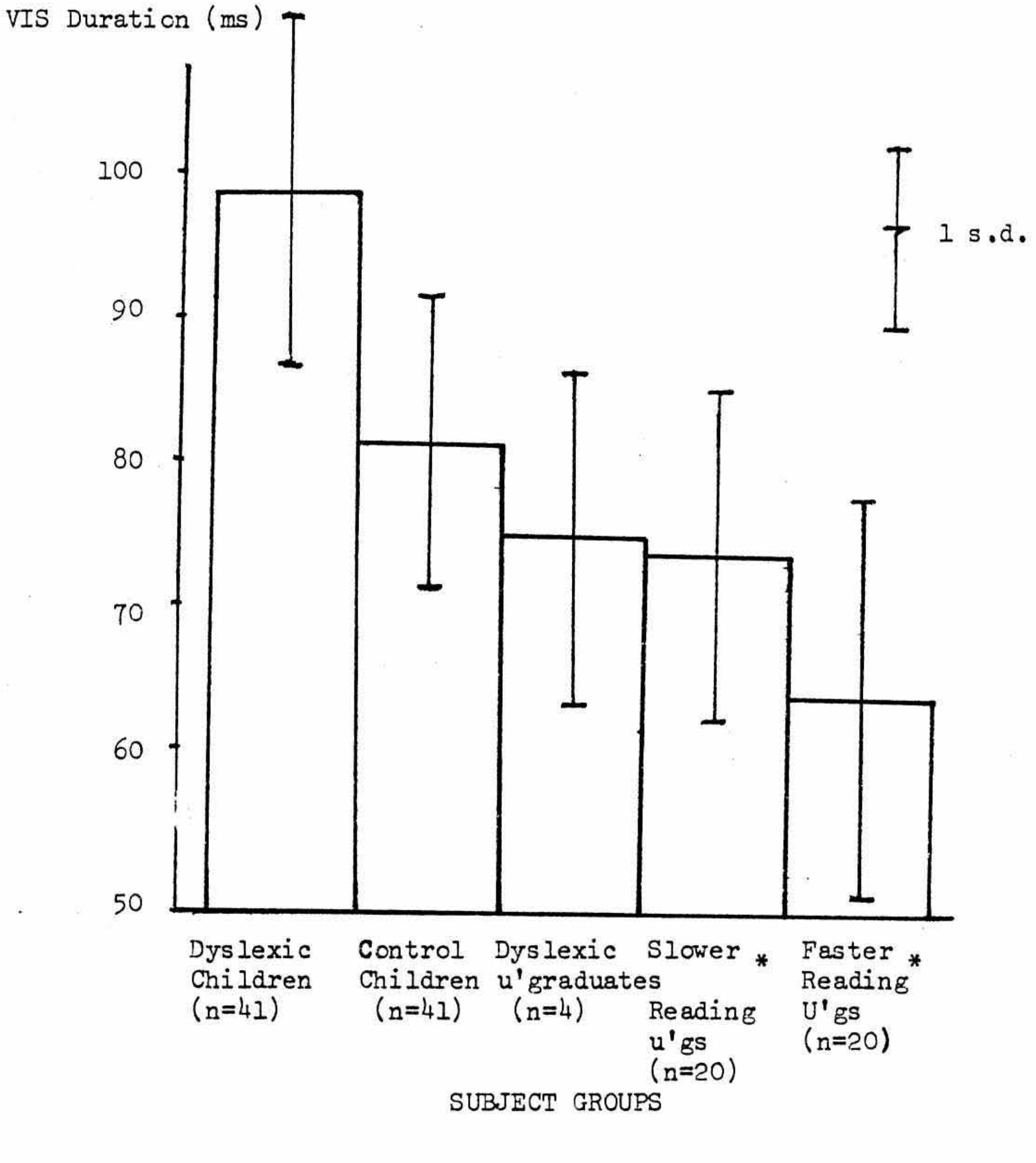
Mean VIS duration over both conditions was 81.4 ms. (s.d. 20.3) for the control group and 98.6 ms. (s.d. 24.2) for the dyslexic group. These figures are significantly different at the 0.1% level ($t = 3.48$, d.f. 80). Correlations between the 2 tests were 0.63 for the control group and 0.67 for the dyslexic children. These figures are taken to indicate that the tests are reliable. The finding of Stanley and Hall, 1973b that the VIS duration for dyslexics is longer than that for controls is thus confirmed.

Comparison of the VIS durations of the 5 subject populations tested in Expts. 1a and 1b (these figures can be seen in fig. 1:2) supports the speculation proposed in the introduction and discussion of Expt. 1a that there exists an inverse relation between speed of processing from the VIS and VIS duration: the faster a subject can read-out from the VIS, the shorter the time he needs to hold it there. To investigate this in more detail, the figures for all 136 subjects participating in Expts. 1a and 1b in respect of VIS duration and SOA at which they could correctly process the digit arrays were subjected to a Spearman Rank Order Correlation. This resulted in a significant rs of + 0.468 ($t = 6.12$, d.f. 134, $p < .001$). Using the 5 digit processing time as the independent variable, a regression analysis yields the following function:

VIS duration = 0.135 Processing time + 74.6 ms.

Figure 1:2

VIS Durations (ms) for the 5 subject populations of differing reading ability tested in Expts 1a and 1b.



* (for the purpose of this analysis, the 50 non-dyslexic adults tested in Expt 1a were divided into 2 groups, the faster 20 readers and the slower 20 readers, on the basis of reading speed over all Conditions.)

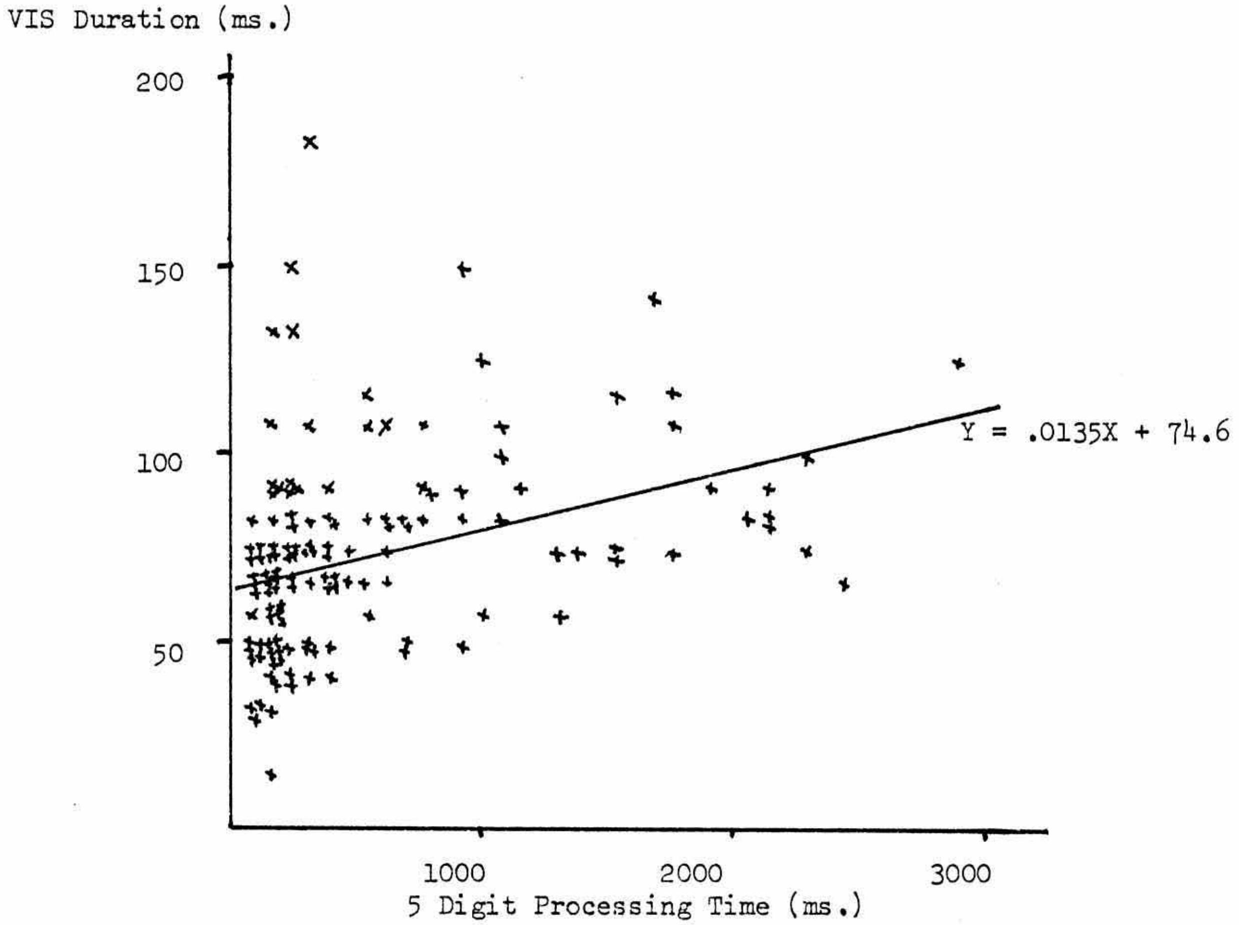


Figure 1:3 Scattergram of the VIS durations and 5 Digit Processing Times for all the subjects tested in Experiments 1a and 1b.

This relation can be seen in the scattergram (fig. 1:3). There is some considerable variability about the fitted regression line, and it must be noted that the correlation between the 2 variables is far from unity; but if these results are considered as a supplement to the evidence reviewed in the introduction they lend further support to the view that post-fixation storage of information in the VIS is utilised during reading.

CONCLUSIONS

From the results of Experiments 1a and 1b, and a review of other studies, it is concluded:

1) Dyslexic type difficulties are a manifestation of some general limitation in processing ability.

2) Processing from the VIS, as operationally measured by speed of recognition of 5 digit arrays, can be the rate limiting step of reading ability.

3) This being the case, it is considered that those functions involved in digit array processing can be profitably investigated in the search for the functional deficits underlying reading disability.

4) It is proposed that those subjects who are fast at processing from the VIS tend to have a shorter VIS duration.

EXPERIMENTAL CHAPTER 2

EXPERIMENTAL CHAPTER 2

CONTENTS

EXPERIMENTAL CHAPTER 2

In which ability at processing from arrays of digits is investigated over a wide range of exposure times for dyslexic and control children, fast undergraduate readers and adult low-literates - there is a strong correlation between reading ability and the rate of initial stimulus acquisition-ability at visual and lexical encoding underlies this performance - good readers differ from poor readers on one or both of these functions.

Introduction

In Expts. 1a and 1b it was found that processing time for 5-digit arrays was over four times as long for dyslexic children as it was for matched controls, and that there exists a correlation between visual information processing speed and reading speed. It was therefore suggested that dyslexia can be regarded as a deficiency in information processing, and that it is the functions involved in digit processing which should be investigated to determine the functional deficiencies resulting in reading disability.

The next step is therefore to attempt to break down the concept of 'digit processing'. Even in its present state it is no doubt a 'purer' concept than that of reading, where performance is likely to be more affected by practice, by skilled guesswork, and by degree of familiarity with the material, but clearly more is needed by way of isolating its components. Expt. 2a therefore investigates the ability of dyslexic and control children to process from 7-digit arrays at exposure times from 50-1200 ms. To study these children's processing ability at very short expsoure times, a backwards masking paradigm is used in Expt. 2b. Finally, in Expt. 2c, adult low-literate and fast undergraduate readers are compared on this task.

The suggestion that dyslexia can be regarded as a deficiency in information processing is also reflected in the work of Stanley and Hall (1973 a,b), Miles and Wheeler (1974, 1977), Wheeler (1977), and Ellis and Miles (1977, 1978). In particular, Stanley and Hall (1973b) report that dyslexic children perform less efficiently than controls on a task involving recall from 6-letter arrays presented for brief durations.

If the data of Stanley and Hall (1973b) are replotted in terms of number of digits reported at each exposure time for both groups of subjects, the results obtained are those of fig. 2:1.

Since in this Expt. the letters were followed by a blank field, the time scale of fig. 2:1 represents the time during which the letters were exposed in the tachistoscope. Since it is known, however, that subjects can hold information in iconic memory for usable durations of 100-300 ms. (Sperling, 1963, Neisser, 1967, Stanley and Hall, 1973b), the x-axis scale can be regarded as representing an effective exposure time made up of tachistocopic exposure time plus iconic storage time. It can be seen in fig. 2:1 that both groups of children improve in the number of letters correctly reported as the exposure time increases: the slope of their functions is (aproximately) 0.00036 items per ms. for the control group and 0.00017 items per ms. for the dyslexic group. In terms of speed of processing, however, there is another major difference between the two groups. This is to be found in the ordinate values: if extrapolated back they cross the y-axis at 3.35 items in the case of the dyslexic group and 3.84 items in

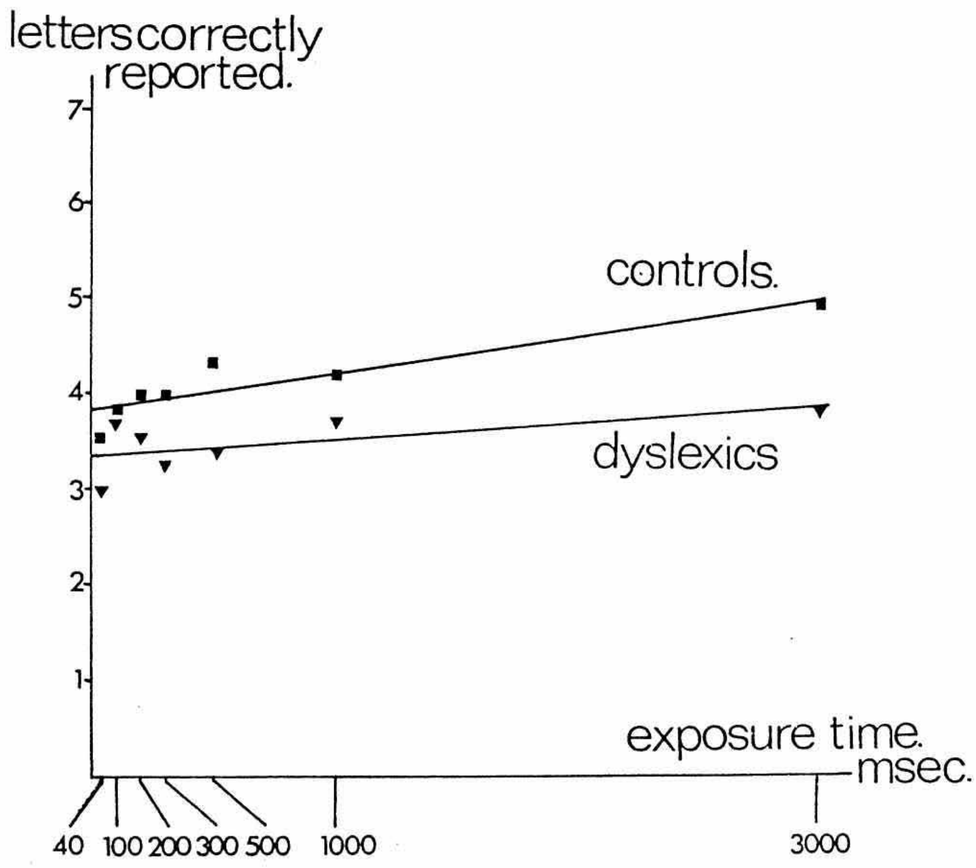


Figure 2:1 Stanley and Hall 1973. Data from figs 2 & 3 replotted as number of letters correctly reported from 7 item arrays by dyslexic and control children.

the case of the control group. One possibility therefore is that dyslexic children regularly display a low level of information pick-up during the exposure of any array of symbols, and that they are deficient at both the initial information acquisition and the later acquisition above this level.

EXPERIMENT 2a

Abstract

41 dyslexic boys between the ages of 10.4 and 14.4 years and 41 age and intelligence matched boys were tested for recall from 7-digit arrays presented tachistoscopically at exposure times between 50 and 1200 ms. It was found that the control children reliably processed more digits than the dyslexics at all exposure times used. The digits correct/exposure time function for the control children was of a slightly greater slope than that for the dyslexic boys, but the major difference between the two functions was the ordinate values: if they were extrapolated back, the dyslexic function crossed the y-axis at 3.3 items, the control function at 4.7 items. These results are taken to imply that the dyslexics are handicapped by a slowness at an early stage of information processing.

Introduction

In order to investigate those functions involved in digit processing, it was decided to carry out a variant of the Stanley and Hall (1973b) Expt. with a modified technique and with children who could be later tested on other tasks.

7-digit stimulus arrays were presented at a range of exposure times up to 1200 ms. There are a number of advantages if one uses digits as stimulus material as opposed to the letters which Stanley and Hall (1973b) used: in particular, each digit can be assumed to have the same prior probability, whereas a child's responses to letters or words may be affected by the extent to which he has learned that some letters and combinations of letters are more frequent than others; in addition digits lend themselves less easily to chunking. It was again decided to analyse the results in terms of correct identity only, no account being taken of order. This was because of the widely held view that dyslexia involves a deficit in temporal order perception (see Bakker, 1972): differences in the ability to order would therefore have been a confounding source of variability. As a consequence it was necessary throughout the course of the experiment that the subjects be strongly discouraged from guessing.

Subjects

The 41 dyslexic and 41 control children tested in Expt. 1b were also used as subjects in this experiment.

Materials and Procedure

12 different cards of 7 quasi-randomly generated digits (no digit could appear more than once on any trial) were the test stimuli (TS). They were presented successively in an Electronic Developments 3-field tachistoscope.

The digits were printed on white card using 28pt Helvetica light Letraset and were presented at a distance of 508 mm from the subject's eyes; this gave an illumination at the eye of approximately 1 lux. Each trial began with the signal 'ready' followed by a fixation cross (illumination at the eye of approximately 0.15 lux) for 2 sec. Digit offset was followed by darkness.

The children were first given a series of practice trials, being told that immediately after the numbers had disappeared they were to report as many of them that they were sure that they saw, in correct order if possible. During practice trials excessive guessing was discouraged whenever this was necessary. For the test trials six different TS exposure times were used, viz. 50, 100, 200, 400, 800 and 1200 ms., with two trials at each exposure time, the presentations being made in a randomized order. The child's response was recorded on each trial and scored as number of digits correct, no account being taken of order.

Results and Discussion

The mean number of digits correct at each exposure time is shown for dyslexic and control subjects in Table 2:1. The functions, fitted by regression, are: dyslexic subjects, $y = 3.3 + .0009x$ items per ms.; control subjects, $y = 4.7 + .0013x$ items per ms. (for regression lines see Figure 2:2). An analysis of variance performed on the results of Expts. 2a and 2b shows that the group differences are highly significant

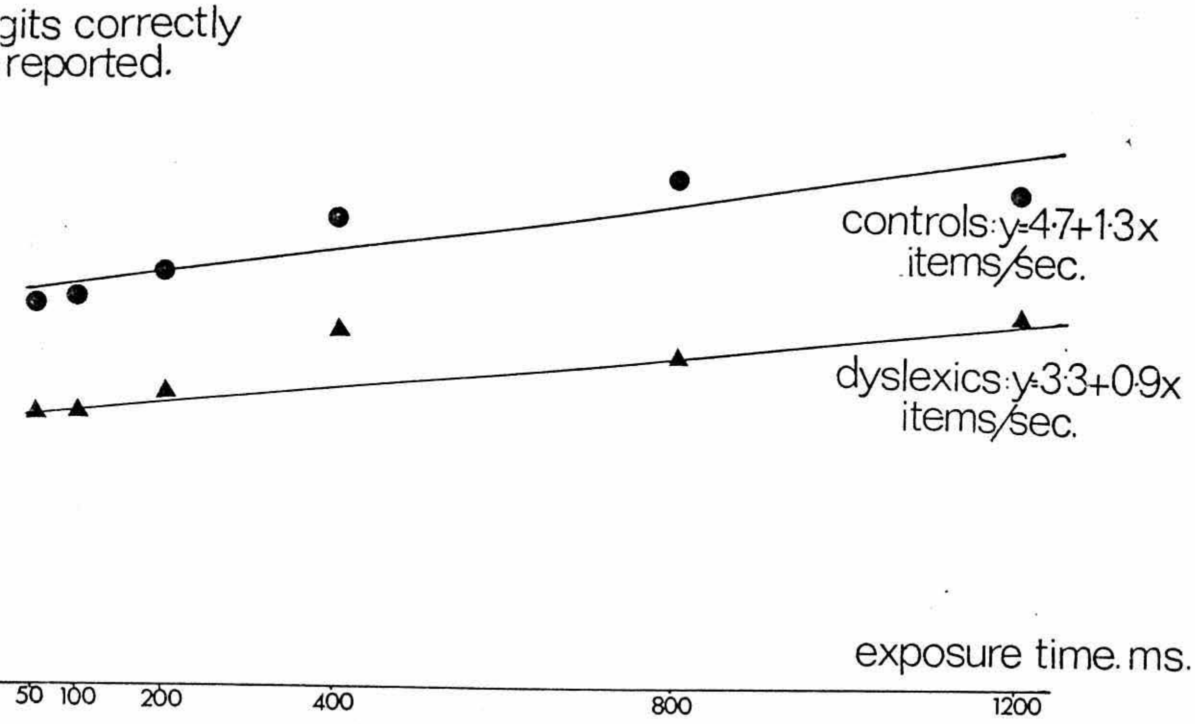


Figure 2:2 Dyslexic and control children's encoding functions derived from the data of Expt. 2a.

(for details see Table 2:2 and discussion of Expt. 2b). The pattern is the same as that found by Stanley and Hall (1973b): there is little difference between the slopes of the dyslexic and control children's functions although the slope of the latter is slightly higher. The major distinguishing feature between the two groups is in the initial level of the two functions, which might imply a slowness at a very early stage of information processing.

EXPERIMENT 2b

Abstract

Those subjects of Expt. 2a were tested at recall from 7 digit arrays which were presented tachistoscopically under backwards pattern masking at exposure times from 50 to 1200 ms. The dyslexic children's performance was significantly inferior to that of the controls, and this was especially reflected in the rate of initial stimulus acquisition.

Literature was reviewed which suggests that both visual processing (the visual code) and non-articulatory linguistic (lexical) processing underlies this rate of initial stimulus acquisition, and it is concluded that at one or both of these functions, dyslexic children differ from controls.

An analysis of the Serial Position effects lends further tentative support to this conclusion.

Correlational analyses were performed for all 82 subjects between efficiency at this task and i) the child's CA, ii) his RA, and ii) his SA. Whilst CA accounted for only 5% of the variability of scores in Expt. 2b, RA and SA accounted for 51% and 54% of the variance respectively.

Introduction

The next requirement was to study in further detail how much could be processed in very short exposure times. Now if it is assumed that iconic storage time is approximately 200 ms., then the shortest exposure time in Expt. 2a (50 ms.) gives an effective exposure time of approximately 250 ms. It is known, however, that the introduction of a pattern mask limits the processing of iconic information. If therefore this mask is introduced immediately upon TS offset the effective exposure time will become reduced by about 200 ms. throughout. It follows that when the tachistoscopic exposure time is 50 ms., the effective exposure time is approximately 50 ms. also.

Materials and Procedure

The subjects were the same as those used in Expt. 2a. The procedure, however, was changed in the following ways: new TS were used, and TS offset was followed immediately in each trial by a pattern mask which replaced the spatial location previously occupied by the TS and which consisted of a jumble of overlapping digit parts. The mask was exposed for 200 ms., with an approximate intensity at the eye of 3.0 lux; and it was known to be effective, because when both the MS and the TS were presented simultaneously for 2 sec. no digits could be reported by the subjects. Practice, instructions, and scoring procedures were identical to those of Expt. 2a.

Results

The mean number of digits correct at each exposure time is shown in Table 2:1. The resultant functions, fitted by regression, are shown in Fig. 2:3.

The data from Expts. 2a and 2b were analysed as a 3 factor ANOVA: 2 groups (dyslexics, controls) x 2 mask (mask, no mask) x 6 exposure times, with subjects nested within groups. The resultant F-ratios are shown in Table 2:2.

All main factors were significant at the 0.1% level. The group x time interaction demonstrates a greater difference between the groups at the longer exposure times; this is especially true in the mask condition, and there is thus a significant GMT interaction. The mask x time interaction is due to the mask having a greater effect at the shorter exposure times than at the longer ones.

The primary conclusion to be drawn is that dyslexic children are much poorer than control children at processing the information in the digit arrays.

How Are These Results To Be Further Analysed?

The evidence of Sperling (1963) shows that the number of items which an adult subject can report from a brief tachistoscopic display of alphanumeric stimuli which are

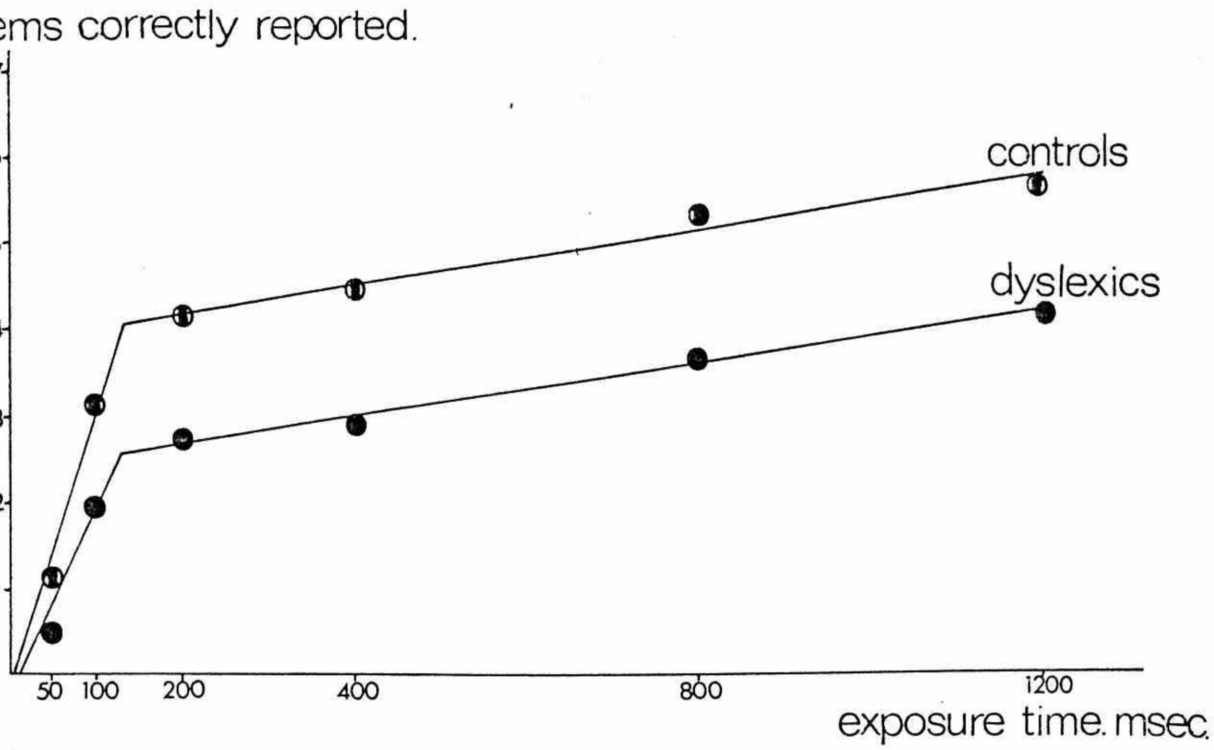


Figure 2:3 Dyslexic and control children's visual information processing from digit arrays presented under backwards masking Data from Expt. 2b.

TABLE 2:1
Mean Number of Digits Correctly Reported in Expts. 2a and 2b

	Experiment 2a (TS post-field dark)		Experiment 2b (TS post-field mask)	
Exposure Time (ms)	Dyslexic Children	Control Children	Dyslexic Children	Control Children
50	3.23	4.56	0.52	1.16
100	3.23	4.62	1.94	3.17
200	3.43	4.89	2.73	4.18
400	4.20	5.56	2.87	4.45
800	3.92	6.01	3.66	5.35
1200	4.35	5.89	4.13	5.62

TABLE 2:2
Essential ANOVA Data of the Digits Correct Results of Expts. 2a and 2b.

Source	F	DF	Probability
Groups(G)	93.4	1,~~983~~ 160	.001
Mask(M)	551.1	1,983	.001
GM	3.3	1,983	N.S.
Time(T)	366.9	5,983	.001
GT	8.4	5,983	.001
MT	135.0	5,983	.001
GMT	3.5	5,983	.05
Subjects within Groups	17.8	80,983	.001

----

followed immediately by a pattern mask increases as an approximately linear function of array exposure time at a rate of 10-35 ms. per item; this function continues up to about 4-5 items at 100 ms., where it levels off, thereafter increasing at a considerably slower rate.

Coltheart (1972) interprets these results as reflecting two processing strategies operating in parallel, and sees the exposure time/items reported function as being two-limbed. The first limb is very steep with, apparently, a capacity limitation (represented by the dog-leg point) of around 4-5 items. The second limb is much less steep, but appears capacity limitless over the first second at least. In contrast Sperling (1963) draws a single curvilinear function through the data.

For the data of Expt. 2b it is difficult to decide between a 'two-limb' or 'logarithmic' function. If a regression analysis is performed against log exposure time, extremely good fits are obtained:

Controls: items correct = $-0.293 + 1.89 \log_{10}$ exposure time

Dyslexics: items correct = $-0.683 + 1.47 \log_{10}$ exposure time

Both groups pooled: items correct = $-0.488 + 1.68 \log_{10}$ exposure time

These functions are extremely good predictions of the data, explaining 98% of the variability.

If, however, the results of Expt. 2b are referred to, where the effective exposure times are in the approximate range 300 - 1500 ms., it can be seen that the linear-linear functions are still rising (1.3 items/sec. for the controls and 0.9 items/sec. for the dyslexics) and this rate of increase appears to be faster than that predicted from the asymptoting logarithmic formulae. Even so, it is to be expected that the functions will eventually asymptote at short-term memory capacity is reached.

With so few exposure times used in Expts. 2a and 2b it seems impossible to resolve this choice between 'two-limb' or 'logarithmic'. The question is largely academic however, and appears little to affect the arguments as to the underlying cognitive functions. For the sake of uniformity, however, the 'two-limbed' functions will be referred to in data analysis.

With regard to the arguments of hypothetical underlying cognitive functions, the following background is relevant. Since the subjects are required to report verbally and since pre-report storage in short-term memory has been found to be subject to phonemic confusion, it has been argued that some form of phonemic or articulatory encoding is involved (Sperling 1963, 1967; Conrad 1964, 1972; Baddeley, 1966, 1968). Articulatory encoding, however, is slow: Landauer (1962) has demonstrated that its rate approximates to that of explicit speech which is about 150 ms. per monosyllabic item. To explain the relatively faster rate of initial encoding, therefore, it has been necessary to postulate some kind of buffer store between icon and articulatory code mechanism. According to this view the rate of initial information acquisition reflects the rate of readout from icon into buffer store and the dogleg point where the function levels off indicates the buffer store's capacity. Now since it is known that initial rate of information acquisition is unaffected by articulatory suppression

(Experimental Chapter 7) the information in the postulated buffer cannot be articulatory in character, and the precise form of the storage therefore requires discussion.

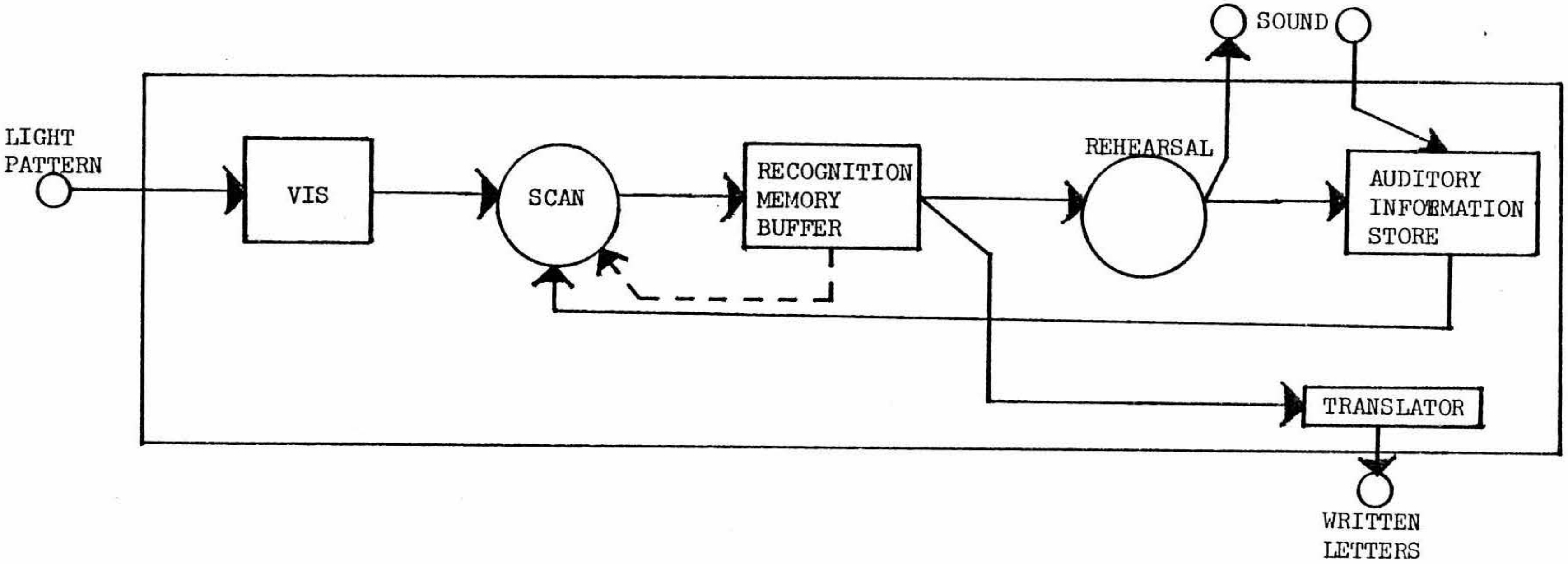
Sperling (1967) argues for a 'scan' of the visual information contained in the icon which results in a code representing the names of the characters in terms of 'programs of motor instructions'. These programs are held in a 'recognition memory buffer' (rate of input to the buffer 10ms.) item, rate of output from the buffer 150 ms./ item) until they can be executed. This proposal will explain that the rate of first limb slope is much greater than that of the rate of implicit speech,and if a buffer capacity limitation of 3-4 items is assumed, as Sperling, 1967 proposes, it also explains why the dogleg point is reached. The second function, above the dogleg point, is assumed to reflect name coding direct from the icon since its slope is in close correspondence to the rate of implicit speech, 150 ms./item. The Sperling, 1967 model can be seen in fig. 2:4.

The problem with this model is that it leaves the iconic store, which is of very short term duration, as the only visual store in the system. As there is considerable evidence for a longer term visual store (the visual code of Posner, 1969, Phillips and Baddeley, 1971 and Phillips, 1974) which can survive pattern masking (Phillips, 1974), Coltheart (1972) has argued for a non-iconic visual code buffer, and similarly Mitchell (1976) proposes that short-term visual memory may act as the buffer store between icon and articulatory encoding.

In more detail, Coltheart's hypothetical organization of information processing subsystems underlying the two-limb function data is as follows. The second limb is said to show items processed via the <u>name code</u> pathway. Evidence for this comes from its close correspondence in rate to that of implicit speech (approximately 150 ms. per monsyllabic item; see Landauer, 1962) and also from studies of prelingually deaf children who show an almost horizontal second limb slope (Henderson & Henderson, 1973). The slope of the first limb is obviously much too steep to reflect name coding; and it is therefore proposed in the Coltheart model that it chiefly represents processing through a <u>visual code</u> pathway. The mechanism involved here may or may not be the same as that stüdied by Posner (1969), who found that responses of 'same' to physically identical letters (AA) occurred more quickly than responses of 'same' to

FIGURE 2:4

Sperling's 1967 Approximation to a Model of Short-Term Memory

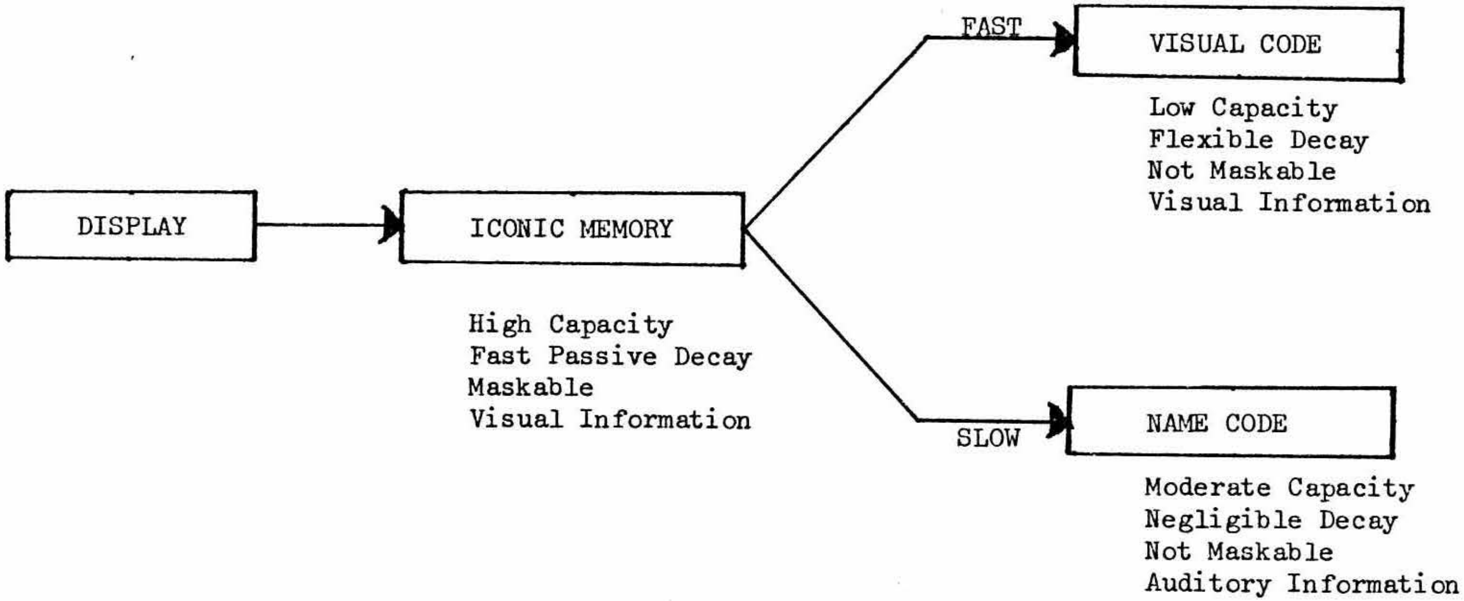


Adapted from Sperling, G., 1967 "Successive Approximations to a Model for Short-Term memory" Acta Psychologica, 27, 285-292 physically dissimilar letters (Aa), and who distinguished therefore between visual code comparisons and name code comparisons. The visual code mechanism was believed by Posner to hold information in terms of its visual features, while the name code mechanism had the function of translating the visual array into auditory information. Coltheart takes the matter further by suggesting that these two encoding processes occur simultaneously and that visual encoding is fast up to its capacity limit, while name coding is slower but less limited in respect of capacity. The model of Coltheart (1972) is shown in Fig. 2:5.

Whilst the models of Sperling (1963, 1967, 1970) concentrate on the aspects of grapheme-phoneme conversion to the exclusion of visual short-term memory, that of Coltheart (1972) lacks detail of name coding, having the reader believe that there is only the motor articulatory code available to represent linguistic stimuli. In contrast, Allport (1973, 1977, 1978) reports that the masking interval function is essentially the same for unrelated consonants as it is for arrays of unrelated common words of 3-6 letters in length, from which he concludes that the masking function does not simply reflect a capacity in the processing of visual or graphemic features. He therefore argues for a non-visual, abstract linguistic or 'lexical code' buffer. According to this view the rate of information acquisition may reflect the rate of production of lexical codes following logogen unit (Morton, 1969, 1970) activation, with

FIGURE 2:5

Coltheart's 1972 Hypothetical Organization of Memory Sub-Systems involved in Visual Information Processing.



From: Coltheart, M., 1972 "Visual Information Processing" in P.C. Dodwell (ed.) New Horizons in Psychology 2, 1972, Harmondsworth: Penguin.

the dogleg point perhaps reflecting the number of outputs from unrelated logogen units which can become available concurrently.

What then of the present data? There are substantial group differences of performance on this task. The dyslexic children are significantly slower at processing the arrays than are the controls, and this is particularly evident in the rate of initial stimulus acquisition. Regression lines in respect of the post-dogleg second limb are as follows: dyslexic children $y = 2.38 + 1.5$ item/s., control children $y = 3.91 + 1.5$ item/s.: the dyslexic and control children's functions run parallel after the dogleg point. The slope of the first steep limb, however, is approximately 30 item/s. for the controls compared with about 19 item/s. for the dyslexic subjects, dogleg points being at 4.1 items and 2.6 items respectively.

According to the alternative theories outlined above the following interpretations seem prima facie possible: (a) dyslexic children are slow at scanning iconic information and creating 'programs of motor instructions' for the graphemic stimuli; they have a 'smaller capacity' recognition buffer; (b) they are slow or inefficient at creating visual codes for the graphemic stimuli; they have a 'smaller capacity' visual code; (c) they are slow at producing lexical code representations and can hold fewer such representations available. These alternatives fall into two broad classes: naming/abstract linguistic (a and c) and visual (b) deficiencies.

The dyslexia literature yields possible support for both classes. For example dyslexic children typically confuse b and d (Vernon, 1971; Critchley, 1970), which may reflect problems with manipulating the visual representations of stimuli; on the other hand they also show slow reaction times in naming colours and pictures (Denckla and Rudel, 1976) which may reflect problems at the level of naming.

We must ask therefore, what is the rate limiting function underlying the first limb, since this differentiates the dyslexic and control children. This question is addressed in detail in Experimental Chapter 7, however for the present, a summary of some relevant literature should suffice.

There is a considerable body of relevant evidence based on studies of the rates of processing of different types of stimuli. Thus Mackworth (1963) presented arrays of colors, digits, shapes and letters tachistoscopically at short exposure times and demonstrated that the rate of stimulus information acquisition increased from shapes to colors to letters to digits. She concludes that speed of naming is an important variable in rate of processing. Allport (1968) showed that the rate of encoding of information of Landolt C's occurs two to three times more slowly than for numerals.

Visual features and ease of naming are discussed as being potential independent variables underying this effect. In addition, after a series of experiments where stimulus characteristics are manipulated, Allport (1973) concludes that :

(i) the rate of acquisition from an array of letters or words is determined not by the number of visual characteristics to be processed but by the number of names into which they are to be encoded.

(ii) the rate of stimulus information acquisition is independent of the pool size (4, 8 or 16 consonants) from which the characters of the array-to-be-encoded are drawn.

(iii) the time needed to identify words of the same frequency of occurrence is unrelated either to word length or to the number of syllables in the name.

(iv) the backwards masking paradigm provides a direct measure of naming latency.

In an unpublished Expt., Ellis has demonstrated that the initial rate of processing 7 item arrays increases according to the series: 7 nonsense symbols, 7 consonants, 7 letter arrays forming pronounceable nonwords, 7 letter English words. In a second experiment subjects initially tested for speed of processing the nonsense symbol arrays were divided into four groups. Group I copies the symbols, Group IV learned names for the symbols such that this code would later allow translation of the symbol arrays into English words. The subjects participated in these training schedules daily and the groups were equated for exposure to the symbols. On retest with the nonsense shape arrays one week later a trend similar to that of the aforementioned experimant was obtained. The Group I subjects who had increased familiarity with the visual characteristics of the stimuli improved from the session 1 levels where they processes on average 2.2 items in 400 ms. to processing 3.1 items in 400 ms. in session 2; those Group IV subjects who had both increased familiarity with the visual stimulus characteristics and in addition learned names for the symbols improved from 2.4 items/ 400 ms. session 1 to 4.9 items/ 400 ms. session 2.

Finally of relevance, Coltheart and Glick (1974) have described the performance of Sue d'Onim, a subject who when presented with a word or sentence was abnormally proficient at spelling this material in reverse order. She reported that she was able to do this by visualising the material and reading off from this visual image. When she was tested on the masked letter array processing task of Merickle et al. (1971), the rate of initial stimulus acquisition was exceptionally fast, approximately 120 items/s. compared with adult control rates of about 35 items/s. Coltheart and Glick (1974) interpret these findings in terms of the Coltheart (1972) model and suggest that her performance reflects a superiority in visual encoding.

These studies provide some clues to the factors relevant to the initial rate of processing visual information, viz. visual features, familiarity and nameability. Although the majority of these studies stress nameability in this respect, whether the buffer is visual or abstract lexical in nature has not been unequivocally resolved.

It seems therefore that both visual features and nameability (ease with which lexical referents can be accessed) can be rate limiting in the first limb slope, and this indeed is the conclusion reached in Experimental Chapter 7. It must therefore be left open as to whether the dyslexic child's limitation in the rate of initial acquisition of visual information is to be found at visual or lexical processing functions, but as the majority of the studies stress nameability in a determinative role, lexical processes must be considered to be most likely areas of deficiency. in dyslexia.

Serial Position effects

The conclusion that the dyslexic subjects show a deficiency in the rate of initial acquisition of visual information is based on the shallow 1st. limb slope of the dyslexics' data. Since Merickle, Coltheart and Lowe (1971) demonstrated that it was the end serial positions of an array which are preferentially first processed, it should also be that the data of dyslexic children differ more from these of the control children at the end serial positions. (S.P. 1,2,3,7) than at the mid SPs (4,5,6).

The results of experiments 2a and 2b were therefore scored for serial position effects: the proportion of the 41 subjects in each group which was correct on any trial was calculated. The serial position curves for experiment 2a, where no mask was used, can be seen in fig. 2:6; those for experiment 2b where the digits, when followed by the pattern mask, can be seen in fig. 2:7.

These serial position effects are shown in table 2:3 and analysed as a 4 factor randomized block ANOVA (7 serial positions x 2 groups (dyslexics, controls) x 2 experiments (mask, no mask) x 6 exposure times (50 - 1200 ms.) with 2 blocks of replications). This ANOVA data is shown in table 2:4.

All of the main factors are again significant at the .01 level. This analysis tells us nothing new about the group, mask or time factors which were analysed in the previous ANOVA; it does however, show that overall some serial positions are more correctly reported than others, the serial positions being reported correctly (over both groups and both experiments) the following proportions of the time: SP1: .89, SP2; .71, SP3: .70, SP4: .55, SP5: .37, SP6: .30, SP7: .38. The order of positions in terms of statistical significance is:
$1 > 2, 3 > 4 > 5, 7 > 6$.

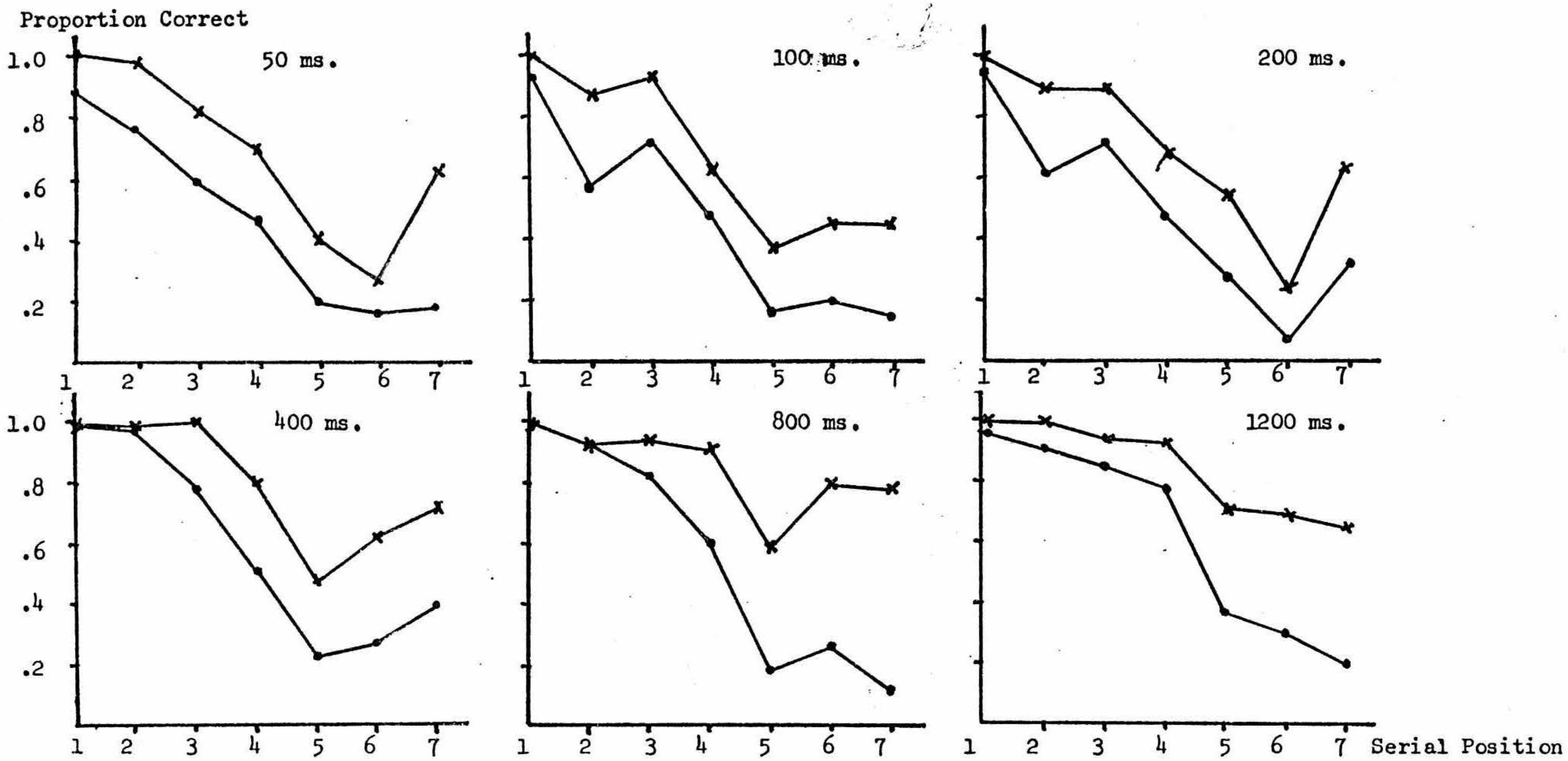


Figure 2:6. Proportion of trials correct for the Serial Positions 1 to 7 at exposure times from 50 to 1200 ms. in the Postfield Dark procedure of Experiment 2a.

x—x Controls (n=41)
•—• Dyslexics (n=41)

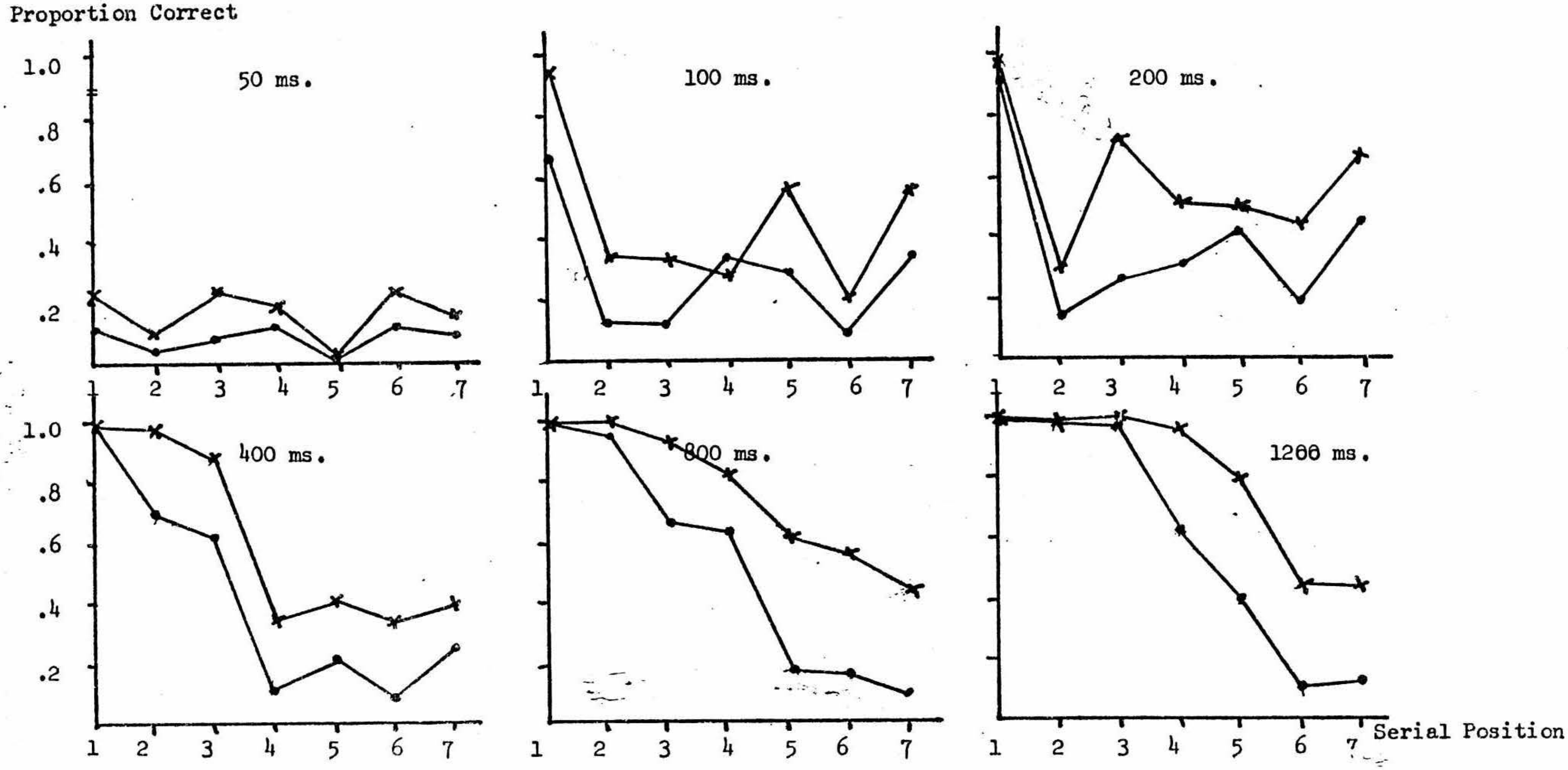


Figure 2:7. Proportion of trials correct for the Serial Positions 1 to 7 at exposure times from 50 to 1200 ms. in the Backwards Masking procedure of Experiment 2b.
×—× Controls (n=41)
●—● Dyslexics (n=41)

EXPERIMENT 2a: Postfield Dark.

	RUN 1							RUN 2						
Exposure Time (ms)	1	2	3	4	5	6	7	1	2	3	4	5	6	7 SP
50	1.00	.95	.68	.56	.29	.32	.34	1.00	1.00	.95	.83	.51	.22	.90
100	.98	.88	.93	.68	.29	.32	.41	1.00	.85	.93	.59	.44	.59	.49
200	.98	.83	.95	.61	.51	.41	.61	1.00	.95	.83	.76	.56	.07	.66
400	1.00	.98	1.00	.68	.76	.66	.76	.98	.98	1.00	.93	.20	.59	.71
800	1.00	.88	.95	.95	.73	.80	.76	1.00	1.00	.95	.90	.44	.80	.80
1200	1.00	1.00	.88	.93	.73	.76	.66	.98	1.00	1.00	.93	.68	.63	.66
50	.85	.71	.32	.39	.22	.24	.20	.90	.80	.85	.54	.17	.07	.17
100	.93	.73	.85	.37	.15	.12	.12	.93	.41	.59	.59	.20	.27	.17
200	.93	.56	.78	.39	.20	.10	.32	.98	.66	.66	.56	.37	.05	.32
400	1.00	.98	.59	.49	.44	.37	.56	.98	1.00	.98	.49	.02	.17	.24
800	1.00	.93	.88	.61	.20	.27	.17	.98	.93	.78	.59	.17	.24	.07
1200	.98	.85	.76	.83	.46	.37	.22	.95	.98	.95	.73	.27	.24	.17

EXPERIMENT 2b: Postfield Mask.

	RUN 1							RUN 2						
Exposure Time (ms)	1	2	3	4	5	6	7	1	2	3	4	5	6	7 SP
50	.20	.02	.20	.07	.00	.20	.22	.27	.17	.29	.29	.05	.27	.07
100	.93	.20	.20	.24	.44	.29	.63	.95	.49	.46	.32	.68	.10	.49
200	1.00	.20	.90	.46	.71	.27	.68	.95	.41	.54	.56	.29	.61	.63
400	1.00	1.00	.93	.20	.34	.27	.54	.98	.95	.88	.51	.49	.44	.27
800	1.00	1.00	1.00	.85	.66	.59	.44	.98	1.00	.85	.78	.56	.54	.41
1200	1.00	.98	1.00	.98	.78	.41	.37	1.00	.98	1.00	.95	.80	.46	.54
50	.10	.02	.00	.00	.02	.07	.12	.12	.05	.15	.22	.02	.15	.05
100	.63	.12	.15	.27	.12	.07	.46	.68	.12	.07	.39	.44	.10	.22
200	.95	.10	.37	.15	.66	.05	.39	.88	.17	.15	.46	.34	.32	.49
400	.95	.76	.66	.07	.15	.00	.15	1.00	.63	.59	.15	.27	.17	.17
800	.98	.98	.68	.63	.17	.12	.10	.98	.95	.63	.63	.15	.17	.07
1200	.98	1.00	1.00	.41	.39	.07	.07	.98	.98	.95	.83	.41	.12	.15

TABLE 2:3

Proportion Correct at Each Serial Position in Experiments 2a and 2b.

TABLE 2:4

Essential ANOVA Data of the Serial Position Results of Expts. 2a and 2b.

Source	SS	DF	MS	F	Probability
Blocks	0.0256	1	0.0256	1.85	N.S.
Positions(P)	13.753	6	2.2922	166.07	***
Time(T)	5.3134	5	1.0627	76.99	***
PT	2.9669	30	0.0989	7.17	***
Groups(G)	3.6479	1	3.6479	264.30	***
PG	0.5633	6	0.0939	6.80	***
TG	0.0963	5	0.0193	1.39	N.S.
PTG	0.6313	30	0.0210	1.52	*
Mask(M)	2.4944	1	2.4944	180.72	***
PM	0.8112	6	0.1352	9.80	***
TM	1.5608	5	0.3122	22.62	***
PTM	2.3443	30	0.0781	5.66	***
GM	0.0288	1	0.0288	2.09	N.S.
PGM	0.1182	6	0.0197	1.43	N.S.
TGM	0.0479	5	0.0096	0.69	N.S.
PTGM	0.2513	30	0.0084	0.61	N.S.
ERROR	2.3050	167	0.0138		
TOTAL	36.960	335			

N.S. Not significant
* Significant at the 5% level
** Significant at the 1% level
*** Significant at the 0.1% level

It can be seen from table 2:4 that the majority of the interactions are also significant. Those will not be discussed in detail here since the Group, Mask and Time factors and interaction have already been analysed and discussed for these data. What is of interest here, is the group x position interaction. The mean proportions correct for the two subject groups on each of the 7 serial positions are shown in table 2:5. Whilst the null hypothesis in this respect is that there is no significant G x P interaction, one alternative hypothesis which was proposed was that, should the interaction be significant, it would demonstrate that the groups would differ more on serial positions 1,2,3 and 7 than on positions 4,5 and 6. This alternative hypothesis can be elaborated. The dyslexics' function in fig 2:3 doglegs at 2.6 items, and this is interpreted as the processing capacity through the functional pathway underlying the 1st limb performance. The equivalent figures for the control is 4.1 items. If a left to right processing strategy is assumed, and if, as Merickle et al., 1971 propose, the end items are those preferentially encoded, this will predict that the controls will be performing preferentially well on serial positions 1,2,3 and 7 (or perhaps 1,2,3,6 and 7: there is no hard and fast rule as to the cut-off point between 'end' and 'middle' items) since they have a capacity of '1st limb processing', as reflected by the dogleg point, of 4.1 items. The

TABLE 2:5

Group x Serial Position Interaction Means from Expts. 2a and 2b.

Serial Position	Control Children	Dyslexic Children	Difference
SP1	0.92	0.86	0.06
SP2	0.78	0.64	0.14
SP3	0.80	0.60	0.20
SP4	0.65	0.45	0.20
SP5	0.50	0.25	0.25
SP6	0.44	0.16	0.28
SP7	0.54	0.21	0.33

L.S.D. (T5%) = 0.067

dyslexics, however, with their capacity of only 2.6 items should equate with the controls on SPs 1 and 2 but should differ from them significantly especially on SPs 6 and 7 since there is no remaining processing capacity to deal with those items.

The results shown in Table 2:5 lend some support to this claim. Apart from SPs 3 and 4 where the difference between the two groups remain roughly constant, the dyslexics do relatively worse than the controls as serial position increases. At serial position 7, where both groups improve (this perhaps being due to this serial position being preferentially encoded) the controls improve more than the dyslexics; indeed it is at this serial position where the two groups differ most. It should be noted, however, that these serial position means are taken over all the exposure times used, and at exposure times above 200 ms. eye movement will be possible and the subject's report will be the combination of items processed from more than one fixation. The Group x SP x Time interaction is barely significant, suggesting that the Group x SP means are representative of the processing strategies operating at all exposure times. However as a result of this assertion it is necessary to examine serial position differences at exposure times when no eye movements are possible.

In this light, if the serial position effects between the two groups at 100 ms. exposure times are studied in fig. 2:7

it does appear that there is again some support for the proposition that the groups differ more on the end serial position than those in the middle, indeed there is a cross over at SP4 where the dyslexic subjects actually perform slightly better than the controls.

The analysis of the SP effects does then lead some weak supportive evidence that it is processing through the function pathway underlying 1st limb performance which is deficit in dyslexics. This confirmatory evidence must be stressed as being highly tentative, the SP effects are somewhat messy and inconsistent and are averages over many trials for many children.

A practical implication of this finding ensues. Firstly the fixation-span of the dyslexics is less than that of controls which means that they will be incapable of processing longer words from a single fixation. In addition to this the ends-first processing strategy of the controls is more an end-first processing strategy for the dyslexics: of all the serial positions, SP7 was relatively worse for the dyslexics than the controls - i.e. in reading it in the last letters of the word which is most likely not to be processed by the dyslexics. It is suggested however by Merickle et al. 1971 that the ends-first processing strategy of adults has developed because the ends of the words are psychologically more important than the middle portion, and that therefore reading strategies have developed which preferentially process these 'ends'. They cite the 3 following lines of evidence for this:

1) Brunner & O'Dowd (1958) found that a reversal of the positions of two letters in a word has a greater detrimental effect on tachistoscopic identification when the letters at the ends of the words are reversed than when letters in the middle of the word are reversed.

2) Jensen (1962) in a study of spelling errors found that the greatest number of errors occurs in the middle of words.

3) In the much cited "tip of the tongue" phenomenon Brown & McNeill (1966), S's have the most difficulty recalling the middle portions of words.

The dyslexic child therefore, with his end_first processing strategy is at a handicap not only because he can process less than the control from a single fixation, but also because he is especially processing less of the last few letters of words which carry relatively more information than those middle letters.

One final conclusion can be drawn from the analysis of serial position effects. The position x time two way interaction is highly significant ($F = 7.17$, d.f. 30, 167, $p < .001$).

Analysis of this interaction by inspection of the 6 curves of fig. 2:8 shows that the proportion correct increases for all SPs up to 400 ms. Thereafter, however, the proportion correct on SPs 1,2,6 and 7 does not increase (and presumably therefore SPs 1,2, 6 and 7 are no further processed after 400 ms.) whereas the proportion correct on SPs 3,4 and 5 continues to increase above 400 ms., this is most markedly the case for the mid array S.P.4. This finding supports that proposition of Merickle et al. 1971; Coltheart, 1972 that it is the middle items which are speech-motor encoded and the end items which are processed through the preferential fast pathway underlying 1st limb performance: the end items are processed through the fast pathway and this processing is completed by 400 ms., speech-motor coding can still occur after 400 ms. and it is SPs 3,4 and 5 which are still being further processed by this mechanism. The 'second limb' of fig. 2:3 must therefore be viewed in this light.

A Correlational Analysis

It has been demonstrated that dyslexics perform at a significantly lower level than controls at processing from tachistoscopically presented, backwards masked 7 digit arrays. In Expts 1a and 1b there were also demonstrated reading group differences in 5 digit processing time. In addition to these between-group differences, it is of interest whether there are within-group differences in processing time. For example, is it the case that the slower a dyslexic is at processing from the

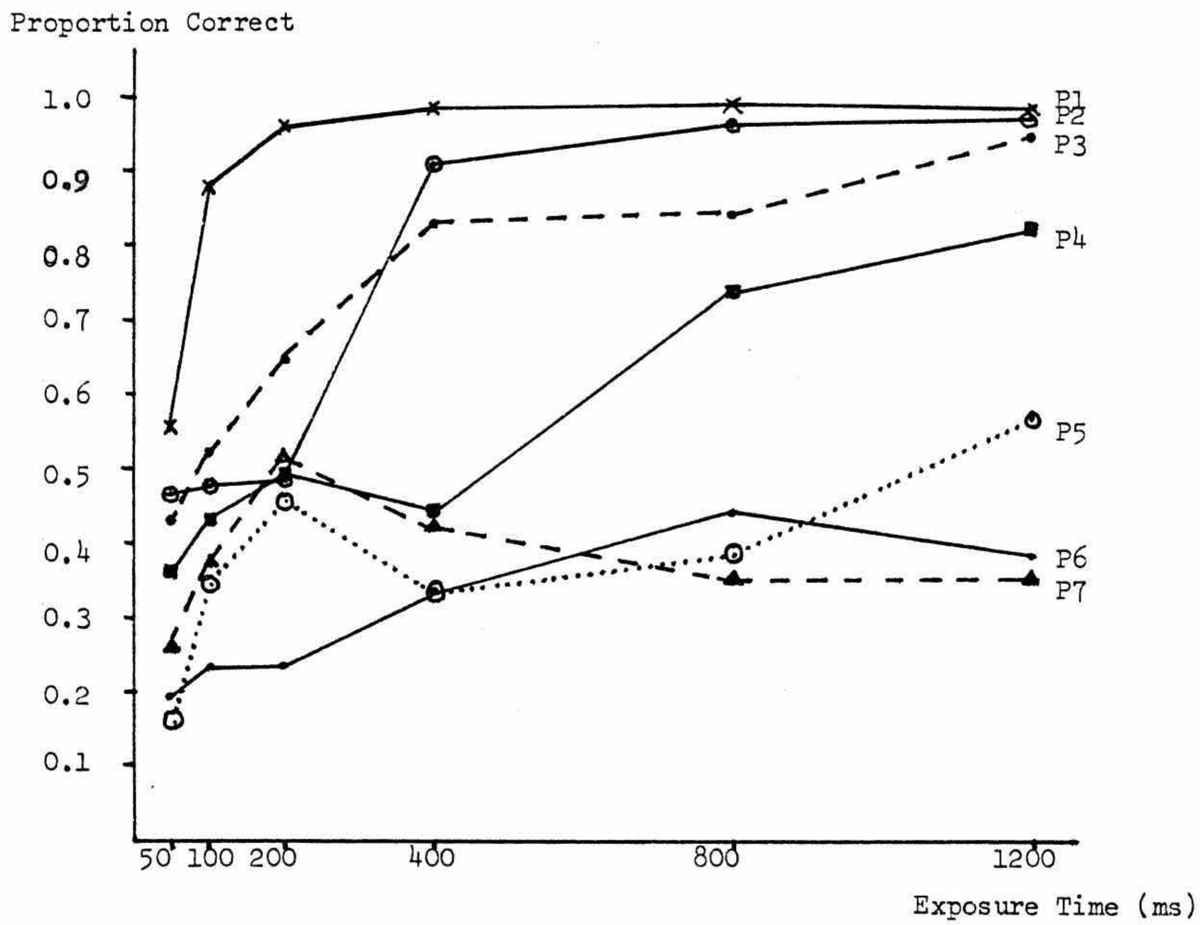


FIGURE 2:8

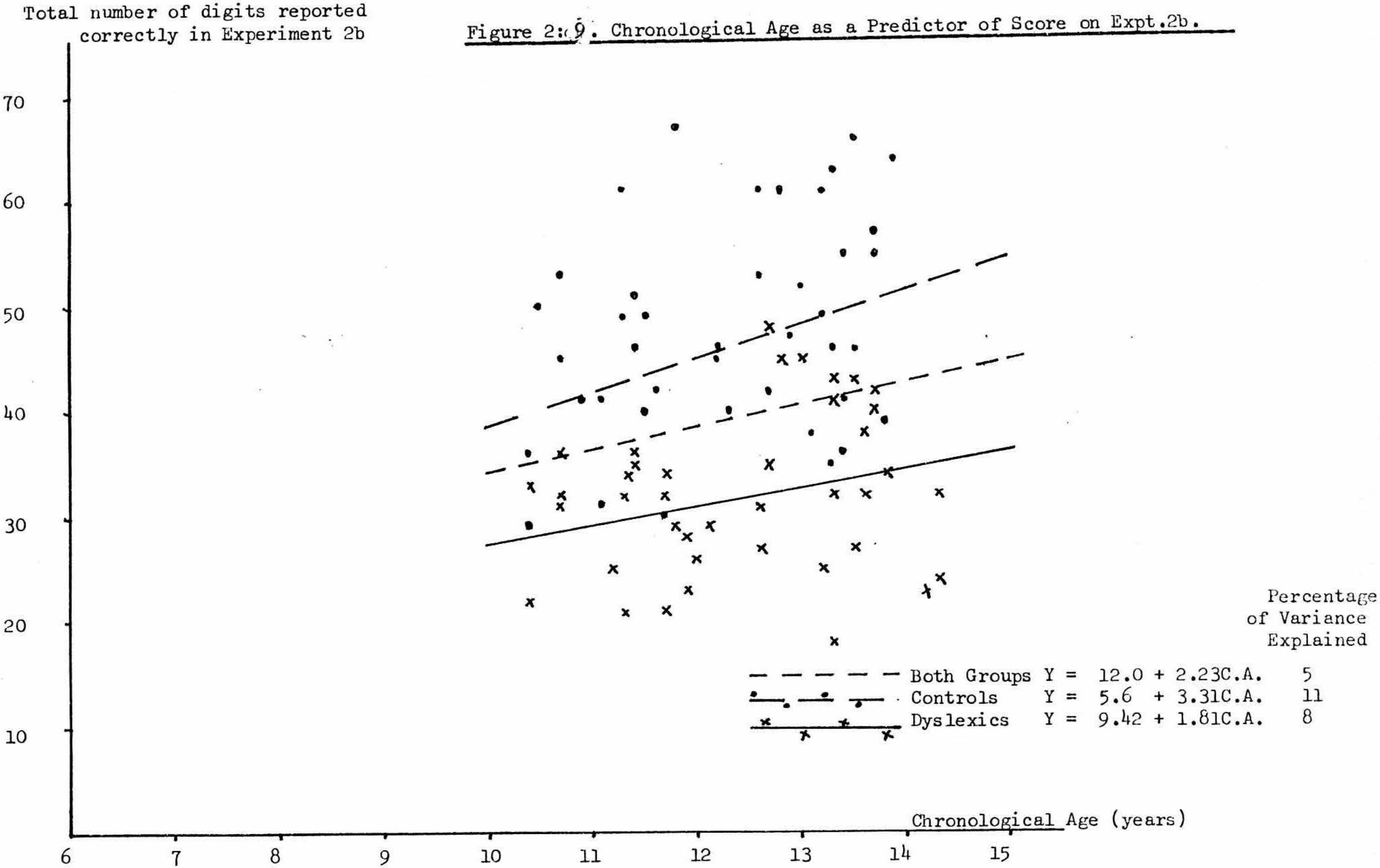
The Increase in Correct Recall of Serial Positions 1 to 7 with Increasing Exposure Time.

7 digit arrays, the greater his degree of reading retardation?

The total number of digits correctly reported are the twelve trials of Expt. 2b was calculated for each of the 82 children who participated and correlations and regressions were therefore performed against each of the 3 variables: CA, RA and SA. The resultant function can be seen in the scattergrams, figs. 2:9, 2:10 and 2:11. It can be seen that, predictably, there is hardly any relationship between score on Expt. 2b and CA; CA explains only 5% of the total variance. RA and SA are much better predictors of the Expt. 2b score, explaining 51% and 54% of the variance respectively.

Therefore within either of the groups tested digit processing ability correlates closely with reading ability, and this again confirms that the correct processing areas are being investigated to ascertain the functional deficiencies underlying reading retardation.

Figure 2:9. Chronological Age as a Predictor of Score on Expt.2b.



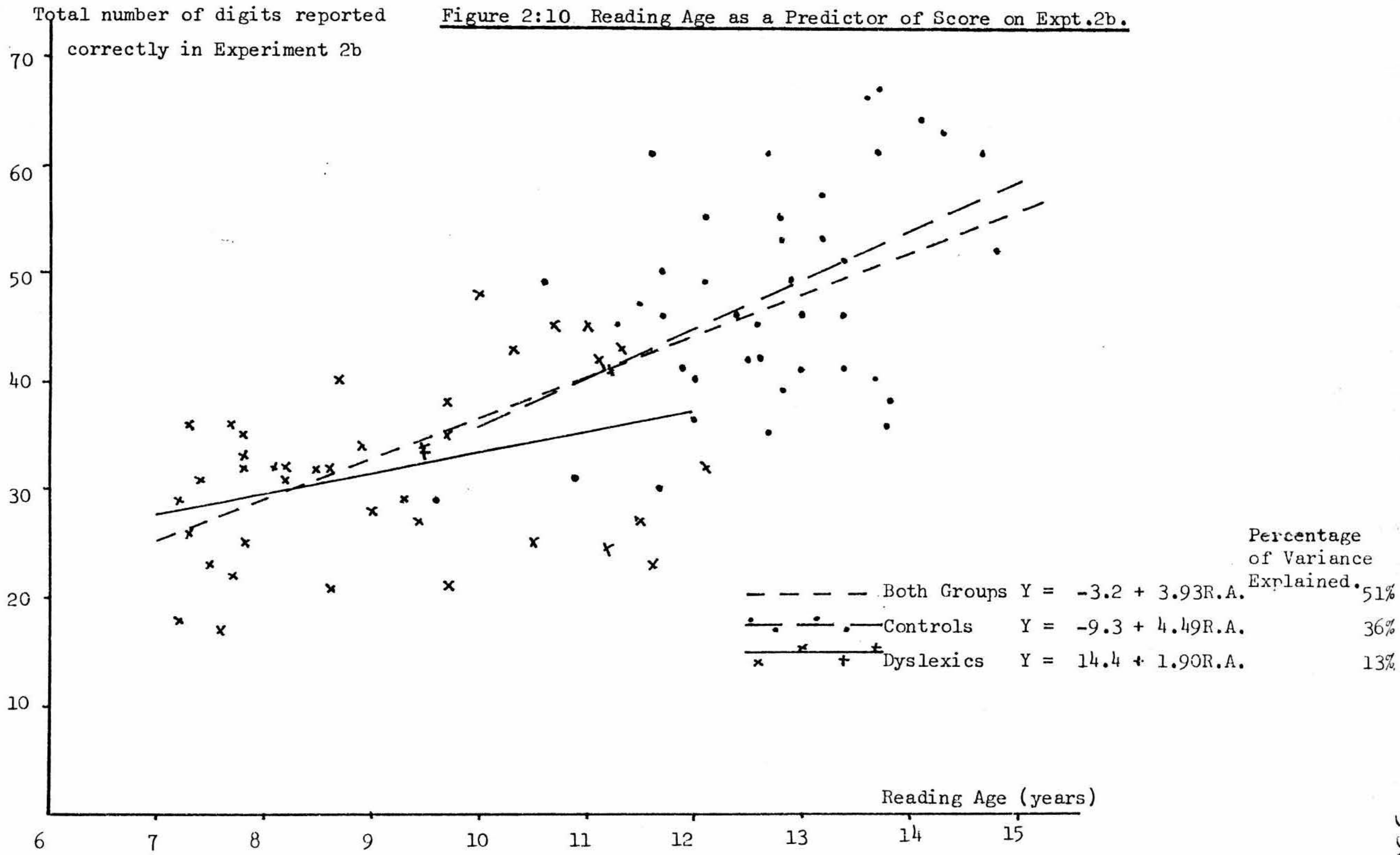
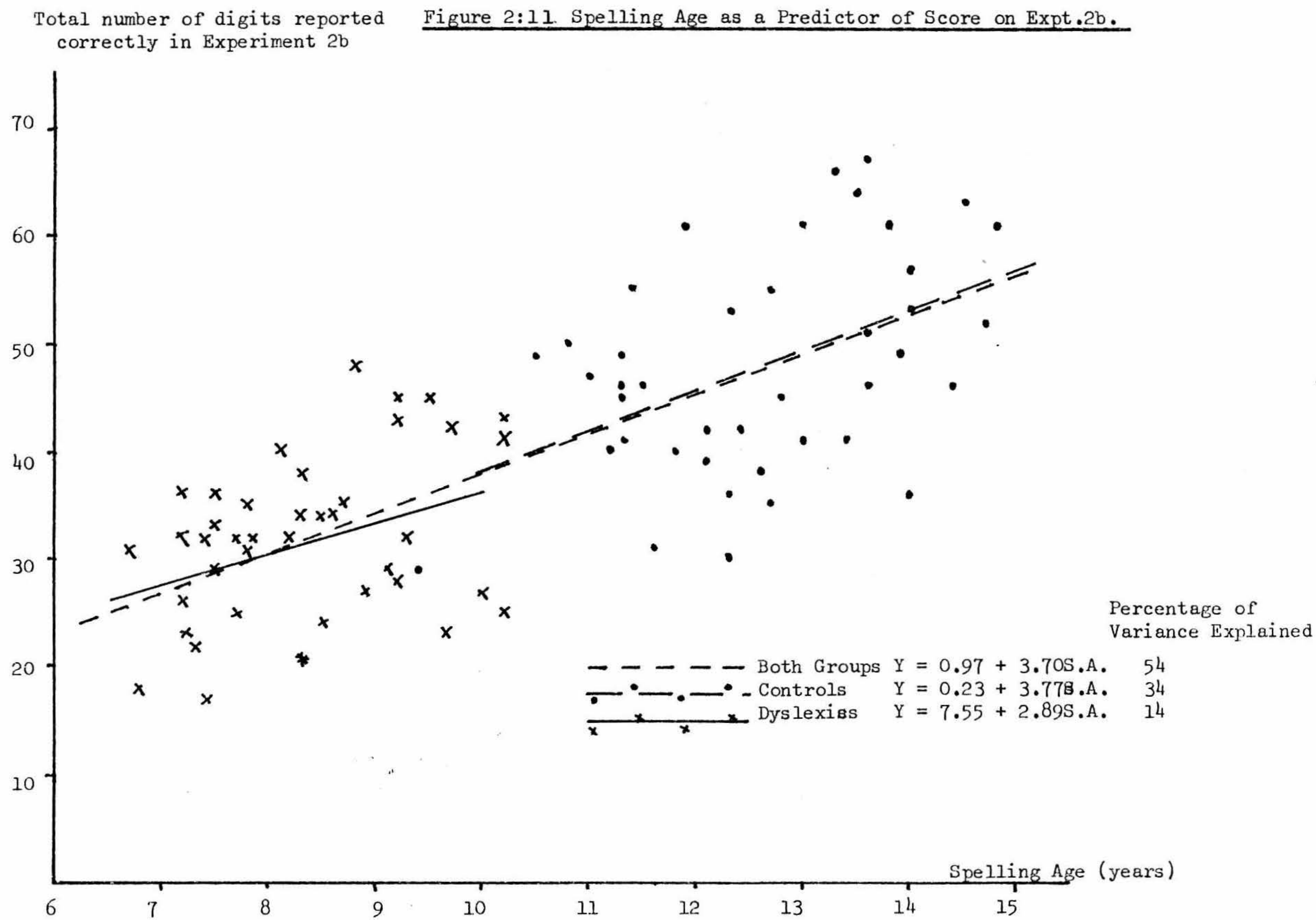


Figure 2:10 Reading Age as a Predictor of Score on Expt.2b.

Figure 2:11. Spelling Age as a Predictor of Score on Expt.2b.



EXPERIMENT 2c

Abstract

13 adult low-literates of mean R.A. 8.1 years and 10 of the fast reader undergraduate readers of expt. 1a were compared for speed of proeessing from 7 digit arrays presented tachistoscopically under backwards masking at exposure times from 25-3000 ms. The main difference between the two groups is again to be found in the slope of the first limb of the items reported/exposure time function. It is concluded that these two groups differ in terms of processing ability through the functional pathway underlying preferentially fast 1st limb performance, and that there is a correlation throughout the population between speed of processing, as measured using the digits task, and reading ability.

Introduction

A further question which arises from these findings is whether the limitation in rate of initial stimulus acquisition specific to those poor readers who are dyslexic or whether, as is likely from the results obtained in Expts. 1a, 1b and 2b, other slow readers also display a limitation at this stage.

Subjects

13 adult low-literates were tested. They were within the age range 20-55 and were participating in evening classes under the Adult Literacy scheme. All were backward in reading, but for a variety of different reasons: there were recent immigrants who were learning English as a foreign language; in the case of some subjects the poor reading appeared to be due to absence from school when they were younger; there were ESN and SSN subjects and one case of probable brain damage. Their one common factor was their weakness at reading, the mean reading age, as measured by the Schonell R_1 test, being 8.1 years.

10 first-year undergraduates were used as controls (age range 18-24 years). These subjects came from the top 30% of a pool of 50 undergraduates and Technical College students ranked for reading speed over 5 conditions in Expt. 1a. For present purposes they will be referred to as 'fast-reading undergraduates'.

Materials and procedure

Procedure and test stimuli were identical with those of Exp. 2b, except for the exposure times used. The range of exposure times best suited to the two subject groups to give most information was determined in a pilot experiment, the result being a range of 25-800 ms. for the fast-reading undergraduates and 30-3000 ms. for the adult low-literates.

Results and discussion

The resultant digit proeessing functions for the two groups are shown in Fig. 2:12.

Again it seems that the major differences between these two groups in terms of items processed per second is found in first limb slope and dogleg point. In this experiment, however, we also find a slightly lower second limb slope for the adult low-literates and a somewhat atypical first limb slope which doglegs at about 300 ms. - a considerably longer time than that found for the other three subject groups tested, where the dogleg point was nearer 100 ms. In any interpretation of these results it is necessary to take into account the variety of subjects who made up this group.

However, it seems that many slow readers, whether or not they display the dyslexic pattern of difficulties, show a limitation in the rate of initial stimulus acquisition. Although it is still puzzling that some people (those designated as 'dyslexic') should continue to show this limitation despite adequate intelligence and opportunities for practice, it is important to remember that slow processing can also occur either if intelligence is relatively low or if opportunities for practice have been limited.

If the digit processing functions for the four groups of subjects tested in exps. 2b and 2c are shown together, as in

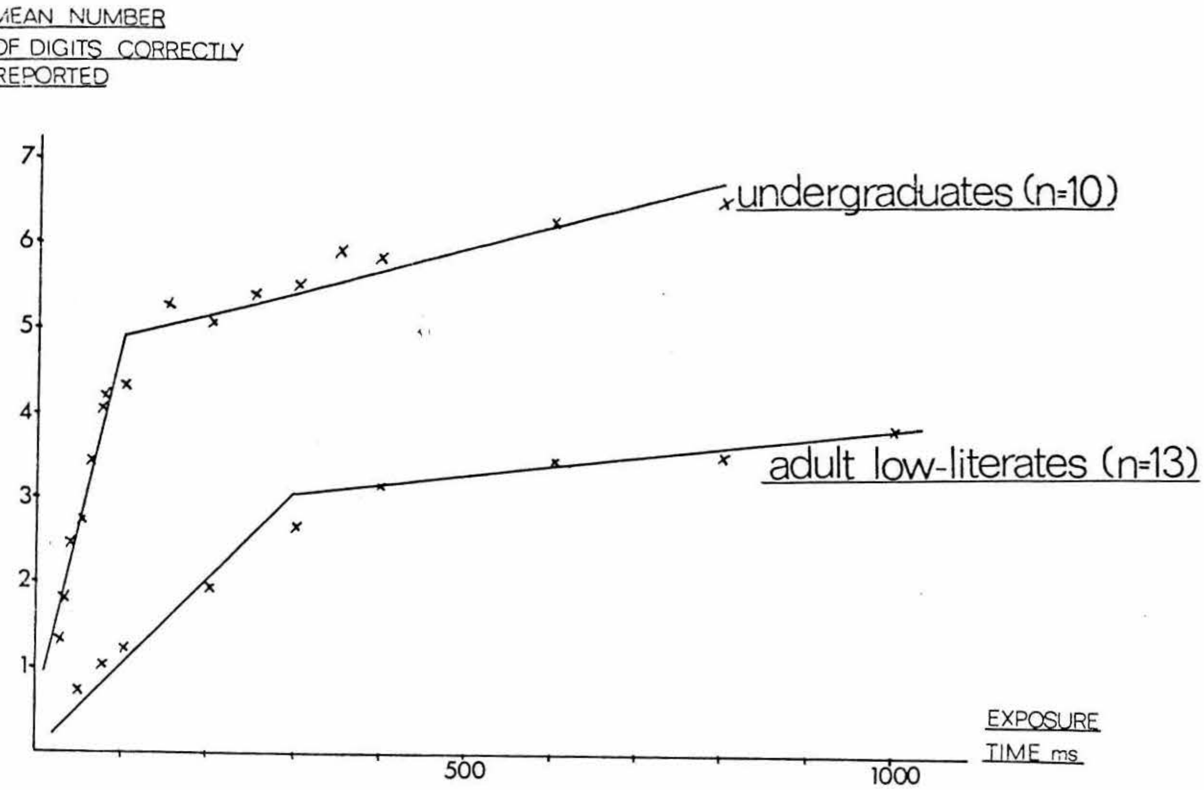


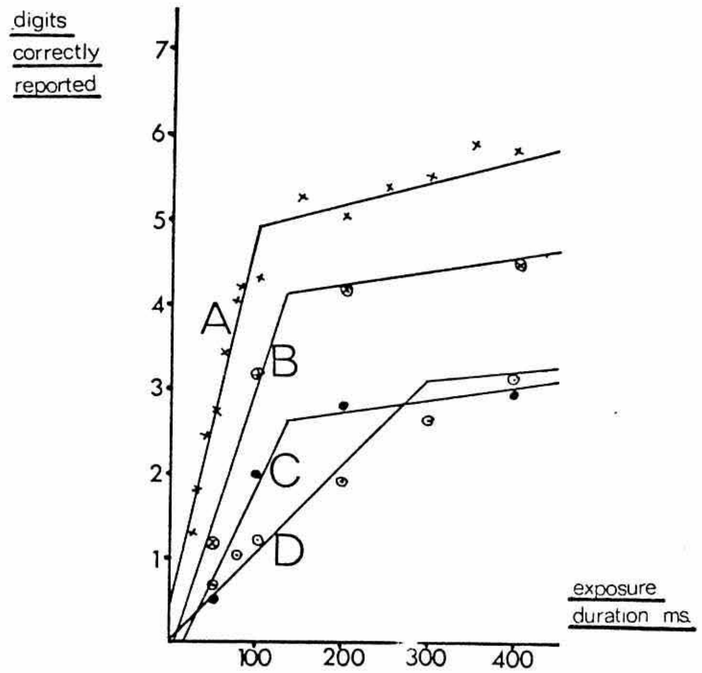
Figure 2:12 Undergraduate and adult low - literate subjects' visual information processing functions derived from the data of Expt. 2c.

Fig. 2:13, an interesting picture emerges. Second limb slopes are similar in all cases, whereas first limb slopes are in direct correspondence with skill at reading.

Now it has been found that, during reading, a single fixation pause lasts, on average, for about 330 ms. in the case of 6-year old children and for about 230 ms. in the case of college students (Taylor, 1957); and it has also been found that for adults the saccadic movement time is less than 50 ms. (Tinker, 1951). Thus if fixation time is added to saccadic movement time, one can say, at a conservative estimate, that the time between the onset of one fixation to the onset of the next is about 400 ms. for young children and about 300 ms. for college students.

If the control children, who in effect represent the mid-range of reading ability in this study, are considered in this light, some interesting observations emerge. It follows from the last paragraph that the information from a single fixation is processed in around 350 ms. According to Fig. 2:13, the major contribution to items processed from a single reading fixation (about 4 items) comes from that process underlying 1st limb slope. Although because of the effects of chunking and of the pronounceability and meaningfulness of verbal material there are important differences between responding to visually presented digits and responding to visually presented words, it nevertheless seems correct to claim that rate of encoding underlying the fast rate of initial information acquisition is a major factor in determining the

subjects	$\overline{X}$ reading age	1st limb slope ITEMS PER SEC	1st limb peak ITEMS
A UNDERGRADS	approx 19	46	4·9
B CONTROL CHILDREN	12·3	30	4·1
C DYSLEXIC CHILDREN	9·4	19	2·6
D ADULT LOW-LITERATES	8·1	11	3·1



Encoding functions of the 4 groups of Ss of differing reading ability

Figure 2:13

amount of information processed from each single fixation in reading; and it may therefore well be that individual differences in the rate of this process contribute in an important way to differences in speed of reading.

CONCLUSIONS

From the results of Experiments 2a, b and c it is concluded

1) The difference between dyslexic and control children in terms of visual information processing resides in the rate of initial stimulus acquisition.

2) Visual encoding and lexical encoding are involved in this initial rate of stimulus acquisition.

3) Dyslexic children differ from controls either at visual encoding and/or at lexical encoding.

4) Reading age correlates more with processing ability than does chronological age. In general, whether the subjects be dyslexic or control children, adult low-literates, or fast undergraduate readers, there is a large positive correlation between reading ability and ability at these functions underlying the initial rate of stimulus acquisition.

EXPERIMENTAL CHAPTER 3

EXPERIMENTAL CHAPTER 3

CONTENTS

EXPERIMENTAL CHAPTER 3

In which dyslexic children are shown to be slower than control children at name-encoding letters, but not at visually encoding them - they are slightly less accurate but no less slow at matching highly confusing letter like forms - the rate of visual code production and matching and the capacity of this system is the same for dyslexic and control children - it is concluded that there is no serious problem in dyslexic children at dealing with the visual characteristics of alphanumeric stimuli, but that dyslexic children are deficient in non-articulatory name or lexical encoding.

Introduction

The findings in Experimental Chapter 2 suggest that dyslexic children are slow at initial stimulus acquisition and that this may reflect either deficient visual encoding or lexical encoding. The experiments which follow are aimed at investigating the performance of dyslexic and normal ability children on tasks involving these functions.

By adapting the procedure devised by Posner (1969) it is possible to test speed of production of the visual code and speed of matching two visual codes without the necessity of further processing or visual-auditory translation (exp. 3a). This would be especially clear if nonsense shapes were used as stimuli (exp. 3b), since in that case there is no auditory 'tag' for the symbols and hence no visual-name translation is possible. In expt. 3c, the decay rate of the visual code is measured using the procedure devised by Posner and Keele (1967). As this method yields immensely variable results, the capacity and decay rate of the visual code is studied by means of a procedure developed by Phillips and Baddeley (1971) and Phillips (1974); these constitute expts. 3d(i) and 3d(ii).

EXPERIMENT 3a

Abstract

21 dyslexic children of mean CA 11.8 years and 21 control children (mean C.A. 11.8 years), matched with the dyslexics for intelligence, were tested on an adaptation of the Posner (1967) paradigm. This investigated the speed at which these children could make, 'visual code' and 'name code' matches of two letters which were either the same or different. Visual and name confusability of letters were included in the experiment to test the assumption that dyslexic children have difficulty in distinguishing between certain confusable letters, e.g. b/d.

In Posner's terminology the dyslexic and control children did not differ on the rate at which they made 'visual code' matches, but the dyslexics were reliably slower at making 'name code' matches.

It is concluded that the speed of visual encoding for letters is as fast in the dyslexic as in the control children.

Introduction

Posner (1969) has demonstrated, in a letter matching task, that responses of 'same' to physically identical letters (AA) occurred more quickly than responses of 'same' to physically dissimilar letters (Aa). He therefore distinguished between visual code comparisons and name code comparisons; and it is possible as a result of his technique to collect speed and error data for the production and matching of both types of stimulus representations. If dyslexic subjects are slower or less efficient at encoding the visual features of the stimulus independently of their ability to name, then more errors and relative slowness as compared with controls would be expected in situations of visual code comparison. In contrast, if their deficiency is primarily one involving the name-code, then they would be slower and/or make more errors in name-coding conditions than individual-coding conditions.

In the present experiment a variation on the Posner procedure was introduced. This involved pairs of letters which, though different, were either visually similar (e.g. OQ) or phonologically similar (e.g. Gd). These 'similar' conditions were included since it is to be expected that a deficiency in the production or comparison of a given type of stimulus feature representation will be associated with slower and/or more error-prone performance with letter pairs which are confusable on that stimulus feature dimension. Thus, for example, longer latencies or more errors may be expected for the phonologically similar letter pairs if the subject has difficulty at name encoding.

Subjects

Two groups of 21 boys were tested. The dyslexic subjects were chosen from a private school which specialised in dyslexia. A check was made of the school records so as to ensure that no child was chosen as a dyslexic unless all of the following conditions were satisfied: (a) reading age (RA) on the Schonell R_1 test was at least two years behind chronological age (CA), (b) spelling age (SA) on the Schonell S_1 test was at least two years behind CA, (c) there was no evidence of any gross behavioural problem or of any gross organic disorder, and (d) there was average intelligence or above, as determined by recognised intelligence tests, usually the Wechsler or the Terman.

Members of the control group were also chosen from private schools. Inclusion was conditional upon (a) a score of average or above on a recognised intelligence test and (b) RA and SA not more than one year behind CA.

The CA, RA and SA characteristics of the two groups are as follows

	Chronological age		Reading age		Spelling age	
	$\bar{X}$	s.d.	$\bar{X}$	s.d.	$\bar{X}$	s.d.
Dyslexic Group (N = 21)	11.8	0.7	9.0	0.5	8.3	0.6
Control Group (N = 21)	11.8	1.0	12.7	1.3	12.6	1.1

Materials and procedure

Six categories of test stimuli were used, each category comprising pairs of letters. The types of pairs were as follows:

Same-case pairs

VI: visually identical

VD: visually dissimilar

VS: visually similar

Different-case pairs

PI: phonologically identical

PD: phonologically dissimilar

PS: phonologically similar

For the VD condition the pairs were chosen so that they were as far as possible neither physically nor phonologically confusable, while for the VS condition the letters, though different, were designed to be visually but not phonologically similar. Visual similarity was achieved by the presentation of two upper case letters, choice of letter pairs being influenced by the findings of Townsend (1971). For the PD condition the letters were designed to be neither visually nor phonologically confusable, while for the PS condition the letters were designed to be phonologically but as far as possible not visually similar. Guidelines for choice were taken from the confusion data of Conrad (1964) and Wickelgren (1965)

The resultant test letter pairs are given in Fig. 3:1.

Letter pairs, printed centrally on white card with 28pt folio light letraset were presented in an Electronic Developments 3-field tachistoscope. Each trial began with the warning signal 'ready', followed by the presentation of a fixation cross for 1000 ms. at an intensity at the subject's eyes of approximately 0.15 lux. The offset of the fixation cross was followed by the exposure of a test letter pair for 2000 ms. at an intensity at the subject's eyes of approximately 1.8 lux. The on-set of the letter pair started a Dawes digital meter, counter and timer, type 3000A, accurate to 1 ms., and the subject's vocal response stopped the timer by means of a voice key.

Testing occurred in a quiet, dimly lit schoolroom. The subject was told that he would be seeing pairs of letters printed

SAME CASE PAIRS

Visually Identical run1	Visually Identical run2	Visually Dissimilar	Visually Similar
(VI)	(VI)	(VD)	(VS)
OO	OO	OB	OQ
RR	RR	RM	RP
FE	FE	FS	FE
CC	CC	CT	CG

DIFFERENT CASE PAIRS

Phonologically Identical run1	Phonologically Identical run2	Phonologically Dissimilar	Phonologically Similar
(PI)	(PI)	(PD)	(PS)
Bb	Bb	Ba	Bd
Mm	Mm	Mb	Mn
Dd	Dd	Ds	Dp
Gg	Gg	Gw	Gd

FIGURE 3:1
Test Letter Pair Stimuli Used In Experiment 3a

on cards held in front of him and that these pairs would consist either of two capital letters or of one capital and one small letter; if the two letters were the same (i.e. of the same name) he was to say 'yes', and if they were different he was to say no, and he was to give his answer as quickly as possible. He was then given eight practice trials with flash cards; this was done under close supervision, and he was corrected if he made a mistake or was confused. He was then moved to the tachistoscope where, under the same instructions, he received 8 further practice trials. None of the different letter pairs in any of the practice trials were either acoustically or visually confusable.

After the practice trials, he then participated in 32 test trials with the stimuli shown in Fig. 3:1; these were presented in quasi-random order and were counterbalanced for both condition and response-type in such a way that the sequence of 'yes' and 'no' trials varied randomly, with the constraint that no sequence of any one kind was longer than three trials.

A record was kept of the time between the onset of each letter pair and the child's response. Errors were also noted.

A baseline reaction time measure was also taken for each child. As the experiment involved two responses ('yes' and 'no'), a two-choice reaction-time procedure was used rather than a measure of a simple reaction time: the child was instructed to say 'yes' as soon as possible after the onset of a solid blue circle and 'no' after the onset of a faint circle outline. Practice was given with a series of flash cards until he was sure of the appropriate responses. Four practice trials were then conducted using the tachistoscope, followed by eight test trials. Each trial consisted of a warning signal - a fixation cross, exposed for 2000 ms. at 0.15 lux - and then one of the two circle stimuli, exposed for 2000 ms. at 1.8 lux. The baseline reaction time was measured by means of the same timing arrangement as that used with the letter pairs. Reaction time was recorded for the eight test trials and a mean two-choice reaction time baseline was calculated for each child.

Results

The mean condition reaction times and errors for the dyslexic and control children are shown in table 3:1 and Fig. 3:2.

The 2-choice reaction time baseline means do not differ significantly ($t = 1.5$, $df = 40$). The remaining data were analysed as a 3-way factorial with subjects nested within groups: 2 groups (dyslexic, control) x 2 types (visual, phonological) x 4 conditions (totals for each subject of 'run 1 identical', 'run 2 identical', 'dissimilar', 'similar'). The 'type' ($F = 51.84$; df 1,280) and 'condition' ($F = 50.9$; df 3,280) factors were significant at the 0.1% level. The 'group' x 'type'

TABLE 3:1.

Mean RT (ms) and total errors for the dyslexic and control children in the 6 conditions of Experiment 3a.

SUBJECT GROUP	2-Choice RT Baseline (ms)	Visually Identical (VI)	Visually Dissimilar (VD)	Visually Similar (VS)	Phonologically Identical (PI)	Phonologically Dissimilar (PD)	Phonologically Similar (PS)
	CONDITIONS						
Control Children							
Mean RT	780	933	1023	1200	1039	1059	1188
Number of Errors	-	0	0	0	4	1	2
Number of Trials	-	168	84	84	168	84	84
Dyslexic Children							
Mean RT	838	960	1065	1219	1156	1159	1304
Number of Errors	-	3	1	8	5	0	13
Number of Trials	-	168	84	84	168	84	84
Group RT Difference:	58	27	42	19	117	100	116

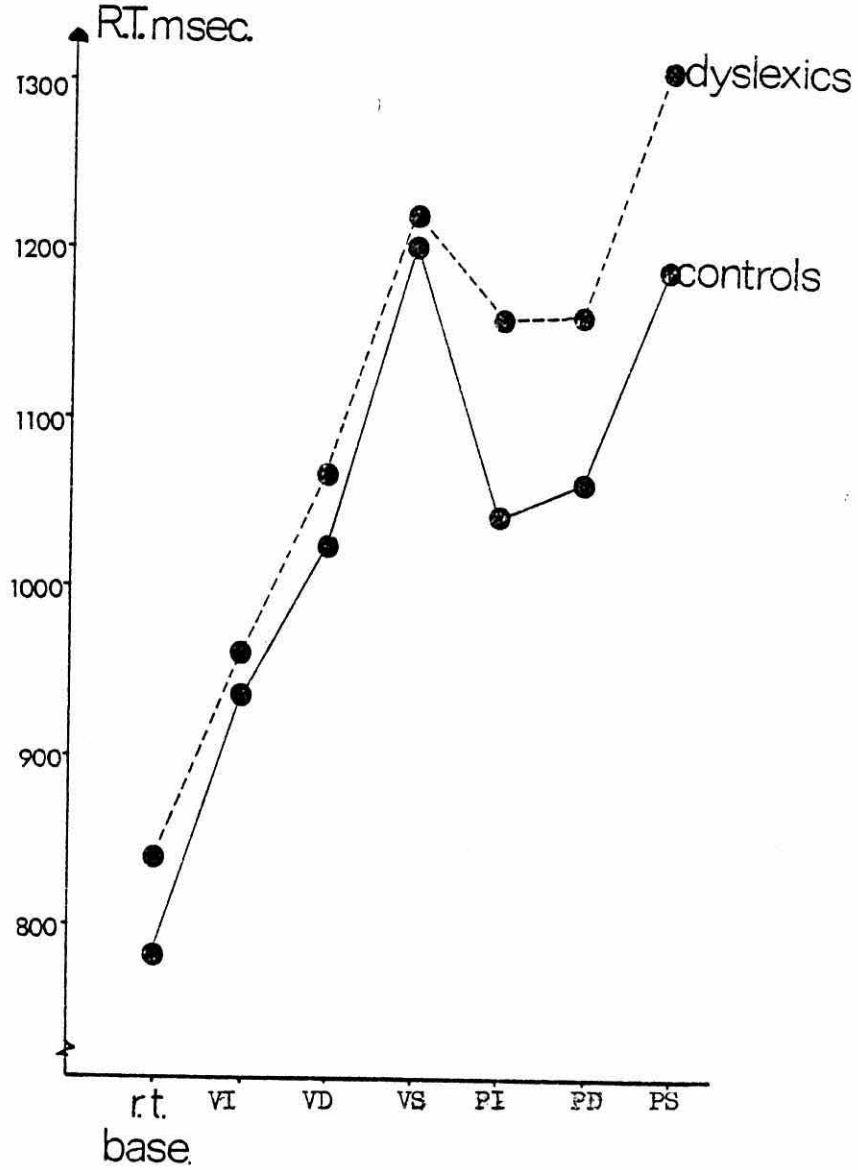


FIGURE 3:2

Group RTs For The Dyslexic and Control Children On The 6 Conditions of Expt. 3a.
(see text)

interaction (F = 9.01, df 1,280) and the 'type' x 'condition' interaction (F = 8.38, df 3,280) were significant at the 1% level. The ANOVA table is shown in Table 3:2.

Discussion

The 'condition' means are consistently higher in the case of the dyslexic group. Since the inter-subject variability within each group is large, however, the 'groups' factor (F = 1.59, df 1,40) does not reach the 5% confidence level.

Within the present framework, the 'group' x 'type' interaction is the most interesting and significant one. It can be seen from Table 3:1 and 3:3 that the dyslexic subjects do not respond more slowly than the controls on the same case letter pairs which are considered to be adjudged same or different on the basis of their visual characteristics, but they are slower at adjudging the different case pairs where the comparison is one of name codes. Supramanian and Audley (1976) have found a similar pattern of results with poor reading subjects.

There are a number of possible conceptualisations of the processes and the order of operation of processes involved in such tasks where stimuli are sometimes visually identical (RR) requiring a 'Same' response, sometimes phonologically but not visually the same (Mm) requiring a 'Same' response, and sometimes different both visually and in name (RM or Ds) requiring a 'Different' response.

TABLE 3:2

ANOVA Data For the Results of Experiment 3a

ource of Variation	D.F.	SSq.	MSq.	Variance Ratio	Probabilit
roups (G)	1	6702311	6702311	1.59	NS
ubjects within G	40	168739290	4218482	16.02	**
ype of Response (T)	1	13645984	13645984	51.84	**
ondition (C)	3	40203604	13401201	50.91	**
C	3	6621065	2207022	8.38	**
G	1	2370648	2370648	9.01	**
G	3	7038	2346	0.01	NS
CG	3	195979	65326	0.25	NS
rror	280	73710115	263250		
otal	335	312196034			

NS: Not Significant
**: $p < .01$

TABLE 3:3

Group x type interaction response time means obtained in Experiment 3a.

Letter pair type	Dyslexic subjects	Control subjects	
Same case	1051 ms	1022 ms	NS
Different case	1194 ms	1081 ms	$t = 5.69$ $p < .01$

All the models assume that letter stimuli can be both encoded for their visual features and for their name representations. Another common assumption is that the production of name codes takes longer than the production of visual codes (c.f. Posner, 1969; Coltheart, 1972). These assumptions fit the present data since the 'type' factor is highly significant: the different case pairs which are assumed to involve name code comparisons take on average 101 ms longer to adjudge than the same case pairs (reaction times 1137 and 1036 ms respectively).

The models differ in the temporal ordering of these processes. A parallel encoding possibility assumes visual code comparison operates in parallel with name code comparison (see e.g. Cohen, 1969). With visually identical (RR) stimuli, visual code comparison indicates a 'Same' response, which is rapidly produced. However, when visual code comparison indicates a difference between the two stimuli these models predict that no response can be made since the visual-code system cannot tell whether the stimuli are of the 'Mm' type (requiring a 'Same' response) or of the 'Mb' type (requiring a 'Different' response); both are different as far as visual comparisons are concerned. The subject must then await the outcome of the slower name code comparison process which is able to differentiate between 'Mm' and 'Mb'.

Alternative serial encoding models assume that in determining whether two simultaneously presented multi-dimensional stimuli are the same or different, the two stimuli are compared dimension by dimension, one comparison after another (see e.g. Egeth, 1966). Thus visual comparisons are first made. If these indicate the stimuli are the same, the 'Same' response is made, otherwise name comparisons are initiated to distinguish between 'Mm' and 'Mb'. In this scheme visual and name comparisons do not operate in parallel but are organised in series.

On the parallel view visual codes affect the response times <u>only</u> when two stimuli are physically identical; in all other circumstances the stimuli are dealt with by the name code system; and in this case visual similarity or dissimilarity would not be expected to influence the 'Different' latencies. On the serial view, however, it will take longer for visual comparisons to reach a 'Different' decision when stimuli are visually similar and hence the implication of name matching will begin later for such stimuli. This would result in longer 'Different' latencies for visually similar stimuli.

The parallel view thus predicts similar latencies for the 'Different' response to VS and VD stimuli; the serial view predicts slower 'Different' response latencies to VS stimuli than to VD stimuli. The present data (Table 3:1) are more consistent with the serial view: the average VS latency was 1210 ms, the average VD latency 1044 ms ($p < .01$, Duncan's Multiple Range Test).

Both the serial and parallel views, as stated, assume that the 'Different' response to same-case different stimuli (OQ, RP, EF, CG, OB, RM, ES and CT) requires the comparison of name codes. Such responses could not be a result of visual code comparisons since when visual code comparisons reveal that two stimuli are visually different a 'Different' response may not be warranted because the stimuli may be of the 'Mm' kind: visually different but requiring a 'Same' response. The data (Fig. 3:2) demonstrated, however, that the dyslexic children are reliably over 100 ms slower than the control children in responding on the basis of name code comparisons with the different case stimuli. If name code comparisons were also involved in the production of 'Different' responses to the same case stimuli, a relative slowness on the part of the dyslexic children would again be predicted. It can be seen from Tables 3:1 and 3:3 that this is not the case: dyslexic and control children do not differ significantly in the latency at which they adjudge same case stimuli to be Same or Different. It is therefore concluded that the physical characteristics of the large upper case second letter of the same case pairs are, as a class, so distinctly different from those of lower case second letters of different case pairs that 'Different' responses to visually different upper case letters are warranted without recourse to name code comparison. This does not seem implausible at an introspective level: inspection of Fig. 3:1

shows the same and different case pairs to be clearly visually distinct, and this distinction occurs at a lower spatial frequency than that necessary to distinguish between an 'a' or a 'b' when paired with a 'B'. There is good evidence that low spatial frequency information is processed faster than high frequencies (Breitmeyer & Ganz, 1976; Broadbent, 1977).

If this is indeed that case then comparison of the latencies of the 'Different responses to VS and VD stimuli is no longer relevant to the question of serial/parallel encoding.

Now from the data in fig. 3:3 it might be suggested that any differences which exist between dyslexic subjects and controls in the three 'physical' conditions can be explained solely in terms of initial baseline differences between the two groups in a 2-choice reaction time situation. These differences in fact fail to reach the 5% level of significance, though they are significant at the 10% level ($t = 1.5$, $df = 40$). If the data of exp. 3a are re-analysed by subtracting from each subject's score in a particular condition his mean baseline reaction time in a Donderian fashion (which in the ANOVA affects only the group and subject-within-group factors), the group factor F-value drops from 1.59 (ns) to 0.09 (ns). These computed data, shown in fig. 3:4, demonstrate clearly that the major differences between the two groups lie in their responses in the 'name' condition.

With respect to the main theme of this expt., it must be concluded that the speed of production and matching of visual codes for letters is as fast and efficient in dyslexic children as in control children. The production and matching of name codes,

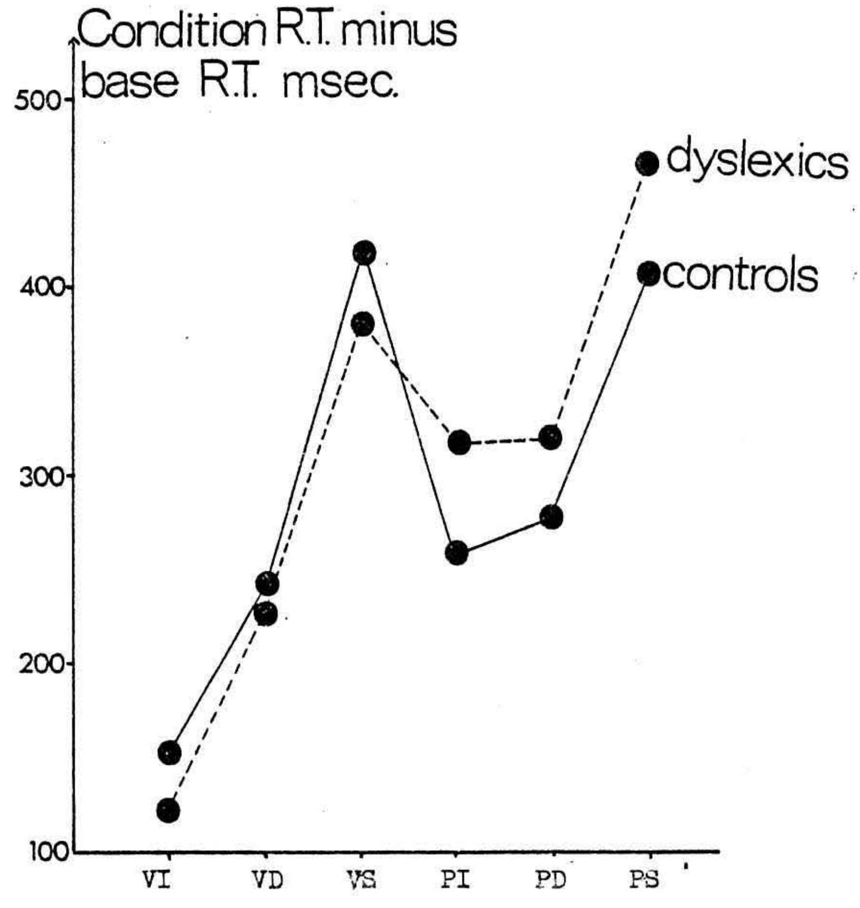


FIGURE 3:3

Mean Group/Condition RTs Minus Group 2-Choice RT Baseline Values On The 6 Conditions Of Experiment 3a. (see text).

however, takes on average 113 ms longer for the dyslexic subjects than for the controls. This between-group difference on the phonological pairs may reflect either differential speeds of name encoding, differential speeds of name-code comparison, or both.

Regarding name codes, a distinction needs to be drawn between an articulatory code (i.e. a code of implicit or explicit speech) and the precursor of such a code where the stimulus information is represented in a non-articulatory form before any mechanism for articulation comes into play. Thus Sperling (1967) has suggested that as a result of a 'scan' of the visual information store there arises a 'programme of motor instructions' for later articulation, while Allport (1978a, b) postulates the production of a 'lexical code' as a consequence of input logogen activation.

The question then arises as to whether it is the non-articulatory or the articulatory (or conceivably both) type of name code which is the locus of deficiency in dyslexia. Experiment 7e was performed to throw light on this question by using articulatory suppression (which can be assumed to interfere with articulatory encoding) in Posner-type tasks with undergraduate subjects; it was found, that neither 'visual code' or 'name code' matching were affected. It seems, therefore, that at least for undergraduates the name code used in such tasks is non-articulatory. Thus the most likely candidate for the functional deficiency in dyslexic children which underlies their slower name code matching in the present experiment is the production (or matching) of non-visual and non-articulatory codes. This issue, however, remains open for the present. Although the same different-case letters (Bb) are traditionally discussed (e.g. Posner, 1969) as requiring name code matching, these letters, albeit different visually, share the same name, represent the same language element, and share the same meaning (if it makes sense to talk of letters having associated meaning). The 'Same' response to such letter pairs may strictly therefore be the result of the matching of either non-articulatory name, lexical or semantic codes.

Now it is regularly claimed that young dyslexic children show confusion in both the reading and the writing of certain letters (see for example, Critchley, 1970; Vernon, 1971; Liberman, Shankweiler, Orlando, Harris and Berti, 1971). This is especially the case when the letters are reversible, e.g. b/d and p/q.

It can be seen from Table 3:1 however, that although the VS letter pairs are responded to as being different more slowly than VD pairs, this trend is seen to an equal extent in both the dyslexic and the control children. Thus the letter confusions so often seen clinically in dyslexic children cannot simply be due to a limitation at the visual code level. On the contrary it is necessary to push back the level at which these confusions occur at least one step further towards the centre; and from the present evidence it is possible that the production of the non-articulatory name code or lexical representation is the locus of the fault. The same pattern is also found in the phonological conditions: the addition of confusability appears to slow down both dyslexic and control subjects equally. It should be noted that dyslexic subjects make more errors than controls, especially in the 'confusable' conditions but this result must be seen in the framework of very low error rates overall, viz. approximately 1% for the controls and 4% for the dyslexic subjects.

Mackworth and Mackworth, 1974 performed a similar matching experiment on good and poor readers(from 7 to 12 year olds) using letter and word stimuli. The subjects were asked to judge whether pairs of pictures, letters, or words looked or sounded the same. This test measured i) the coding of written letters or words with sounds; ii) the detection of small visual differences and iii) the speed of processing. The letter matching stimuli were all of the name code type (the test pair used were Hh, Ce, Db, Ga, Ee, Bb, Hg, Dd, Nn and Bd), and the good readers (as in the present experiment) reliably responded faster than the controls (over all 6 grades the mean R.T.s for the pair were 2.58 sec. for the controls and 2.74 sec for the poor readers). For the word stimuli there were three categories

i) identical e.g. felt-felt 'yes' response

ii) homophones e.g. Bare-bear 'yes' response

iii) different e.g. Hot-got 'no' response

and the children had to respond by pressing the 'same' button if the words looked or sounded the same and were otherwise to press the 'different' button.

The mean reaction times (sec.) for the two groups are as shown in table 3:4.

In confirmation of the present results, the homophone and different categories (which are name matches) are made slower by the poor readers than by the fast readers. In addition, however, Mackworth and Mackworth, 1974 also find a small difference between the good and poor readers on the identical matches which could be made by visual code comparisons. There are two problems with this interpretation, however. i) there is no 2 choice control reaction time figure for each child, ii) the experiemnt is designed so that visual code matching is in fact biased against: for 30/40 stimuli the children have to make name comparisons before making their decision (with homophone and different categories): it is possible therefore that they are carrying this strategy over on the remaining 10 identical category trials. This was not the case in experiment 3a where all the physical trials (which consitute 50% of the trials) could be made on the basis of visual code matches since even in the case of the Physical Different pairs (e.g. OB) the two letters being both upper case is a cue for a visual matching strategy. For those reasons, and in addition because the Mackworths demonstrated that there was no relation between reading ability and performance in a non-verbal pictorial task which must has involved visual code matches, the finding that their good and poor readers differ

TABLE 3:4

Mean Reaction Times for the Good and Poor Readers on the 4 conditions of the Expt. of Mackworth and Mackworth, 1974.

Material	Example	Good Readers RT (sec)	Poor Readers RT (sec)	Difference (sec)
Letters	Ce	2.58	2.74	0.16
Identical	many-many	2.71	3.62	0.91
Homophones	real-reel	3.90	5.23	1.33
Different	chain-chair	3.66	5.24	1.58

Adapted from Mackworth, J.F. and Mackworth, N.H., 'How children read: matching by sight and sound.' Journal of Reading Behaviour, 1974, 6(3), 301.

on the identical pairs cannot be taken to contradict the present findings. Their other conclusion of the superiority of good readers and poor readers in making name responses both accord with the present findings and also demonstrate that this name match problem is to be found in poor readers who are not necessarily dyslexic.

Vellutino, Steger and Kandel (1972) and Vellutino, Smith, Steger and Kaman (1975), presented their subjects (good and poor readers in the range between second and sixth grade) with tachistoscopic exposures of both verbal and non-verbal stimuli and asked them to identify and/or reproduce these stimuli both orally and in writing. The poor readers manifested considerably greater accuracy in copying and naming letters in words than they did in pronouncing these same words. The poor readers also differed from the controls in the types of errors which they made, but this occurred only in the case of oral responses, not in the case of written ones. Here, too therefore, the same general pattern of results is found, in that poor readers perform normally in dealing with graphemic stimuli as such but once they are set a task which requires graphemic to phonemic translation they perform less well.

It appears that the 21 10.7 to 12.7 year old dyslexic children tested here behave uniformly as a group in that they show no impairment in the speed or accuracy with which they can adjudge letters on the basis of their visual features, and in that they are consistently slower than the controls in comparing letters on the basis of name or lexical features.

Additional support for the interpretations proposed for these data can be found in the following studies. Calfee, Chapman & Venezky (1970) have shown that visual matching tests (Posner task, same case letter matching) are uncorrelated with tests of verbal performance (e.g., knowledge of the alphabet). Moreover, letter identification, which involves both visual and name factors, shows intermediate correlations with both visual and verbal tests. A related finding with brain-damaged adults is that physical matching is relatively or completely unimpaired in patients suffering from aphasia, while there is a severe loss in name and meaning level matches (Boies, 1971).

EXPERIMENT 3b

Abstract

To further investigate whether there is a visual code problem in dyslexic children, the same subjects of Expt. 3a were tested for the speed of matching non-verbal, non-alphanumeric stimuli. Since these stimuli were both not-nameable and novel, the task tests visual code matching in the absence of any possible learning overlay.

The dyslexic and control children did not differ in the speed with which they could make these visual code matches, and it is therefore concluded that the speed of visual code production is the same in both these subject groups. The dyslexic children did tend to make more errors than the controls (10.4% vs 5.0% respectively), and this implies some slight accuracy problem with dyslexics on visual code matches.

Introduction

It does not follow from expt. 3a that there is no visual code problem in poor readers. Any such deficiency which occurred in the dyslexic children of expt. 3a may have been masked by learning overlay: the children tested with the Posner task has long mastered the skills necessary for correct identification of single letters. This may have resulted in dyslexic and control children performing at a similar level on the 'visual' letter pairs at the age range tested, but it may also be the case that the dyslexic children mastered these skills with more difficulty than the controls and at a later stage in their ontogeny.

To test the matter further, a visual matching task was devised which involved the use of confusable non-alphanumeric stimuli. Since these stimuli were new to the children there was no possibility of the immediate results being affected by learning overlay, and since they were not nameable (or at least not nameable at first glance), there could be no competition between visual and name coding. Letter-like forms were presented in pairs, the children being asked to say 'yes' if the two stimuli were identical and 'no' if they were different. Each pair always consisted of graphic shapes which were either identical or, if not identical, different in only a small number of features. The second stimulus of the pair was transformed in ways similar to those devised by Gibson, Gibson, Pick and Osser (1962). In these experiments it was found that young children, aged 4 to 8, when shown rotated or reversed versions of previously presented shapes, made many errors in reporting whether they had seen these shapes before; and although the number of errors decreased with age, even the 8-year-olds made mistakes about 7% of the time. Now Gibson and Levin (1976) claim that the 'increase in specificity of correspondence between discriminations and stimulus information is critical for the development of reading skill'; and, if this is correct, the prediction is that poor readers, whatever their age, will be weak at this kind of task and that improvement will occur pari passu with increasing reading age rather than with increasing chronological age.

Now the dyslexic children who took part in expt.3a had a mean reading age of 9.0, compared with a mean reading age for the controls of 12.7; and if discrimination of visual features is an important component of reading, as Gibson and Levin (1976) imply, one would predict that these children would be more prone to error than controls matched for chronological age.

It is obvious, of course, that individuals can learn to identify shapes with practice; for example, a Western European can without too much difficulty learn to read Hebrew, Greek, or Japanese. It is also obvious that what are called 'nonsense shapes' need not remain as nonsense indefinitely, since once they have been named they are no longer nonsense. In the present experiment, however, no such learning had taken place with either group. The experiment can therefore be regarded as a test of visual code production or visual matching independently of naming.

Subjects

The subjects (21 dyslexic children and 21 controls) were the same as those who took part in expt. 3a.

Materials and procedure

The procedure was basically the same as that of expt. 3a. Baselines for 2-choice reaction time were determined for each child. He was then told that he would be seeing pairs of shapes, the two shapes being exactly the same or different; if they were the same, he was to respond 'yes' and if they were different he was to respond 'no', and he was to give his answer as soon as he could. 16 letter-like pairs were then shown sequentially on flash cards for practice and all errors were corrected. Next came 8 practice trials on the tachistoscope, followed by 32 test trials. Exposure sequences on the tachistoscope and timing procedures were identical with those used in the previous experiment. The test stimuli are shown in Fig. 3:4. The four basic stimuli were chosen to be examples of simple and complex straight and curved features: stimulus 1, simple straight lines; stimulus 2, simple curves, stimulus 3, complex straight lines; stimulus 4, complex curves. The transformations used included reversed and rotated versions of the basic stimuli, since these might be expected to create special difficulties for dyslexic children in view of their alleged difficulties over 'left' and 'right' and over 'up' and 'down'. The presentation order of the stimuli was counterbalanced in respect of both response type ('yes' or 'no') and in respect of the different variants of the basic stimuli. Times were noted between stimulus onset and the onset of the subject's verbal response and all errors were recorded.

Results and discussion

The mean reaction times and the standard error of these means for the two groups of subjects are shown in Table 3:5, as are the total group x condition errors.

FIGURE 3:4

Test Letter-Like-Form Stimuli Used in Experiment 3b.

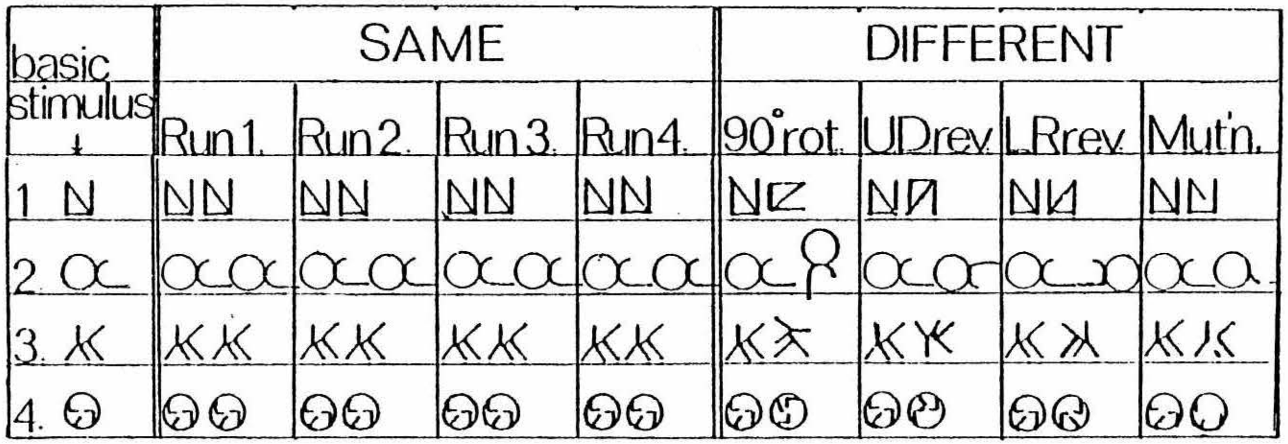


TABLE 3:5

Mean Condition Reaction Times (ms), Standard Errors of these Means, and Total errors for the Dyslexic and Control subjects in Experiment 3b

Condition	Mean Reaction Times		Total Errors	
	Dyslexics	Controls	Dyslexics	Controls
Same Run 1	1185	1117	3	1
Same Run 2	1296	1160	8	2
Same Run 3	1266	1217	1	0
Same Run 4	1269	1173	13	1
Different 90° Rotation	1263	1182	2	0
Different UD Reversal	1317	1251	9	1
Different LR Reversal	1422	1269	14	5
Different Mutation	1427	1356	28	24
	Standard error of the means = 34.3		Total no. trials/group, condition = 84	
Group mean RTs over the whole exp.	1306	1216		
	Standard error of the means = 56.3			

The data were analysed as a 3 factor ANOVA with subjects nested within groups : 2 groups (dyslexic, control) x 8 conditions (runs 1, 2, 3 and 4, where the required response was 'Same', and the 90° rotation, updown reversal, left-right reversal, and mutation where the response required was 'Different') x 4 letter-like forms.

The main group factor ($F = 1.28$, d.f. 1,40) failed to reach the 5% level of significance.

The subjects within groups factor ($F = 21.57$, d.f. 40,1240, $p < .0001$), the conditions factor ($F = 10.06$, d.f. 7,1240, $p < .0001$), the letter like form factor ($F = 42.25$, d.f. 3,1240, $p < .0001$), and the condition x letter like form interaction ($F = 2.86$, d.f. 21,1240, $p < .001$) were all highly significant.

No other factors or interactions reached the 5% level of significance. As the interactions with groups were insignificant it must be concluded that the dyslexic and control children were affected by the differing conditions and letter like forms in a similar manner.

Total error data (see Table 3:5) were analysed as their angular transformations in a 2-factor ANOVA: 2 groups x 8 conditions, with letter-like forms as blocks. The groups factor ($F = 24.1$; d.f. 1,45; $p < .01$) and conditions factor

($F = 18.7$; d.f. 7,45; $p < .01$) were significant. Thus although the dyslexic subjects were not significantly slower at the present task they did tend to make more errors than the controls (10.4% vs 5.0% respectively).

The condition factor is significant at the .01 level ($F = 10.1$, d.f. 7,1240). Mean reaction times for each condition are shown in table 3:4 a Newman Keuls test shows that all conditions are significantly different from all other conditions at the .05 level at least, except for the '90° rotation' vs 'up-down reversal' and 'up-down reversal vs 'left-right reversal' conditions. The condition producing the longest response times is that of 'mutation different'. This result seems at variance with those of Gibson, Gibson, Pick, and Osser (1962), where fewest errors were made by the younger children on the break and close conditions. The result, however, is not surprising in the present experiment, where the subjects, being older than those in the Gibson study, are used to accepting a stimulus as being a letter, even though it is written in one of many different handwritings or typefaces: the presence of a 'small crack' in an 'a', for example, might not be enough to cause these children to question its identity. It seems likely that this strategm of pattern recognition was carried over to the present test; indeed in the flash card practice session several children showed concern with the mutated 'different' stimuli, in some cases suggesting that the two stimuli were the same but that the letraset had cracked; for this reason they may have been under a misapprehension as to what response they were expected to give.

Rotations and reversals, however, are transformations which are important in the pattern recognition of letter stimuli: an up-down reversed 'u' means something different from the original 'u', and a left-right reversed 'b' is notoriously different from the original 'b'. For both groups of children the second slowest condition was left-right reversal and the next slowest was up-down reversal. The 90^{o} rotation produced the fastest reaction times of the 'different' conditions, while 'run 1 same' produced the fastest condition of all. Over all four 'same' runs the mean reaction time was 1268 ms., compared with a mean reaction time of 1253 ms. for the 'different' run, the difference between the two means being insignificant. A likely explanation of the relatively fast times for 'run 1 same' is that once the subjects encountered the confusing features of the 'different' conditions they became slower at responding when the stimuli were the same.

There was a significant condition x letter-like form interaction ($F = 2.86$, df. 21,1240, $p < .001$). For example, form 2, whilst producing the fastest mean reaction time overall, requires longer time than either forms 1 or 3 to be determined as different when paired with its up-down reversal, being almost symmetrical about its horizontal axis. Similarly form 1, being almost symmetrical about its vertical axis, is easy to distinguish from its up-down reversal but much more difficult to distinguish from its left-right reversal. It must again be stressed that the group x condition x letter-like form interaction fails to reach any level of significance: both groups of subjects were reacting to the increasing difficulties in the same way.

The other significant factor is that of letter-like form ($F = 42.3$; df. 3,1240; $p < .0001$). Mean reaction time for each form is as follows: Form 1, 1226 ms., Form 2, 1206 ms., Form 3,1237 ms., Form 4, 1447 ms. A Newman Keuls test demonstrates that form 4 produces significantly longer reaction times than the other forms, and it seems in general that an increase in complexity of the stimulus produces slower processing and comparison times.

From the analysis of response times it can be seen that there is considerable variability of subjects within groups, and, as a result of this, the mean response times of the dyslexic and control groups do not differ significantly. The lack of significance of the group x condition interaction implies that this is also the case when the condition means of the two groups are compared. Thus, even though these means in Table 3:5 follow a reliable trend where the condition mean of the dyslexic group is consistently larger than that of the control group, the large subject within group/condition variability results in the group condition mean difference being insignificant. As groups, therefore, the dyslexic and control children do not differ significantly in the mean time with which they can match two highly confusing letter like forms of the type used in this experiment.

The fact that dyslexic children made more errors at equivalent response times, however, invalidates any statement about their being able to process these letter-like stimuli as well as controls. One possibility is that the results are due to different speed-accuracy trade-offs in the two groups. Panchella (1974) has shown that only a very small difference in accuracy could be evidence of a major speed-accuracy trade-off, and it is plausible to suppose that because of long-standing educational pressures it has become a habit with some dyslexic subjects to sacrifice accuracy for speed.

EXPERIMENT 3c

Abstract

To investigate the rate of decay of the visual code, a variant of the procedure described by Posner and Keele, 1967 was used to test 19 control children (mean C.A. 11.84 years) and 19 dyslexic children (mean C.A. 11.83 years). Letter pairs, (either visually identical (AA), phonologically identical (Aa), or different (AF,AL) were presented tachistoscopically as in Expt. 3a, and the reaction time for the children to decide whether the letters were the same or different recorded. In contrast to Expt. 3a, the letters were separated by ISIs of either 0, 1 or 2 sec.

At all ISIs the dyslexic children show a greater advantage of 'visual code' matches over 'name code' matches. When the data are analysed as either Name same RT - Physical same RT, or Physical Different RT - Physical Same RT for each subject at each ISI, methods which Posner and Keele (1967) suggest allow the derivation of estimates of the rate of decay of the visual code, there is no significant group x time interaction. Due to the limitation of the design and analysis, nothing can be concluded about the differential rates of decay of the visual codes of dyslexic or control children.

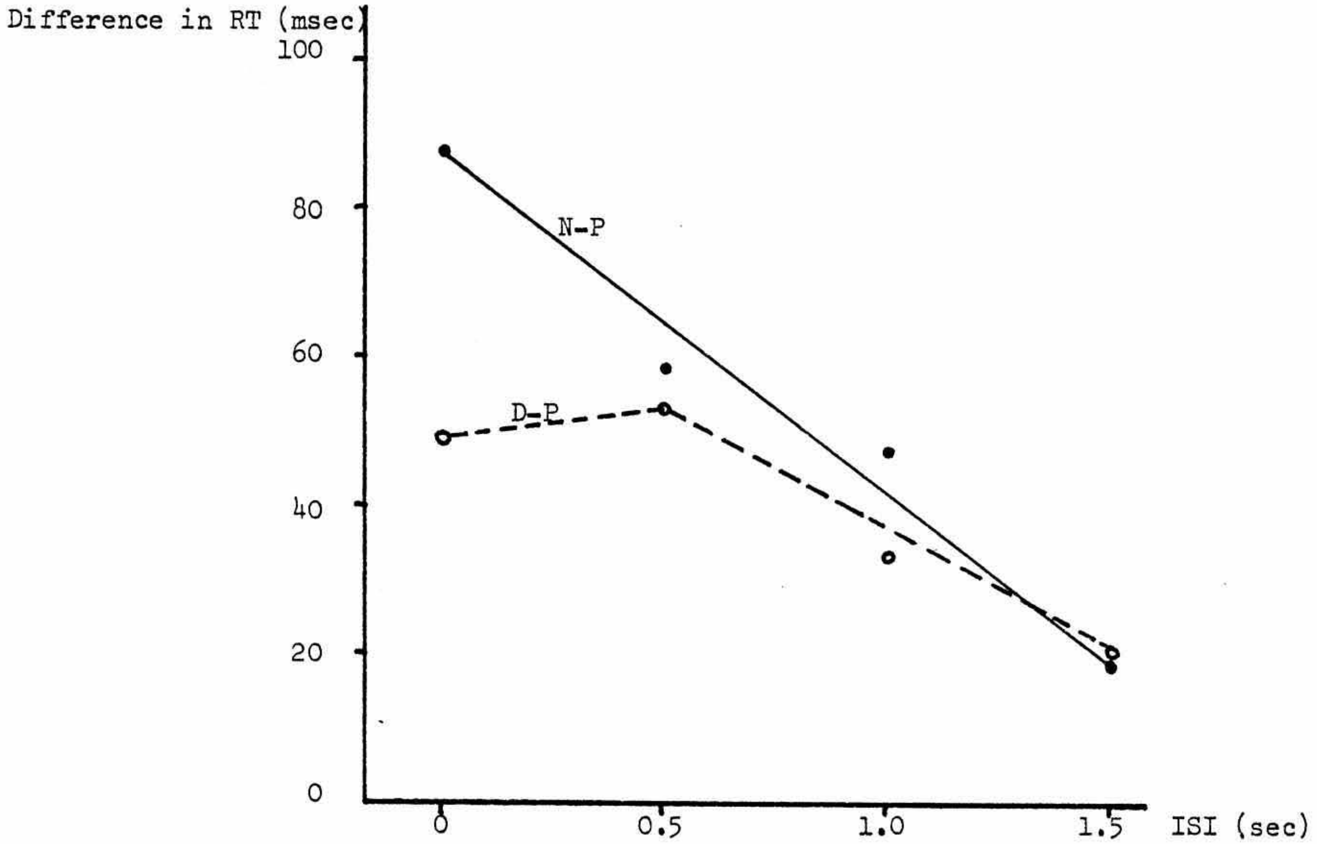
Introduction

One of the conceptualizations of cognitive functions underlying visual information processing detailed in Expt. 2b, that of Coltheart (1972), suggests the visual code to be the 'buffer' which stores the representations prior to naming. Dyslexic children are deficient at visual information processing, and one possibility in the causation of this deficiency is that the visual code representation, the main date-base for naming, decays away too rapidly thus preventing adequate further processing. This experiment attempts to test this hypothesis.

Posner and Keele (1967) describe a method by which, they suggest, the rate of decay of the visual code may be ascertained. This method is an adaptation of that used in Expt. 3a. Letter pairs are presented which are either physically identical e.g. AA, or name identical e.g. Aa, or different e.g. AF or Ah. In contrast to the procedure used in Expt. 3a the letters are not always presented simultaneously, but are presented separated by ISIs of 0, 1 or 2 sec. Posner and Keele (1967) used ISIs of 0, .5, 1 and 1.5 sec. and demonstrate that by 1.5 sec. there is no RT advantage of visual identity matches over name identity matches (they calculate this by 2 matches: either (i) name same RT-physical same RT, or (ii) different RT-physical same RT. The logic of these operations is that the former element in both equations reflects name-code matching whilst the latter reflects visual code matching; thus if the resultant equation value is positive, visual code matches are made faster than name code matches). Their results, beautifully neat, can be seen in Fig. 3:5.

FIGURE 35

Decay Functions for Visual Information obtained by the use of 2 different subtractio
ethods: N-P is name identity minus physical identity, D-P is different minus physical
dentity (see text). From Posner, M.I. and Keele, S.W. 1967 'Decay of Visual Information
rom a single letter' Science, 158, p 137.



If their interpretations are correct, it should therefore be possible to investigate the rate of decay of the visual code in dyslexic and control children. 19 dyslexic and 19 control children were therefore tested using a variant of the Posner & Keele (1967) procedures.

Subjects

19 dyslexic children (dyslexic criteria as stipulated) of mean CA 11.83 years (s.d. 0.73), mean RA of 8.92 years (s.d. 0.30) and mean SA of 8.27 years (s.d. 0.38), and 19 control children of mean CA 11.84 years (s.d. 0.96), mean RA of 12.74 years (s.d. 1.15) and mean SA of 12.54 years (s.d. 1.00) were tested in Expt. 3c. These children were all of average of above average Intelligence, as measured using recognized intelligence tests, and all attended private schools.

Materials and Procedure

The procedure was identical to that of Expt. 3a except for the following modification:

i) new test stimuli were used. These conditions were:

Physical same: AA, HH, FF, GG.

Physical different: AF, HG, FH, GA.

Name same: Aa, Hh, Ff, Gg.

Name different: Ah,Hg, Fa, Gf.

ii) each stimulus pair was presented three times, the two members of the pair being separated by ISIs of either 1 ms. (which is effectively 0 sec.), 1 or 2 sec. The individual letters were presented for 3000 ms. at 3.0 lux.

A 2 choice baseline 'reaction time was taken for each child as in Expt. 3a. The child was then given practice using 'flash-cards' before performing on the tachistoscope a further 8 practice trials. There were then 48 test trials where the stimulus type and condition were randomized, with ISI changing every 4th trial.

Results

The mean RT for each group, condition and ISI are shown in table 3:6, as are 2 choice RTs for the groups. These are also shown graphically in fig. 3:6 . These results were analysed as a four factor ANOVA using the four letter pairs in each condition as replications: 2 groups x 2 identity types (physical/name) x 2 response types (same/different) x 3 ISIs, with subjects nested within groups. The ANOVA data is shown in table 3:7. It can be seen that the groups do not differ significantly. Responses to the name letter pairs are made reliably slower than those to the physical letter pairs ($F = 37.6$; df 1,396; $p < .01$), and same responses are made faster than different responses ($F = 58.3$; d.f. 1,396; $p < .01$). The group x response type interaction is significant ($F = 5.15$; d.f. 1,396; $p < .05$) demonstrating that the dyslexics are significantly slower than the controls at making 'name code' matches. The ISI factor is highly significant ($F = 175.8$, d.f. 2,396; $p < .01$): as the ISI between the two letters minimizes so the speed of making the matching responses minimize.

TABLE 3:6

Mean ISI/Condition Reaction Time Means For The Dyslexic and Control Children Participating In Experiment 3c.

CONDITION	ISI (sec)	DYSLEXIC MEAN RT (msec)	CONTROL MEAN RT (msec)
Physical Same	0	895	884
	1	736	759
	2	690	748
Physical Different	0	1005	940
	1	827	806
	2	807	797
Name Same	0	1013	966
	1	774	774
	2	775	801
Name Different	0	1067	999
	1	867	848
	2	853	814
2 Choice RT Baseline:		752	716

FIGURE 3:6

Matching Response Times for the Dyslexic and Control Children on the 4 Letter-type Conditions at each ISI of Experiment 3c.

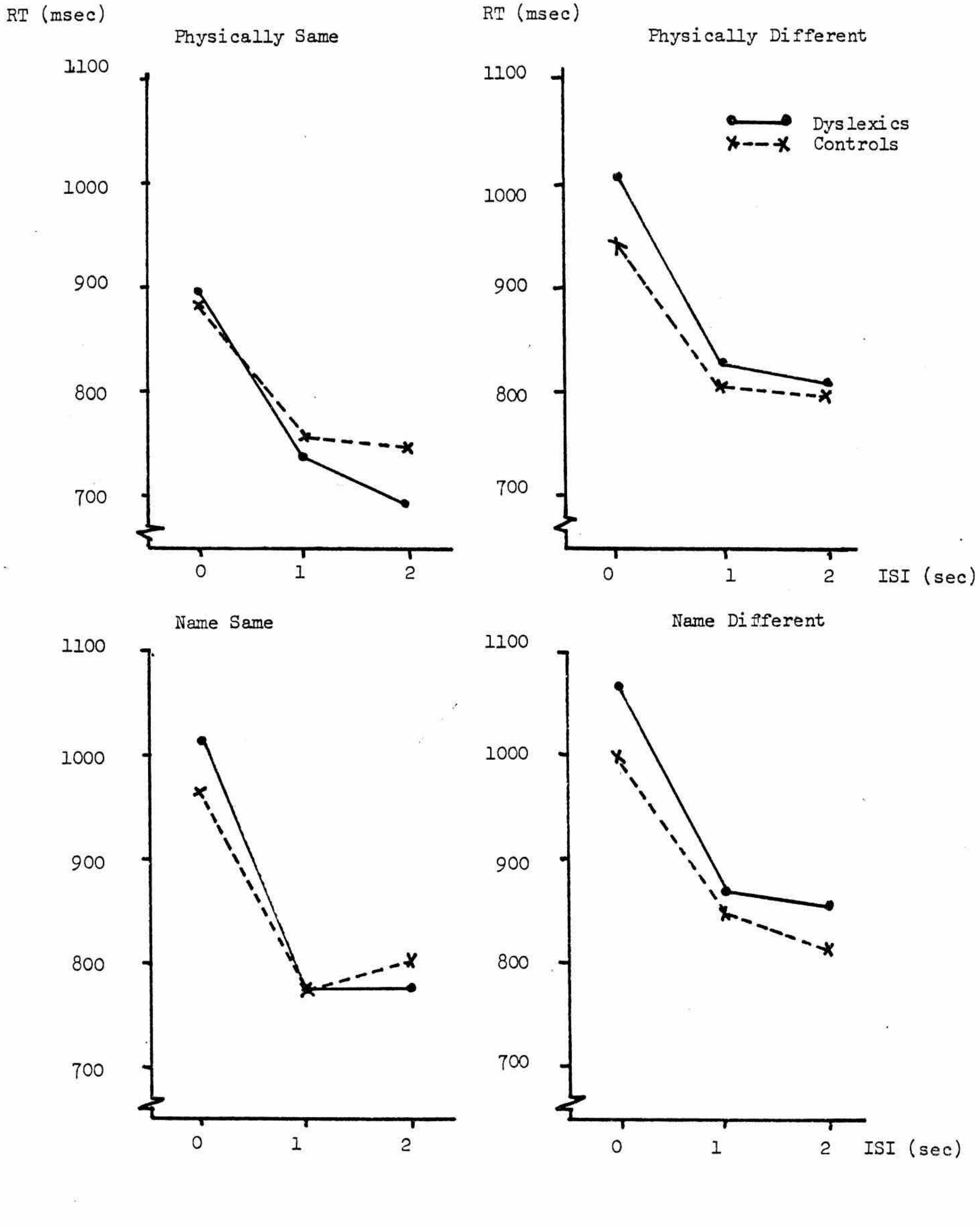


TABLE 3:7

ANOVA Data for the Raw Data Analysis of Experiment 3c (see text).

Source of Variation	D.F.	SSq.	MSq.	Variance Ratio	Probability
Groups (G)	1	375017	375017	0.16	NS
Subjects within G	36	83174673	2310408	16.16	**
Physical/Name (P)	1	5381391	5381391	37.63	**
Response type (R)	1	8340597	8340597	58.32	**
PR	1	135516	135516	0.95	NS
ISI (I)	2	50279710	25139855	175.8	**
PI	2	684545	342272	2.39	NS
RI	2	69472	34736	0.2	NS
PRI	2	242700	121350	0.85	NS
PG	1	268690	268690	1.88	NS
RG	1	735934	735934	5.15	*
PRG	1	54409	54409	0.4	NS
IG	2	1081857	540928	3.78	NS
PIG	2	40689	20345	0.14	NS
RIG	2	149921	74961	0.52	NS
PRIG	2	13428	6714	0.05	NS
Error	396	56633119	143013		

NS: Not Significant

* : $p < .05$

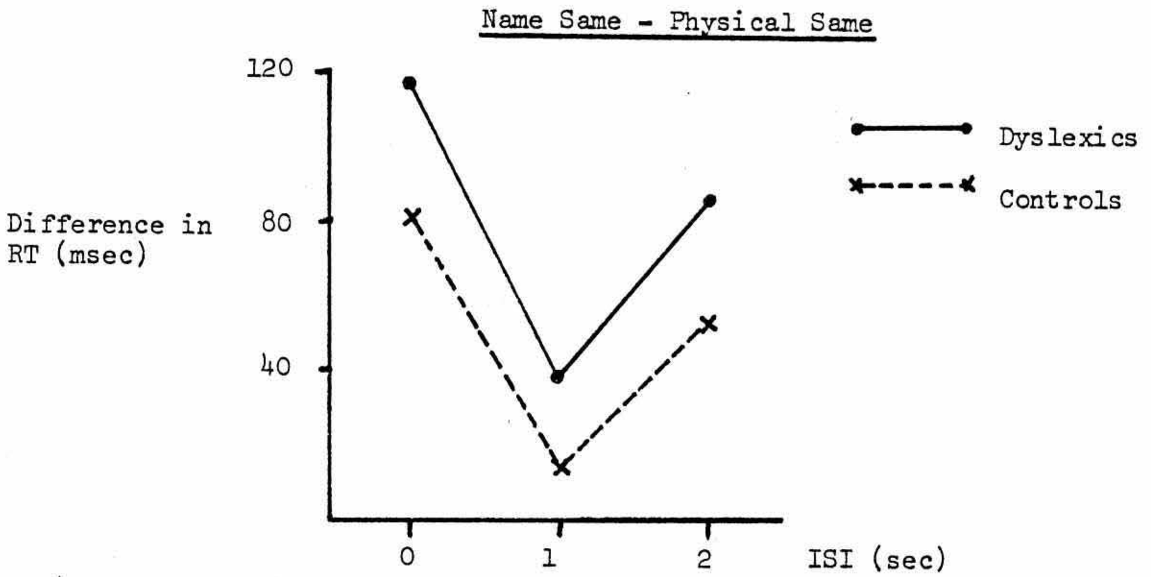
**: $p < .01$

If the speed of visual code decay is to be investigated, the subtraction methods of Posner and Keele (1967) must be performed. For the purpose of this analysis, a mean figure for the Name-same minus physical same judgement times was calculated for each subject at each ISI. A similar calculation was performed for the physical different minus physical same matching times. The results are shown graphically in Fig. 3:7. If these results are compared to those of Posner and Keele (1967) (Fig. 3:5) it can be seen that in the present experiment neat linear visual code decay functions were not obtained. The difference in RT which reflects the advantage of 'visual code' matches over 'name code' ones decreases up to 1 sec. ISI and then increases again. Figure 3:7 is deceptive, however, in that it implies there are differences to be analysed. If the calculated differences are analysed as a 3 factor ANOVA (see table 3:8): 2 groups x 2 calculation methods x 3 ISIs with subjects nested within groups (see table 3:9) it can be seen that the variability of scores is so great that the only significant factor is that of subjects within groups ($F = 2.42$; d.f. 36,180; $p < .01$). It is therefore meaningless to discuss for example, rates of decay since the ISI factor is insignificant. The same is true of any group differences, although this only just fails to reach the 5% level of significance.

It therefore appears that this is a poor method of determining rate of visual code decay (should there be any). As to why this is the case, one possibility is that Posner and Keele (1967) used highly practised adult subjects, thus

FIGURE 3:7

Estimates of the Decay of Visual Information from a single letter derived from the of Expt.3c using the 2 different subtraction methods of Posner and Keele, 1967.



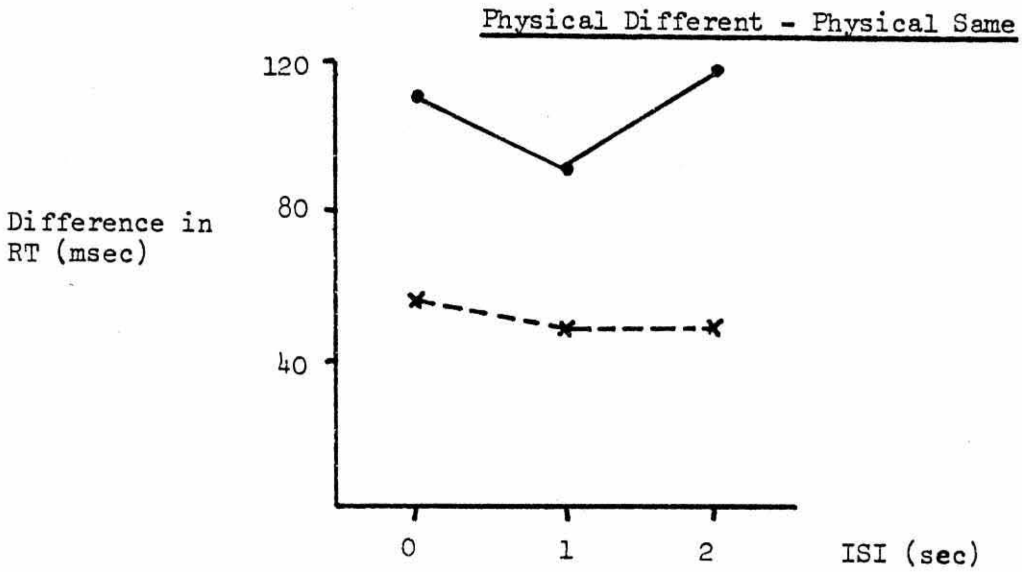


TABLE 3:8

ANOVA Data for the Estimates of Rate of Decay of Visual Information Derived from the Raw Data of Experiment 3c (see text).

urce of Variation	D.F.	SSq.	MSq.	Variance Ratio	Probability
oups (G)	1	1697832	1697832	3.89	NS
bjects within G	36	15707160	463310	2.42	**
lculation Method (C)	1	161441	161441	0.9	NS
I (I)	2	1199508	599754	0.03	NS
	2	545663	272831	1.51	NS
	1	138775	138775	0.77	NS
	2	50535	25267	0.14	NS
G	2	16152	8076	0.04	NS
ror	180	32450134	180279		

NS: Not Significant

**: $p < .01$

decreasing the amount of variability present.

There is an important theoretical debate as to whether this method of Posner and Keele (1967) does indeed measure the rate of decay of visual information. While in their experiment they do find that the advantage of physical identity matching and name-identity matching decreases with increasing ISI up to 1.5 sec.,it is not necessarily the case that this quantitatively reflects visual code decay. Phillips, and Baddeley (1971) suggest that this decrease in physical-identity matching over time may instead reflect both the decay of the visual code record and the subject using name codes, of which a 1 sec. ISI allows production, in preference to the decaying visual code:

> "Once the name code has developed to a point at which it allows faster RTs than the visual code, S will presumably use it in preference to the visual trace continues to be available. Since S need no longer use the visual trace, the RTs will no longer reflect its strength. In short, Posner's technique confounds the fading of the visual trace with the development of the name code, and as such cannot give a valid indication of the time course of visual STM.
>
> This suggests that the method of Posner and Keele (1967) may give an underestimate of the duration of visual STM, and that the longer times suggested by the other experiments are more accurate." (Phillips & Baddeley, 1971, p.73).

Similarly Parks, Kroll, Saltzberg and Parkinson (1972) used the Posner and Keele (1967) task filling the ISI between the two letters with a shadowing task to prevent name coding. They found, in contrast to the Posner and Keele (1967) study, an advantage of physical identity matching speed over name identity matching even at ISIs of 8 sec. They concluded that subjects could continue to maintain the visual code provided there is an incentive to do so. It might in the present experiment be the case that the dyslexics show a greater advantage of visual matching over name matching at all ISIs (see fig. 3:7) since, as is shown in Expt. 3a, they are considerably slower at making name matches, and thus visual matches are optimal.

There is now a body of evidence re the use of strategies in coding tasks (c.f. Tvesky, 1969), and in any area where the subjects can choose strategies, variability of performance is bound to be high.

It is concluded that Experiment 3c fails to either confirm or reject the hypothesis that visual code decay in dyslexic children is faster than that in control children.

EXPERIMENTS 3d(i) and 3d(ii)

Abstract

To investigate the relative capacities and decay rates of the visual codes of dyslexic and non-dyslexic children the matrix match procedure devised by Phillips and Baddeley (1971) was used. 61 dyslexic children, 22 control children and 26 undergraduates were tested for their ability to match 4 x 4 and 5 x 5 cell matrices which were either identical or which differed by one cell only. The two matrices were presented separately by ISIs ranging from 1/24 sec. to 9 sec.

The results demonstrate no significant differences between the 3 groups on either the 4 x 4 or the 5 x 5 matrices. It is therefore concluded that visual code capacity and decay are similar in dyslexic and control children and undergraduate adults.

Introduction

Having failed to do so in Expt. 3c, it is necessary again to attempt to compare dyslexic and control children in respect of the capacity and decay rate of the visual code. One possibility, for example, is that the code decays more rapidly in dyslexic children, with the result that name-coding is impeded. It will also be recalled that Coltheart (1972) views the dogleg point of the two-limb function obtained in Expts. 2b and c to reflect visual code capacity, and thus according to this interpretation dyslexic children differ from controls in respect of visual code capacity. Although there are alternative interpretations (Sperling, 1967; Allport, 1973) Coltheart's suggestions should be put to an independent test: if the visual code is not the locus of deficiency in dyslexia, then all such possibilities need to be excluded.

In these experiments two further tests of visual code production and visual matching were therefore given. In brief, what was involved was the presentation of either two 4 x 4 or two 5 x 5 matrices, with varying inter-stimulus intervals (ISIs) between them; the second matrix had either the same number of cells filled in as the first, or one cell more, or one cell less, and the subjects were required to say whether the two presentations were 'the same' or 'different'. During the ISI there was either a blank field or a pattern mask.

This procedure is in effect a variant of that used by Phillips and Baddeley (1971) and Phillips (1974). Like that of exp. 3b it excludes the possibility of learning overlay, since the material was unfamiliar to the subjects and had no symbolic significance. Unlike the procedures of exps. 3a and 3b, however, it has the advantage of making possible the determination of the rate of decay of the visual code. As described in Expt. 3c, Posner (1969) did in fact claim that this could be done if one determined the duration with the two letters presented sequentially at which physical-match reaction time was no quicker than name-match reaction time. It is possible, however, as Phillips and Baddeley (1971) have pointed out, that in this case there may have been both visual code decay and increased use of name code, since the subject may use the name code in preference to the decaying visual code even though there is still some information in the latter. In contrast, the present procedure is not open to this objection.

Subjects

These were (i) 61 male dyslexic children (diagnosed by the same criteria as before) with a mean CA of 12.3 years (s.d. 1.0), a mean RA of 9.9 years (s.d. 1.5) and a mean SA of 9.0 years (s.d. 1.3), (ii) 22 male control children with a mean CA of 11.9 years (s.d. 1.0), a mean RA of 1.28 years (s.d. 1.3), and a mean SA of 12.5 years (s.d. 1.1), and (iii) 26 first year undergraduates with a mean CA of approximately 19 years.

Materials and procedure

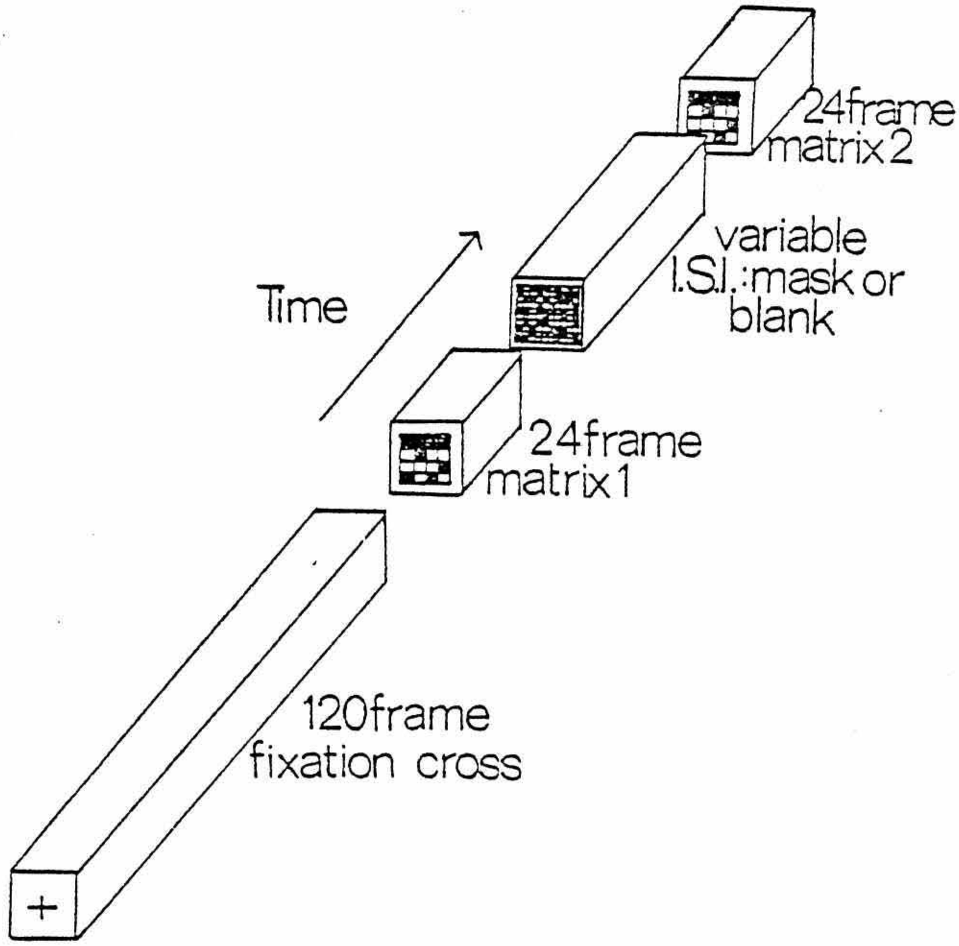
Exp. 3d(i) 4 x 4 square cell matrices were constructed on white cards with half the cells blacked in at random.

A new pattern was used on each trial. The matrices were photographed with a Bolex cine camera on 16 mm Kodak High Contrast negative film 7457. Each trial consisted of 120 frames of fixation cross followed by 24 frames of the randomly filled 4 x 4 matrix. There was then a variable ISI (either 1,2,5,10, 48 or 143 frames) before the second matrix appeared, again for 24 frames. The second matrix was either identical with the first or had one cell more or one cell less filled. During the ISI there was either a blank field (dark when projected) or a pattern mask consisting of a larger matrix with cell size linear dimension half of that used with the test matrices, approximately half of the cells of the mask matrix being filled randomly. Each trial followed the sequence shown in Fig. 3:8.

The film was constructed so that after 6 practice trials there were 48 test trials (4 trials at each ISI with ISI blank, 4 trials at each ISI with ISI filled by a mask) with order of presentation of trials counter-balanced for ISI, mask/no mask, and same/different, matrix 1 being identical with matrix 2 in half the trials and in half the trials differing from it by one cell.

The subjects saw the film in large groups in a dimly lighted room and were instructed to mark an 'S' on their score sheet if the cell arrangements in the two matrices

FIGURE 3:8
Exposure Sequence of a Single Trial from Experiment 3d(i),



were the same, and a 'D' if they were different. The subjects were questioned during the practice trials so as to ensure that they understood the instructions and that they did not 'get lost'. The number of each trial was spoken before each pair of presentations. There was a break of approximately five seconds between each trial.

The film was projected on to a white screen at a speed of 24 frames per second by means of a Bell and Howell 644 projector. The complete procedure for each trial was thus:

Fixation cross	5000 ms
Matrix 1	1000 ms
Variable ISI	42,83,208,417,2000, and 6006 ms
Matrix 2	1000 ms

The percentage of subjects in each group correct on each trial was then calculated.

Exp. 3d(ii)

After a break of approximately 10 minutes the subjects took part in a further experiment. The equipment, instructions and method of projection were identical with those of exp. 3d(i). More complex matrices were used, however, consisting of 5 x 5 cells. Exposure time was increased for both matrix 1 and matrix 2 to 48 frames (approximately

2 sec); the same ISIs were used but no ISI was filled by a mask.

The film was constructed so that after 6 practice trials there were 36 test trials, 6 trials being presented randomly at each ISI and randomised for same/different.

Results and discussion

The percentages of dyslexic children, control children and undergraduates giving correct answers in the different conditions are shown in table 3:9.

These results are shown graphically in Figs. 3:9 and 3:10.

The results of experiment 3d(i) were analysed as a 4-factor ANOVA: 3 groups (dyslexic children, control children, undergraduates) x 6 ISIs x 2 mask (mask, no mask) x 4 blocks. The mask factor ($F = 4.15$, d.f. 5,105, $p < .01$) was significant; no other factors or interactions reached the 5% level of significance.

The significant mask factor demonstrates that the presence of a mask in the ISI decreases the likeliness of correct responding: mean percent correct with the ISI blank is 87.1%, whereas with the mask the percentage falls to 76.7%. This finding replicates that of Phillips (1974),

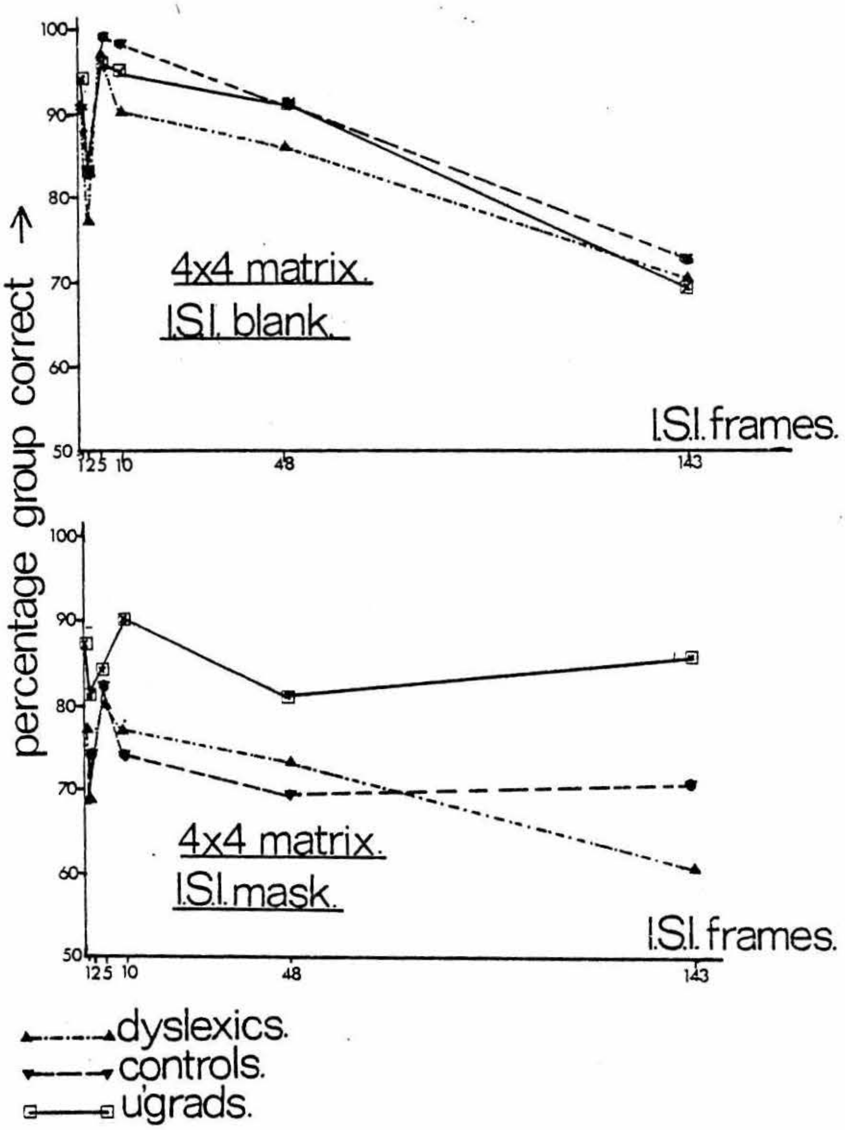
TABLE 3:9

Percentage of subjects correct in the different conditions of

Experiments 3d(i) and 3d(ii)

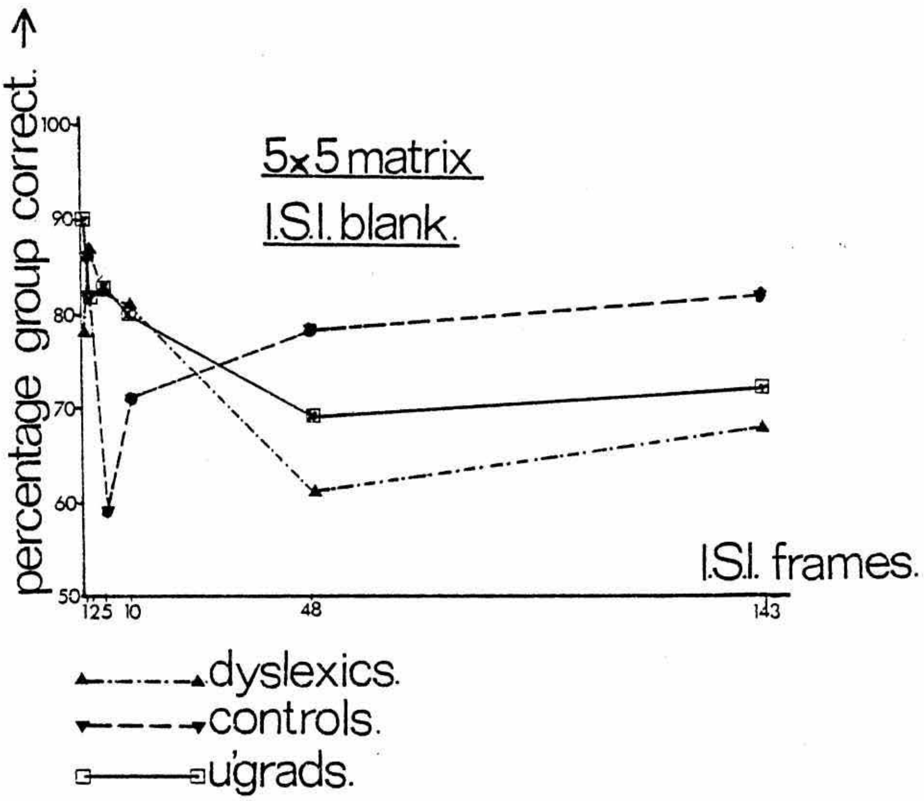
	4 x 4 Matrix, ISI blank			4 x 4 Matrix, ISI mask			5 x 5 Matrix, ISI blank		
ISI frames	Dyslexic subjects	Control subjects	Undergraduate subjects	Dyslexic subjects	Control subjects	Undergraduate subjects	Dyslexic subjects	Control subjects	Undergraduate subjects
1	88	91	94	77	69	87	78	86	90
2	77	83	83	72	74	81	87	86	82
5	97	99	97	80	82	83	82	59	83
10	90	98	95	77	74	90	81	71	80
48	86	91	91	73	69	81	61	78	69
143	70	72	69	60	70	85	68	72	72

FIGURE 3:9



Matrix match expt: visual code decay.

FIGURE 3:10



Matrix match expt.: visual code decay.

who found that the presence of a mask resulted in fewer correct responses, especially at ISIs less than 100 ms. A possible explanation is that the matching task in this experiment has two components, viz. (i) matching of information in sensory (iconic) storage and (ii) matching of information in the visual code. The former, (i), can occur as long as the ISI is shorter than the time taken by the iconic trace to decay, which is approximately 200 ms (see Neisser, 1967; Eriksen and Collins, 1968; Haber and Standing, 1969). Since the iconic trace is highly susceptible to masking, the mask can be expected, as in Phillips (1974), to affect performance only at ISIs less than iconic trace decay time. Although in the present experiment the mask x ISI interaction fails to reach significance, it can be seen from Fig.3:9 that the mask does seem to be having its greatest effect at the shorter ISIs.

With regard to (ii), Phillips (1974) found that information in short-term visual memory is not necessarily masked by subsequent stimulation and that there was no loss of efficiency over the first 600 ms but a slow loss over at least the first 9 sec. In the present experiment, too, the results show a loss of information with increasing ISIs the mean percent correct responses over all conditions in experiment 3d(ii) are as follows:

ISI frames	Mean % correct
1	84
2	78
5	89
10	87
48	82
143	71

Once again, therefore, there is the typical slow loss of information from the visual code with increasing ISIs. The group factor is again insignificant, as is the group x time interaction. From this it follows that, even with these more complex matrices, there is no significant difference between the three groups in respect of either capacity or decay rate of the visual code.

The results of expts. 3d(i) and 3d(ii) therefore seem to strengthen the argument that the production and capacity of the visual code is as fast and efficient in dyslexic subjects as it is in controls.

CONCLUSIONS

When 10-13 year old dyslexic and control children are compared as groups for ability at functions assumed to be involved in the single fixation array processing and the reading at which dyslexic children are relatively poor:

a) With alphanumeric characters dyslexic and control groups do not differ with respect to speed or accuracy with which they can encode and match visual features.

b) The dyslexic group is reliably slower than the control group at encoding-and-matching name features of letters. It is likely that this deficiency is to be found at the level of non-articulatory name or lexical encoding.

c) There is no significant group difference in the speed at which highly confusable letter-like forms can be compared for their visual features, but the dyslexic group is significantly less accurate.

d) There are no significant mean differences in either the capacities or decay characteristics of visual codes in the two groups as determined by the chequerboard techniques of expts. 3d(i) and 3d(ii).

Vernon (1979) says that "much of the confusion which has arisen as to the nature of dyslexia is because retarded readers have so frequently been studied as if they formed a qualitatively homogeneous group", and her discussion implies that any of a number of individual difficulties in information processing may result in reading retardation. After Rourke (1976) she suggests that deficiencies in visual analysis may be of great importance in the early stages of learning to read but that children may grow out of these. Deficiencies in auditory-linguistic processes and grapheme-phoneme conversion are considered to appear later and to be of importance in the causation of reading retardation in the older child. The present study is concerned with older dyslexic children and in its search for a possible homogeneity of functional disorder treats them as a group of dyslexic children rather than individuals. One of the prime aims of such an approach is to guide diagnosis, to answer the question: 'In a school population of older dyslexic children, what skills relevant to the reading process are most likely to be deficient?' While it may be the case that any of several classes of information processing deficiency may result in reading retardation, perhaps some are more likely than others. To use an analogy: whilst there may be many reasons for a car failing to start in the morning, if the weather is damp the best place first to look is the distributor (or, to use a functional approach, investigate the 'electrics'). With this in mind two main areas of function have been investigated in this chapter: visual encoding and name encoding. From the results of expt. 3a (where, as in reading, the stimuli were letters) it can be seen that, as a group, dyslexic children are not deficient in dealing with the visual features of letters but that they are deficient at encoding or matching name or lexical features.

From these results it is possible to assess relative probabilities of functional deficiency. For the analysis of variance it was assumed that the data of the control and dyslexic samples came from normal distributions with similar standard deviations but perhaps different group means. Using the group means and the EMS from the ANOVA, estimates of the population mean and standard deviation parameters of the normal distributions can be derived. Z tables can then be used to produce an estimate of the probability that upon taking at random one dyslexic child and one control child from the sample, the dyslexic child will be slower than the control child. If the group means for the performance on the same case letters are used (visual code production and matching) the probability that the dyslexic child will be slower is 0.58. In contrast if the different case data are used (name code production and matching) this probability rises to 0.73. With these older dyslexic children in the 10-13 year old age band, it follows, as in the findings of Rourke (1976), that the more likely of the two functional deficiencies studied here is that of name encoding. Whilst it appears that there is no visual encoding and analysis deficiency in dyslexic children when the stimuli to be processed are the letters used in reading, this is not the case with novel and highly confusable letter like forms (expt. 3b) where although the dyslexic child is no more likely to be slower than the control child ($p = .50$) he is far more likely to be error prone ($p = .81$).

EXPERIMENTAL CHAPTER 4

EXPERIMENTAL CHAPTER 4

CONTENTS

EXPERIMENTAL CHAPTER 4

In which dyslexic children are shown to be slow at naming single letters, pictures, words and non-words - it is suggested the dyslexic child's reading is primarily orthographic - acquired and developmental dyslexics are compared in respect of ability at phonological encoding - in the light of adequate visual processing in dyslexic children it is argued that the dyslexic child is either (i) slow and inaccurate in accessing linguistic (phonological or lexical) representations for visual stimuli or (ii) slow and inaccurate in articulatory encoding (for rehearsal, concatenation/ chunking, or output) from the preceding lexical representation.

In considering the 'two-limb', rate of initial information acquisition data of Experimental Chapter 2 two broad classes of interpretation were discussed: first limb slope reflects either speed of visual encoding or speed of accessing non-articulatory name referents; with dogleg point reflecting either the capacity of the visual code or the number of unrelated logogens which can be active at any one time. In Experimental Chapter 3 there was repeated failure to find any difference between dyslexic children and control children in respect of either visual code production-speed or capacity, and the dyslexic child's difficulty in creating linguistic representations was evident. Yet dyslexic children (and poor readers more generally) show consistently low rates of initial information acquisition and low values in respect of buffer capacity (Expts. 2b and 2c). That the 'buffer' is non-motor linguistic in nature rather than visual is thus the most consistent interpretation.

The findings so far thus lead to the proposition that the dyslexic child's reading handicap may be attributable to deficiencies at one or more of the following stages or strategies of information processing:

(i) slow rate of lexical encoding from visual representation.

(ii) a limitation in the number of lexical representations which may be active at any one time (recognition buffer capacity).

(iii) slow articulatory encoding from lexical representations.

If the problem were solely one of a limitation in the number of lexical representations which might be active at any one time (a capacity limitation of the 'recognition buffer'), with normal speed of lexical encoding up to that capacity limitation, then it would follow that the dyslexic child would be just as fast as his normal reading peer in processing items which are within the capacity of his recognition buffer. From Expt. 2b it can be seen that, if the dogleg point is taken to reflect 'recognition buffer capacity', the capacity of the 10-14 year old dyslexic child's recognition buffer is about 2.6 digits. Therefore if single items such as letters or simple pictures are used as stimuli to be named, items which can be assumed to be within the recognition buffer capacity, it is possible to investigate whether recognition buffer capacity is the only deficit in dyslexic children. If this hypothesis is true it is predicted that dyslexic children will be just as fast at naming simple stimuli as control children. If this result is not found, however, i.e. if it is found that dyslexic children are slower than controls at naming these stimuli, then this will demonstrate the presence of either a relatively slow 'scan' process (Sperling, 1963, 1967) (or in other words, slow lexical encoding) or slow articulatory encoding from this lexical representation for output.

It has also been suggested by Seymour and Porpodas (1979) that any deficit in dyslexic children is restricted to the graphemic channel. This contradicts many findings of slow objects and colour naming in these children.

To assess the relative merits of these claims the following experiments are performed:

Expt. 4a: dyslexic and CA control children are tested for their speed of naming single letters.

Expt. 4b: dyslexic and CA control children are tested for the speed at which they can name the Oldfield and Wingfield (1965) picture stimuli.

Expt. 4c: dyslexic and CA control children are tested for the speed at which they can read words of differing frequency and word length.

Expt. 4d: the phonological encoding deficiency of developmental dyslexics is compared to that of acquired dyslexics using the non-word homophonic effect in a lexical decision task.

Expt. 4e: efficiency at phonological encoding in dyslexic children is compared with that of CA and RA matched controls in performance at reading orthographically regular nonwords.

EXPERIMENT 4a

Abstract

19 dyslexic children (mean C.A. 13.4 years) and 19 matched control children (mean C.A. 13.4 years) were tested for the speed at which they could name single letters presented tachistoscopically. The control children reliably named the letters in a shorter time than the dyslexic children, the mean RTs being 637 ms. and 763 ms. respectively.

It is concluded that the dyslexic children are relatively slow at accessing the lexical representations of single letters, or that they are slow at articulatory encoding for output.

Introduction

To test whether the 'recognition buffer' capacity is the only deficit in the visual information processing of dyslexic children,single letters (which are within the capacity) can be presented and the time taken to name those letters ascertained.

Subjects

19 dyslexic children (standard criteria) of mean C.A. 13.43 years, mean R.A. 9.97 years and mean S.A. 9.04 years constituted the reading retardate sample. They all attended a private school which specialises in the teaching of children with dyslexic-type difficulties. The control sample consisted of 19 children who also attended private schools. These were of mean C.A.13.40 years, mean R.A. 13.74 years and mean S.A. 13.37 years. All

the children were of average or above average intelligence.

Materials and Procedure

For each child a basic reaction time measure was taken. The child was seated before an Electronic Developments 3-field tachistoscope and instructed that as soon as the light came on he was to say 'now'. He was to do this as fast as he possibly could. The onset of the light (which was a white card presented at an intensity which approximated to 3.0 lux at the subject's eyes) started a Dawes timer type 3000A which was accurate to 1 ms. The child's response, 'now', stopped the timer by means of a voice key, the microphone of which was situated directly in front of the child's mouth. Ten such trials were conducted of which the data for the first four was discarded, these trials being for practice, and a mean RT 'now' figure was taken for each child over the last 6 trials.

The child was then instructed that letters would be shown on the machine and that he was to name these letters as quickly as he possibly could. The exposure sequence on any trial was: the verbal warning signal 'ready', followed by 2 sec. fixation cross with an intensity at the child's eyes of 0.15 lux., this was followed by the lower case letter printed on white card using 26 pt folio light Letraset which was presented at an intensity at the child's eyes of approximately 3.0 lux. The onset of the letter started the timer, and the child's response stopped it by means of the voice key. No practice sessions were given since the child had by now participated in the RT 'now' procedure and had therefore had experience at fast tachistoscopic recognition, and since the perception and naming of letters is a highly practiced skill. Ten letters were chosen for this experiment, these were, in order of presentation: b, t, a, w, i, n, z, e, x, s.

Results

The mean baseline RT 'now' did not differ significantly across the two groups of subjects. For the control children the figure was 335.3 ms. (s.d. 50.0), for the dyslexic children it was 342.8 ms. (s.d. 66.9).

The mean group naming time for each letter is shown in Table 4:1. The letter naming data was analysed as a 2 factor ANOVA: 2 groups (dyslexics, controls) x 10 letters, with 19 subjects nested within each group. This ANOVA data can also be seen in Table 4:1. The Groups differed significantly in the time they took to name the letters ($F = 12.48$; d.f. 1,36; $p < .01$). The letters also differed significantly in the time taken to name them ($F = 2.68$; d.f. 9,324; $p < .01$). The group x letter interaction ($F = 1.52$, d.f. 9,324) was insignificant.

Discussion

The insignificant difference between the two groups on the RT 'now' baseline procedure demonstrates that when only one response ('now') is required to one gross change in stimulation (a bright flash of light), dyslexics respond just as fast as controls. When, however, the overlearned letter graphemic stimuli are used the dyslexics are reliably of the order of 126 ms. slower at naming than are the controls.

The former RT 'now' baseline result contradicts those of Wheeler (1977) who investigated the verbal reaction time for 12 dyslexic and 12 control children to either a light stimulus, a sound stimulus, or both stimuli combined. He obtained the following results:

	dyslexic children mean RT (ms.)	Control children mean RT (ms.)
light	699	422
sound	478	255
light and sound	692	267

TABLE 4:1

ANOVA Data for the Letter Naming RTs obtained in Experiment 4a

SOURCE OF VARIATION	D.F.	SSq.	MSq.	VARIANCE RATIO	PROBABILIT
Groups (G)	1	1517053	1517053	12.48	**
Subjects within G (S)	36	4377050	121585	10.50	**
Letters (L)	9	279761	31085	2.68	**
LG	9	158572	17619	1.52	NS
Error	324	3752925	11583		

NS: Not Significant
**: $p < .01$

Mean Letter Naming Time (ms) for each Letter and Group of Expt.4a

LETTER	DYSLEXIC CHILDREN'S RT.	CONTROL CHILDREN'S RT.
b	742	612
t	713	658
a	726	629
w	767	647
i	732	652
n	746	615
z	842	633
e	742	599
x	836	675
s	785	648

I can propose no explanation for the fact that in his study the dyslexics were 277 m. sec. slower than the controls to the light stimuli, whereas in the present study no significant defferences were obtained.

The insignificant letter x group interaction demonstrates that the two groups of children are similarly affected by increasing letter naming difficulty. This difficulty is considered to be one of frequency since a Duncan's Multiple Range test on the letter differences demonstrates that the letters x and z differ significantly from the remainder in terms of their nameability: the only significant letter contrasts are: x vs i, x vs t, x vs n, x vs a, x vs b, x vs e, z vs n, z vs a, z vs b, and z vs e. This latter hypothesis is proposed since i) the letters x and z do not clearly differ from the remainder in terms of physical characteristics such as angularity, and ii) frequency effects in recognition thresholds and recognition speed have long been demonstrated (c.f. Oldfield and Wingfield, 1965, Howes and Solomon, 1951, and Tulling and Patkău , 1962). The frequency argument appears reasonable since if the average naming time of the dyslexic and control children is compared to letter frequency (an average from the counts of Pratt (1939) and that in Nature (1960) was used), a significant correlation of - 0.71 is found ($p < .02$). It should be noted, however, that other hypotheses are possible, e.g. x and z differ from the remaining letters by the fact that they occur at the end of the alphabet.

Stanley and Hall, 1973(b) compared the SOA 33 dyslexic children and 33 control children needed to correctly identify single letters in a masking paradigm. Single letters from the set, H, J, R, M, K, S, F, C, U and O, were presented for 20 m sec. and was followed after an ISI by a mask (a static rectangular array of dots). The ISI was initially 20 m sec. and this was increased in 20 m sec. increments until a criterion of 3 correct identifications at a given ISI was reached. The mean ISI for correct identification (verbal response) was, for the consonants, 56 m sec. for the controls and 64 m sec. for the dyslexics. For the rounded vowels O and U these figures are 92 m sec. and 122 m sec. respectively. An ANOVA indicated a significant group difference, a significant task difference (vowels vs consonants), and a non significant interaction. Stanley and Hall, 1973(b) conclude from this that the dyslexics are slower at processing the letters than the normals. When Stanley, 1976 repeated this experiment using single digit stimuli (0 through 9) and a manual response he actually found the reverse pattern - over all the experimental trials the dyslexics identified significantly more of the digits correctly. He also found no significant differences in the response reaction time between the two groups. This is in contrast to the results of Blank, Higgins, and Wagner, 1971 who indicated that dyslexics may have a slower reaction time than controls.

Whether or no there are significant differences between dyslexic and control children in the SOA required to correctly preceive single alphanumeric stimuli, these differences, when present in the Stanley and Hall 1975 experiment are very slight (8 ms. in the case of consonants and 30 m sec. for vowels) if compared with the much larger differences (of the order of 126 m sec.) when the naming time for letters are compared for two similar groups in the present experiment. One possible explanation of this is as follows: the SOA required to correctly identify a letter might be thought of as that time x intensity of stimulus exposure necessary for the subject to set up the data base upon which processing may occur. For simple single-name stimuli it is possible that, as long as a sufficient visual code is produced, the stimulus will be further processed. The retention of that visual code is then to a large extent a property of the subject rather than the stimulus (Tversky, 1969). The naming reaction time however reflects the time to completion of the whole processing chain. In contrast to the SOA, it includes such elements the 'scan' and the execution of the recognition buffer. motor instructions to use Sperling's terminology, or, in other words, the accessing of the lexical representation and the articulatory encoding and output from this representation.

The evidence that there is a large differential between dyslexics and controls in terms of naming RT, whilst there is little if any in terms of SOA for correct naming, might be taken as further evidence that whilst speed of visual code production, the data base for further processing is the same in dyslexic and control children, the processing from that base in terms of scan and execution of the result of the scan is slower in dyslexics. Legein and Bouma (1980) come to similar conclusions from similar data: there were no differences between dyslexic and control children in terms of recognition threshold from foveal and parafoveal presentation, but the dyslexics were slower at naming letters.

As the stimuli used were within 'recognition buffer capacity', then a capacity limitation of the buffer cannot be the only limitation in the processing of dyslexic children. The speculation proposed when the alternative deficit areas were being outlined in Chapter is again of interest - it is possible that the limitation in recognition buffer capacity is the result of the slower scan: from a decaying data base, the visual code, the rate of readout determineswhat is held in the next store, the 'recognition' buffer.

The case of letter naming is especially interesting from a terminological viewpoint. It has been argued that there are two available strategies in reading aloud: a whole word or lexical route and an orthographic route where known grapheme-phoneme correspondences are utilized to produce a phonological representation of the stimulus. It is agreed that there is a visual input logogen, a pattern recognizer for symbols such as £, with referent lexical entries ('pound') see e.g. Baron and Strawson

(1976). It must also be agreed that there is a logogen for the word a with a similar lexical referrent. Yet when the letter a appears in the middle of a word, it is said to be subject to a process of grapheme-phoneme conversion. For these and other reasons detailed elsewhere, the lexical/orthographic distinction in this sense seems of little value - that non-articulatory linguistic representation accessed in reading as a result of the 'scan process' can apparently interchangeably be called a lexical code or a phonological code.

EXPERIMENT 4b

Abstract

The subjects of Expt. 4a were tested on the Oldfield and Wingfield 1965 picture naming task. The dyslexic children were slower than the controls at naming all the pictures, and this difference between the groups increased as the word-frequency of the picture names decreased. The dyslexic children also named fewer words correctly, this again being truer for the less frequent stimuli.

It is again concluded that the dyslexics show a deficit in either the rate of 'scan' or in the execution of the recognition buffer's program of motor instruction (to use Sperling's terminology). In other words, the dyslexic children are relatively slow in accessing the lexical equivalents for pictures, or in articulating from this data base.

Introduction

It has been shown that with kindergarten children, in the early stages of reading acquisition, there is a high correlation between reading ability and speed of picture naming. For example, when Jansky (1972) used with young children the procedures described by Oldfield (1966) she found a correlation of .53. This is not surprising: naming a picture and naming an alphabetic array have several processing stages in common. Jansky herself in fact says that 'reading, like picture naming, requires reading elicitation of spoken equivalents' (ibid.). If, therefore, the deficiency in dyslexic subjects found at the phoneme translation stage is a global problem and not one which occurs solely with alphanumeric stimuli, then dyslexic subjects would also be expected to be slower at picture naming. Denckla and Rudel (1976) used the stimuli and procedures of the Oldfield and Wingfield (1965) experiments in order to test picture naming response latencies in dyslexic, minimally brain-damaged, and normal subjects. They found, as predicted, both that dyslexic children named fewer pictures correctly and that those pictures which they did succeed in naming were named more slowly than they were by the other two groups of subjects.

Unfortunately, this study, though admirable in its rigorous procedure for the inclusion of subjects, measured naming response latencies with a stopwatch , and thus individual picture naming latencies were not reported. For this reason, and because it was considered desirable throughout the present thesis to keep both the properties of the dyslexic sample and the age range tested constant, it was decided to test the subjects of Expt. 4a on the Oldfield and Wingfield, 1965, task.

Subjects

Those children participating in Expt. 4a were also tested here.

Method

Line drawings of the stimuli used by Oldfield and Wingfield, 1965, were prepared using indian ink on white card. For practice, these drawings in order of presentation were: bed, telephone, scissors, toothbrush, piano, and comb. The test stimuli, in order of presentation were: clock, typewriter, glove, horseshoe, syringe, dice, metronome, key, octopus, anchor, gyroscope, tuning fork, anvil, chair, drum, screw, stethoscope, bagpipes, cigarette, book, xylophone, tap, basket, windmill, microscope and shoe. (Thanks to Mike Bagshaw for drawing these). The Thorndike-Lorge (1944) frequency count for the names of these pictures ranged from Book (AA) to Xylophone (.33 occurrences per million words), and the order of presentation ensured randomization of position of high/low frequency words. The exposure sequence for each trial was as follows: the verbal warning signal 'ready' was followed by presentation of a fixation cross on the tachistoscope for 2 sec. at an intensity at the S's eyes of approximately 0.15 lux; this was followed immediately by the picture stimulu which was exposed for 4 sec. at an intensity of approximately 3.0 lux. The child was instructed to name the picture as quickly as he could, and that there was a one word answer for each picture which was most appropriate. For all the pictures except one, the only acceptable answer was that label used here. This exception was xylophone, for which glockenspiel was also accepted. The onset of the picture started the Dawes timer, the child's verbal response stopped it by means of a voice key. If a response was not forthcoming within 6 seconds after the onset of picture presentation, the child was told to forget that picture and to get ready for the next trial.

Results

The stimuli names, T-L frequency, log T-L frequency, number of children within each group correctly identifying the stimuli, and mean response latency over those children who correctly identified the stimuli are shown in Table 4:2.

It can be seen, as in the Denckla and Rudel (1976) study, that dyslexic children were able to name significantly fewer of the pictures (Wilcoxon test, $n = 15$, $z = 2.84$, $p < .002$, 1 tailed). This appears to be especially the case with the less frequent picture-names, although ceiling effects with the high frequency names may mask a potential group difference. To further investigate this a 2 factor ANOVA (2 groups x 10 pictures with 19 subjects nested within each group) was performed on the response time data for those pictures where all 19 subjects in each group found the correct name (these being the high frequency pictures: book, chair, shoe, basket, clock, key, glove, cigarette, typewriter and windmill). The ANOVA table can be seen in Table 4:2. Due to high subject-within-groups variability the group differences ($\bar{x}$ dyslexics = 993 ms, $\bar{x}$ control = 930 ms; $F = 2.15$; d.f. 1,36) are insignificant. It must be concluded that the dyslexic and control groups do not differ significantly in their mean naming latency for these 10 high-frequency-name pictures, although the trend is that the dyslexic children are slower ($T = 10$, $L = 0$, $p < .002$, sign test).

TABLE 4:2

The data of Expt. 4b: the number of dyslexic and control children correctly naming each stimulus, and the mean naming time (ms) for these children.

			DYSLEXIC CHILDREN		CONTROL CHILDREN	
STIMULUS NAME	T-L FREQ.	LOG 10 T-L FREQ.	NUMBER OF HITS*	MEAN RT (ms)	NUMBER OF HITS*	MEAN RT (ms)
Book	AA	-4.000	19	960	19	821
Chair	AA	-4.000	19	849	19	808
Shoe	AA	-4.000	19	854	19	845
Basket	A	-4.301	19	1019	19	870
Clock	A	-4.301	19	999	19	864
Key	A	-4.301	19	895	19	890
Glove	43	-4.367	19	1019	19	875
Drum	40	-4.398	17	851	19	808
Tap	32	-4.495	18	850	19	866
Anchor	26	-4.585	17	1101	18	1104
Cigarette	22	-4,658	19	1240	19	1229
Screw	20	-4.699	18	1204	18	1037
Typewriter	12	-4.921	19	1086	19	1074
Windmill	11	-4.959	19	1014	19	953
Microscope	9	-5.046	10	2162	17	1583
Dice	8	-5.097	17	1112	19	951
Anvil	7	-5.179	0	-	16	1286
Horseshoe	4	-5.398	16	1564	19	1130
Octopus	2	-5.699	18	1384	19	1173
Bagpipes	1	-6.000	17	1106	19	1111
Tuningfork	.94	-6.027	11	1957	9	2073
Stethoscope	.88	-6.056	4	1863	12	1653
Syringe	.83	-6.081	8	1084	10	1261
Metronome	.38	-6.420	4	1843	3	1152
Gyroscope	.33	-6.481	4	2535	6	1663
Xylophone	.33	-6.481	5	1623	13	1694

Number of children per group was 19

ANOVA Data for the Object Naming RTs where both groups scored 100% hits

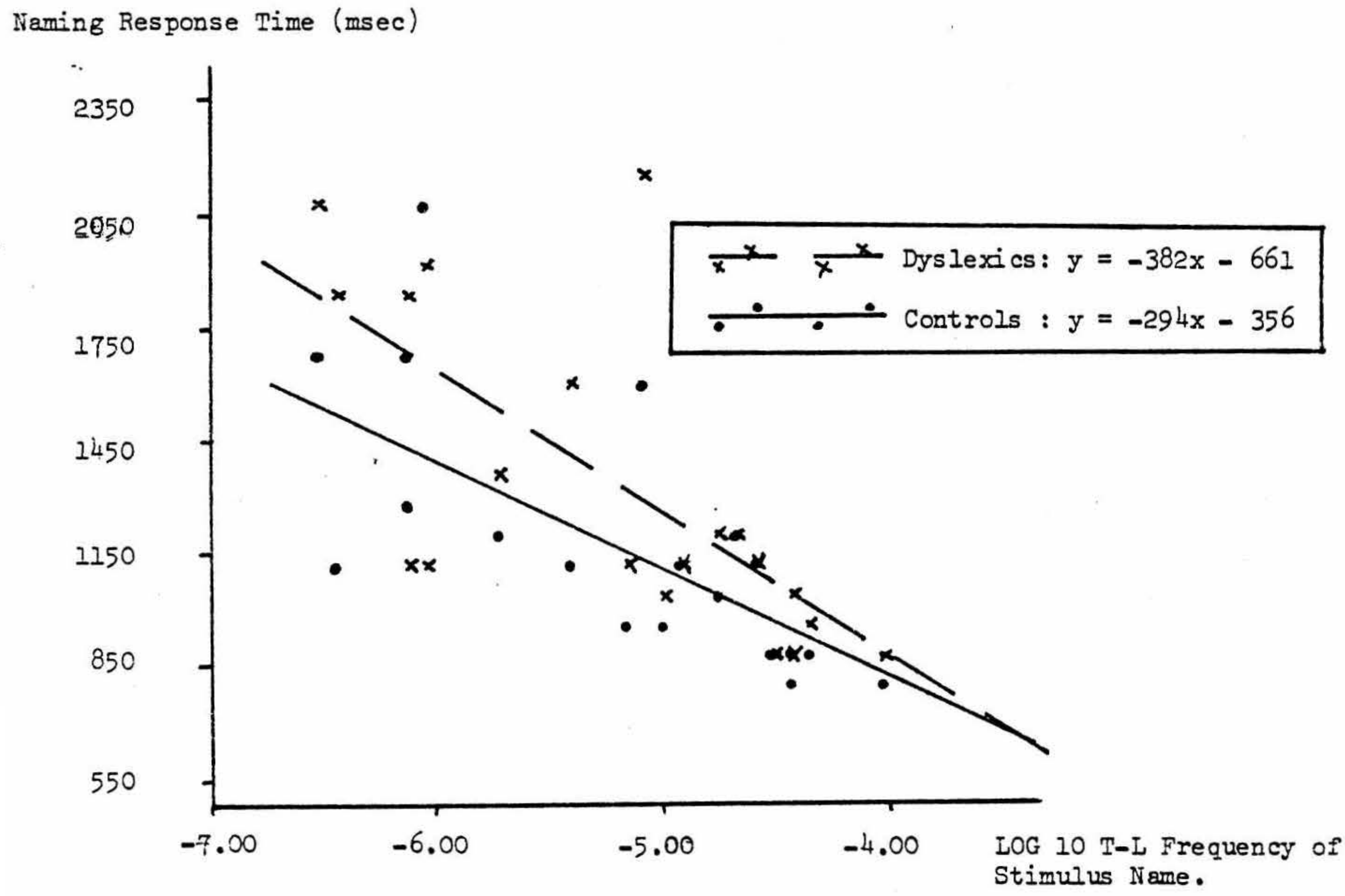
SOURCE OF VARIATION	D.F.	SSq.	MSq.	VARIANCE RATIO	PROBABILIT
Groups (G)	1	381858	381858	2.15	NS
Subjects within G (S)	36	6387879	177441	4.56	**
Pictures (P)	9	4799263	533251	13.7	**
GP	9	297888	33099	0.85	NS
Error	324	12611344	38924		

NS: Not Significant

**: p < .01

FIGURE 4:1

The Picture Naming Response Times For the Dyslexic and Control Children Tested in Expt. 4b. The x-axis represents the Log 10 Thorndike-Lorge Frequency of the Picture Name.



Because of the high number of missing values, the remaining response latency data is unsuited to an ANOVA. For this reason the analysis used by Oldfield (1966) was performed: group mean latency was plotted against $\log_{10}$. Thorndike-Lorge picture name frequency, and regression analyses were performed. The resultant functions (see Fig. 4:1) are dyslexics: naming latency $= -382 \times \log_{10}$ frequency - 661 ms; controls: naming latency = - 294 $\log_{10}$ frequency - 356 ms. These regression coefficients do not differ significantly ($z = .727$; $p = .22$, 1 tailed), but it should be noted that the error term here is a function of residual variation from $\log_{10}$ Frequency.

If the group mean response latencies for each of the 26 pictures are compared using a Wilcoxon test, highly significant group differences can be seen ($N = 26$, $Z = 3.12$, $p < .001$).

Discussion

It is concluded that dyslexic children as a group are relatively slow at producing overt name referents for picture stimuli. When the picture name is of low frequency in the language fewer dyslexic children than control children can find that name at all.

This difficulty might lie in either of the two broad functional areas of(1) picture analysis or (2) the finding and production of the lexical referents. However, Mackworth and Mackworth (1974) showed that while poor readers made more errors than good readers in letter naming and in recognizing homophones (e.g. 'sew' and 'so'), there was no relation between reading ability and performance in a non-verbal pictorial task where the children had to compare a picture with one which they had just seen. In other words the poor readers appear to perform at the same level as good readers in dealing with the visual aspects of pictures. It is therefore considered more likely that the dyslexic children's handicap lies at the stage of name-referent access and overt articulation rather than at the stage of picture analysis or pattern recognition.

EXPERIMENT 4c

Abstract

19 dyslexic children (mean C.A. 13.4 years) and 19 age matched controls were tested for the speed at which they could name single words presented tachistoscopically. The words varied in length, orthographic regularity, frequency and imageability.

The dyslexic children were considerably slower at naming words than at naming frequency matched pictures in Expt. 4b. The reverse pattern was true for the control children. The dyslexic children's naming time was well predicted by word length (r = + 0.93) increasing at 268 ms/letter, the control children's less so (r = + 0.51) increasing at 16 ms/letter.

It is concluded that the dyslexic child's reading is primarily orthographic, the lexical channel being severely impaired in respect of vocabulary and slow in translation time, and that this orthographic strategy in dyslexic children is slow and less accurate than in control children.

Introduction

Having shown in Expt. 4b that dyslexic children are slow at naming pictures, their naming of words can be similarly investigated. Dyslexic children are, of course, as a nature of their disability, deficient at reading words aloud, but this study is a preliminary investigation into this deficiency as a function of word frequency and length. To compare word naming times with picture naming times 26 nouns were chosen which matched word frequency with those picture names used in Expt. 4b. Beside the noun and frequency restraints there was no control for other variables such as word length, imageability, concreteness , orthographic regularity etc. The stimulus words can be seen in

Table 4:3. These stimuli were to be presented tachistoscopically as was the pictures of Expt. 4b and naming times recorded.

Subjects

As Expt. 4b.

Method

The words, printed on white cards using 26 pt. folio light letraset, were sequentially presented in a randomized order using the tachistocope. Methods of stimulus presentation and response recording were identical to those of Expt. 4b.

Results

The group mean naming latencies can be seen in Table 4:3. It is not surprising that the dyslexic group managed to read fewer of the words, this being especially the case with the less frequent and longer words (Wilcoxon test, $N = 21$, $z = 4.01$, $p < .001$). The dyslexic group reliably read the words more slowly (sign test, $T = 26$, $L = 0$, $p < .0001$), and this was the case even with those words (bird, eye, boat, apply, orange) which all the children could read successfully and without apparent difficulty.

If word frequency is taken as an independent variable, dyslexic group naming time follows the function: naming time = $- 455 \log_{10}$ TL frequency - 398 ms. The corresponding function for the control group is naming time = $- 48 \log_{10}$ TL frequency + 461 ms. These functions can be seen in Fig. 4:2. The regression coefficients differ significantly ($z = 3.53$, p $.001$).

If picture and word naming times are compared for the

TABLE 4:3

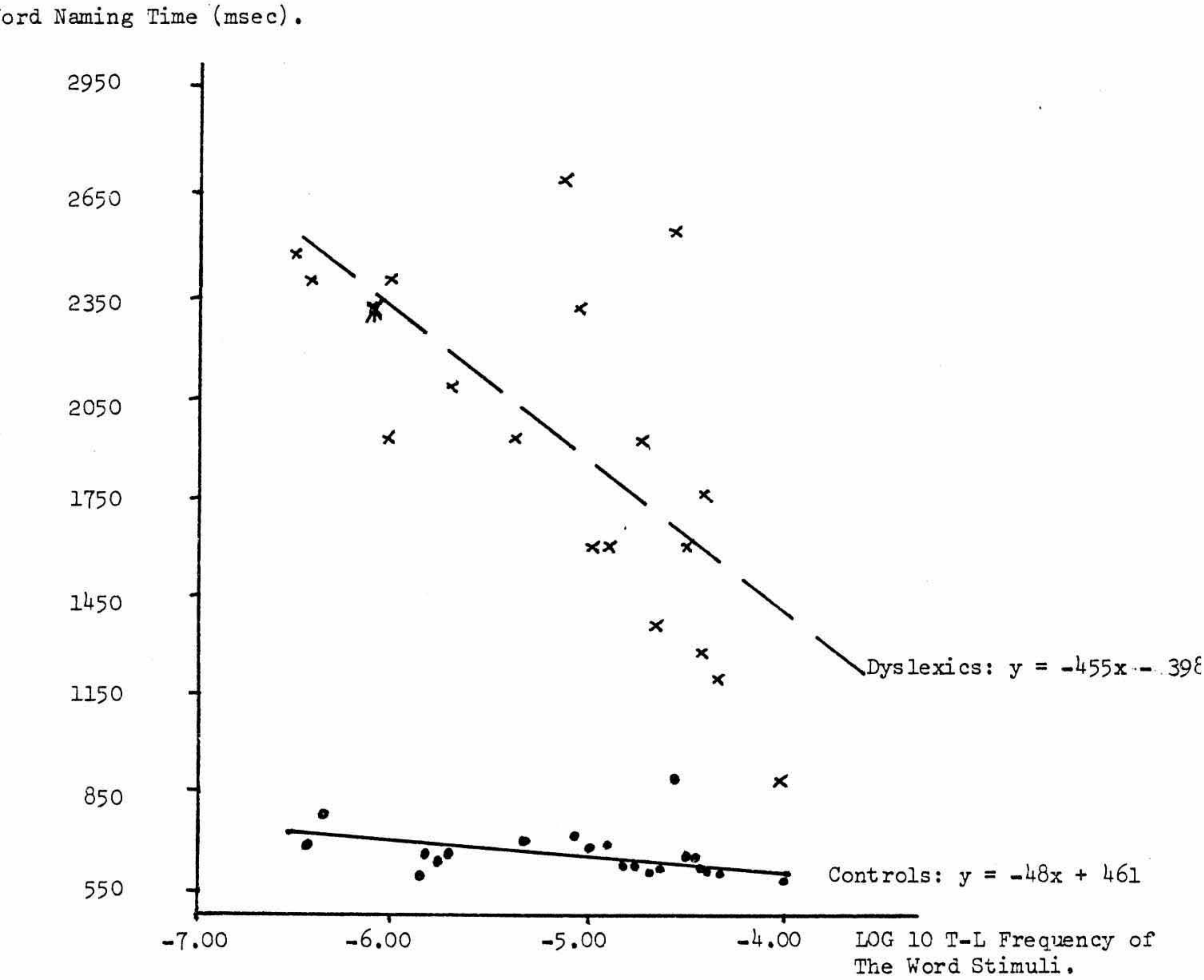
The data of Expt. 4c: The number of dyslexic and control correctly reading each word, and the mean reading time (msec) for these children.

			DYSLEXIC CHILDREN		CONTROL CHILDREN	
STIMULUS NAME	T-L FREQ.	LOG 10 T-L FREQ.	NUMBER OF HITS*	MEAN RT (ms)	NUMBER OF HITS*	MEAN RT (ms)
Bird	AA	-4.000	19	900	19	592
Eye	AA	-4.000	19	914	19	619
Boat	AA	-4.000	19	892	19	582
Apple	A	-4.301	19	886	19	615
Orange	A	-4.301	19	1042	19	586
Evil	A	-4.301	13	1806	19	626
File	43	-4.637	16	1312	19	698
Swift	40	-4.398	17	1754	19	638
Survey	32	-4.495	13	1630	19	684
Prairie	26	-4.585	7	2567	16	969
Ankle	22	-4.658	12	1410	19	632
Drama	20	-4.699	10	1943	19	617
Gallon	12	-4.921	15	1592	19	622
Notch	11	-4.959	16	1640	19	623
Orator	9	-5.046	6	2373	19	824
Turret	8	-5.097	11	2740	19	744
Rainfall	7	-5.155	18	1582	19	662
Antler	4	-5.398	7	1967	19	787
Faggot	2	-5.699	14	2081	19	763
Turbine	1	-6.000	10	2435	19	707
Joiner	.94	-6.027	15	1976	19	734
Rambler	.88	-6.056	13	2367	19	666
Digit	.83	-6.081	8	2308	19	748
Eyeshade	.38	-6.420	8	2440	19	854
Popgun	.33	-6.481	18	2351	19	870
Washbasin	.33	-6.481	13	2627	19	639

umber of children per group was 19.

FIGURE 4:2

The Reading Response Times For The Dyslexic and Control Children Tested in Expt.4c.



dyslexic group (picture naming time = - 382 $\log_{10}$ TL freq -661 ms., word naming time = - 455 $\log_{10}$ TL freq - 398 ms.) it can be seen that while the regression coefficients do not differ significantly ($Z = .50$), the dyslexic group is significantly slower at naming words than at naming pictures when the names are matched for frequency. (Sign test, T = 26, L = 4, p .001). In contrast, for the control group there is a distinct advantage of word naming over picture naming (picture naming time = 294 $\log_{10}$ TL freq - 356; word naming time = -48 $\log_{10}$ TL freq + 461; these regression coefficients differ significantly, $z = 3.06$, p .01; a sign test shows controls' word naming to be significantly faster than picture naming, T = 26, L = 0, p .001).

Word lengths may also be extracted as an independent variable, there being 1 3-letter word, 4 4-letter words, 6 5-letter words, 9 6-letter words, 3 7-letter words, 2 8-letter words and 1 9-letter words. If a mean group/word length naming time is taken, the dyslexic group naming time = 268L + 230 ms. where L is the number of letters in the word. The naming time and word length correlate + 0.93, word length explaining 87% of the variability. The control group naming time = 16L + 587 ms., the correlation being only + 0.51 with word length explainig only 27% of the variability in naming time. These regression coefficients of 268 ms./L for the dyslexic group and 16 ms./L for the control group differ significantly ($Z = 5.29$, $p < .001$).

Discussion

ar Dyslexic children are most certainly both slower and less accurate at word naming. It is certain that orthographically irregular words (such as 'eye') must be read through a whole word (lexical) route, since graph-phon rules simply will not work, as must the letters used in Expt. 4a. As the dyslexic children are slow at naming all these stimuli, a deficiency in lexical reading in dyslexic children must be concluded.

Orthographically regular words, however, may be read either lexically if the child has a visual input logogen for that word, or orthographically using grapheme-phoneme conversion rules. One can only be sure that an orthographic strategy is in use if the stimuli constitute orthographically regular non-words for which there cannot be a whole-word pattern recognizer. Thus in this experiment it is uncertain whether orthographically regular word stimuli (e.g. 'file') are read through an orthographic or a lexical route. It is known, however, that use of an orthographic strategy produces strong word length effects. For example Seymour and Porpodas (1979) had dyslexic and control children reading orthographically regular non-words; for the control children naming time increased 63 ms. for each letter in the word, for the dyslexic children this increment was 721 ms. per letter. Although in the present experiment frequency and word length are confounded, the dyslexic children show very striking word length effects (a correlation of + .93 between word length and naming time), the control children do so to a much smaller degree (the correlation being + .51), and it therefore seems likely that the dyslexic children are primarily reading the words through an orthographic route. This suggestion is strengthened by the findings of Seymour and Porpodas (1979) that when using an orthographic strategy with non-words the dyslexic children's naming time increased 721 ms./letter in non-word; a similar increase of 774 ms./letter in the word was obtained when the stimuli were orthographically regular words: the dyslexic children, in contrast to the controls, showed little or no advantage of stimulus wordiness (which allows for lexical reading) except in the case of a few high frequency words.

The fact that the control children show a striking advantage of word naming over picture naming whilst the reverse is the case for dyslexic children also lends support to the idea that the controls' reading is primarily fast and lexical whilst the

the dyslexics' is comparably slow and presumably orthographic. Gleitman and Rozin (1977) suggest that the evolution of orthographic systems proceeds 'in a single direction: at every advance, the number of symbols in the script decreases: concurrently, and as a direct consequence, the abstractness of the relations between the written symbols and the meanings increases'. It also follows that, as orthographies evolve, there become many more phonemes than graphemes, and consequently these systems become more phonologically irregular. Thus while a dyslexic child shows a significant but comparatively slight deficiency in the Oldfield and Wingfield (1965) task, in which stimulus-name correspondence is unitary for the majority of the stimuli (except in a few cases, e.g. glochenspiel/ xylophone), the same child when presented with English written sentences as stimuli, where there are many more phonemes to be determined from poorer graphemic predictors, shows a marked decrease in performance level.

It is concluded, as in Seymour and Porpodas (1979), that (a) the dyslexic child's reading is primarily orthographic; (b) that this orthographic channel is somewhat impaired as is demonstrated by (i) the slow reading times and (ii) the failure in word naming; (c) there is some operation of the lexical channel; (d) this lexical channel is impaired with respect both of translation time and vocabulary.

EXPERIMENT 4d

Phonological coding in word reading

Abstract

Using the techniques applied by Patterson and Marcel (1977) to adult acquired dyslexics, a group of 15 boys suffering from developmental dyslexia was compared with 15 controls of the same age. Patterson and Marcel's patients were able to perform a lexical decision task but showed no evidence of phonemic encoding of the nonwords; the dyslexic children performed this task very slowly and showed clear evidence of phonemic coding of the non-word items. It is concluded that there is some phonological encoding ability in developmental dyslexic children (in contrast to the acquired dyslexics), but that this encoding is slow and inefficient in comparison to that of CA matched controls.

Introduction

It was suggested in Expt. 4c that the reading of dyslexic children occurred primarily through a somewhat defective orthographic strategy. This orthographic strategy utilizes grapheme-phoneme conversion rules with the concatenation of resultant phonological codes, and as such must be assumed impossible without phonological coding.

In recent years experimental psychologists have shown a growing interest in the process of normal reading. This has been accompanied by an attempt to apply the concepts of cognitive psychology to disorders of reading, both when these are acquired as a result of brain damage (e.g. Marshall and Newcombe, 1973, Patterson and Marcel, 1977, Shallice and Warrington, 1975), and developmental dyslexia, the difficulty that certain children experience in learning to read and spell (e.g.

Barron, 1979; Ellis and Miles, 1979; Liberman, Shankweiler, Liberman, Fowler and Fischer, 1977). In the case of acquired dyslexia, a great deal of theoretical attention has been given to a relatively small number of carefully selected patients by investigators who tend to share basic theoretical assumptions. As a result there has been a good deal of theoretical development in this area (e.g. Coltheart, Patterson and Marshall, in press). One of these common theoretical assumptions is that acquired dyslexics show an almost total inability in phonological encoding. Evidence for this can be found in a study of lexical decision in acquired dyslexics by Patterson and Marcel (1977). When normal subjects are required to decide whether a string of letters is or is not an English word, they are slowed down if the non-words are phonologically similar to actual words (e.g. stane, frute), which suggests that the material is being encoded phonologically prior to the decision. Patterson and Marcel observed that their dyslexic patients were slightly slower and a little less accurate than controls but proved able to do the lexical decision task surprisingly well. They did, however, show no evidence of the phonological similarity effect, which suggests that phonological coding was not playing a role in their performance.

In contrast to the research on acquired dyslexia, developmental dyslexia has been studied by a much more wide-ranging group of investigators, typically rooted in educational rather than cognitive psychology. Perhaps for this reason there appears to have been remarkably little interaction between the two groups, and it is far from clear to what extent the syndrome resemble each other and to what extent the techniques and concepts from one may usefully be applied to the other.

It has been suggested that acquired dyslexics are totally impaired, and that developmental dyslexics show some impairment in phonological encoding. Is it plausible to assume that a related syndrome is involved in the two types of dyslexia?

Although there will clearly be differences between the reading of a child whose disability leads to slowness in acquiring reading skill and an adult who was previously a fluent reader, the possibility remains that the defective component might be the same and that considerable qualitative similarities might exist.

Upon Alan Baddeley's suggestion it was therefore decided to take a series of tasks which had been shown by Patterson and Marcel (1977) to give rise to interesting differences between normal readers and acquired dyslexics and to apply these to the reading performance of a group of boys attending a school for developmental dyslexics. The performance of these boys was then compared with that of a group of boys of comparable age and general intelligence.

Subjects

This experiment used 15 dyslexic boys and 15 controls. The dyslexic boys came from a residential school for children with dyslexia and the controls were boys from a residential private school. The dyslexic group were of mean CA 12 years 10 ms., with mean RA (Schonell R_1) 10 years 3 ms. The CA Controls were of mean CA 12 years 10 ms. and mean RA 13 years 3 ms. All subjects were of average or above average intelligence as measured using one of the well established intelligence tests, usually the Wechsler or the Terman.

Method

The material used was that devised by Patterson and Marcel and comprised three- to six-letter, single-syllable, familiar nouns, verbs and adjectives (minimum frequency of occurrence, 10 per million, Kucera and Francis, 1967) and three- to six-letter single-syllable non-words that were orthographically regular and easily pronounceable by a normal person. Of these, half were homophonic with real words (e.g. stane, frute), and half were non-homophonic (e.g. dake, selt). Subjects were tested on four lists, each comprising 17 words and 17 non-words. The lists were printed in lower case letters on a sheet of paper with order of words and non-words randomized. In the case of two of the lists, the non-words were homophonic with real words, and for the remaining two they were non-homophonic. The lists were presented in an A B B A design, with the first and last list always being non-homophonic. Subjects were asked to respond by underlining the letter strings they recognized as being real words. The time taken to complete the list was recorded by stopwatch.

Results and Discussion

Table 4:4 shows the mean reading time per word and the mean number of occasions on which a word was mis-classified as a non-word and vice versa. While there is a very clear tendency for overall reading rate to be slower in the dyslexic group ($U = 15.5$, $n_1 = n_2 = 15$, $p < .001$, Mann Whitney), the dyslexic subjects show as clear a tendency to be influenced by the phonological nature of the non-word as do the controls. Homophonic non-words lead to slower performance for 12 of the 15 dyslexic subjects ($p < .02$, sign test) and for 13 of the 15 control subjects ($p < .001$, sign test). Dyslexics were 8.0% slower, and controls 9.7%, a difference which does not approach significance ($p > .05$). In the dyslexic group, 13 of the subjects show an overall tendency to make more errors on lists containing homophones, with one subject showing the opposite ($p < .01$, sign test), while 11 of the control subjects show a similar effect, with two showing the reverse ($p < .02$, sign test). Subjects from both groups are somewhat more likely to mis-classify a non-word than a word; this is significant in the case of the

-TABLE 4:4-

Speed and accuracy of lexical decisions by dyslexics and controls of the same C.A.

	Mean Reading Time per Item (sec)		Mean Error Rate (%)			
			Falsely Rejected Words		Falsely Accepted Words	
	Nonhomophonic Lists	Homophonic Lists	Nonhomophonic Lists	Homophonic Lists	Nonhomophonic Lists	Homophonic Lists
DYSLEXIC SUBJECTS	1.78	1.94	8.2	10.6	15.1	27.4
CONTROL SUBJECTS	0.77	0.85	0.6	2.2	2.0	5.3

dyslexics ($T = 7.5$, $N = 12$, $p < .02$), but does not reach significance for controls ($T = 18$, $N = 12$, $p < .05$). Homophonic non-words are more likely to be mis-classified as words than are the non-homophonic letter strings for both controls ($T = 6$, $N = 13$, $p < .01$) and dyslexics ($T = 6$, $N = 14$, $p < .01$).

Overall therefore, the dyslexic subjects are slower and less accurate than controls of the same age, as one might expect in view of their reading difficulty. More importantly, however, the general pattern of reading times and errors is comparable for the two groups; both groups show a consistent tendency for homophonic non-words to lead to slower and less accurate decisions, indicating the use of phonological coding in both groups. This contrasts with the results of Patterson and Marcel (1977) whose acquired dyslexic subjects showed no evidence of such coding.

Although the results are internally highly consistent, they differ from those obtained by Barron (1979) using a comparable task and comparing good and poor readers. He also observed an effect of the phonological characteristics of the non-words on the reading rate of good readers, but the effect was not significant for his poor readers, and he concludes that they do not show clear evidence of phonological coding in this task. He does however find an effect comparable to ours when performance is measured in terms of errors, and it seems possible that his subjects may have been maintaining their speed by reducing accuracy on homophonic non-words. In line with the present results, a decrease in speed and increase in errors on lexical decision has been observed by Seymour and Porpodas (1979) who also used severely dyslexic subjects. Hence, although the pattern for Barron's group is somewhat unclear, the balance of data suggests that developmental dyslexic subjects do use some phonological coding in performing the lexical decision task. As such they differ from Patterson and Marcel's phonemic dyslexic patients who showed no evidence of such encoding, but show a similarity to the phonemic dyslexics in that they show some deficiency as reflected by their slowness on this task.

EXPERIMENT 4e

The phonological encoding deficiency in developmental dyslexia revisited

Abstract

To investigate further the phonological encoding deficiency in developmental dyslexic children and its potential similarity to that of acquired dyslexic children, dyslexic children, CA controls and RA controls were tested for ability at reading orthographically regular non-words. Patterson and Marcel (1976) observed that their acquired dyslexic patients could not read out orthographically regular non-words. The developmental dyslexic children, like those of Seymour and Porpodas (1979) were markedly slower and somewhat less accurate than children of comparable reading age, but were by no means incapable of such reading. The conclusion,as that of Expt. 4d, is that whereas phonemic dyslexic patients appear to have a gross defect in the operation of the grapheme-phoneme component in reading, the developmental dyslexic children appear to have some capability of using such a route, albeit more slowly and less efficiently than either CA or RA controls.

Some speculations are detailed as to the nature of the differences between acquired and developmental dyslexics.

Introduction

To compare further the phonological encoding deficiency in acquired and developmental dyslexic subjects,a further test was administered to the developmental dyslexics to investigate their ability at reading orthographically regular non-words (c.f. Seymour and Porpodas, 1979).

One of the more striking features of the performance of phonemic dyslexic patients lies in their inability to read out non-words, even though these are orthographically regular and easily pronounceable by normal subjects. This defect was illustrated very clearly by Patterson and Marcel (1977) and again on Dr. Baddeley's suggestion it was therefore decided to attempt to repeat their experimental procedure using exactly the same material with the developmental dyslexic children. The test was run on the two groups of 15 subjects tested in Expt. 4d who were matched for chronological age (CA) and as far as possible for IQ but differed in reading age (RA). In this experiment however a second RA control group was also tested. These comprised 15 boys who were normal in their reading development, but matched the dyslexics in reading age, being approximately three years younger in chronological age, again matched as far as possible for IQ. As in the case of the other two groups they were pupils at a private boarding school; they had a chronological age of nine years eleven months, a reading age of ten years and three months and were of average or above average intelligence. (Viv Lewis ran this control group down in Cambridge).

The materials and procedure were based on that used by Patterson and Marcel (1977) and involved presenting the subject with two sheets, each comprising 17 words and 17 non-words randomly arranged in two columns. The subject was instructed to work down the column reading each item, and the correctness of his response and total time per sheet were recorded.

Results and Discussion

The mean reading time and error rate for the three groups is shown in Table 4:5. There is a very clear tendency for the dyslexics again to be slower than either of the control groups, ($U = 20$, $n_1 = n_2 = 15$, $p < .001$ in each case) which do not differ significantly from each other ($U = 74.5$, $n_1 = n_2 = 15$, $p > .05$). Overall error rate is clearly much lower in the CA control than

TABLE 4:5

Speed and accuracy of reading words and nonwords by dyslexic And control subjects.

	Mean Reading Time per item (secs)	Mean % Errors WORDS	NONWORDS
DYSLEXIC SUBJECTS	2.00	6.3	41.6
C.A. CONTROLS	0.85	0.4	6.7
R.A. CONTROLS	0.94	5.9	32.4

in either of the groups of lower reading age for both words and non-words. The dyslexic group shows about the same error rate as the RA control group for words, as one might expect since the groups were matched on ability to read single words ($U = 91$, $n_1 = n_2 = 15$, $p > .05$). In the case of non-words however, the dyslexics do show a significantly higher error rate ($U = 47.5$, $n_1 = n_2 = 15$, $p < .02$). Even so, the RA controls seem much more similar in accuracy to the dyslexics than to the other controls who differ only in being two and a half years older. Using a similar task, Seymour and Porpodas (1979) found dyslexics to be slower but no less accurate than RA controls in non-word reading. Considered overall therefore, dyslexics do not appear to be qualitatively different from their RA controls in their pattern of reading errors. In all three groups, subjects make more errors on non-words than on words; this tendency is shown by all subjects in the dyslexic and reading age control groups, and by 13 of the 15 chronological age controls, although the latter group clearly showed a very much smaller overall error rate.

Once again, the dyslexic group was substantially slower than controls of comparable age, and indeed were very much slower than even the children of a similar reading age who were virtually three years younger. The dyslexic group also made substantially more errors than controls of the same age in the case of non-words, although the difference between these groups is far from dramatic in comparison with the disproportionate difficulty in reading non-words displayed by phonemic dyslexic patients.

It is again concluded that developmental dyslexic children, in contrast to phonemic dyslexic patients who appear to have a gross defect in the operation of the grapheme-phoneme component in reading, appear to have some capability of using such a route, albeit more slowly and less efficiently than either CA or RA controls.

With regard to the similarities/differences between developmental and acquired dyslexics, while these results are reasonably clear-cut, some caution should be used in making generalizations. First, it is logically possible that the phonemic dyslexic patients and the dyslexic boys may have suffered from the defective operation of the same component in reading, but that the pattern of performance is changed either because the patient has a much more dramatic and complete impairment, or because an impairment during the stage of learning to read has a different effect from a similar impairment in a previously fluent reader. A further complication arises from the fact that the dyslexics were all attending a school which explicitly aimed to train them to cope with their dyslexia and develop normal reading. It is hence conceivable that children trained in some other way might show no evidence of using the grapheme-phoneme route. This suggests that this study should be replicated using dyslexic children from a range of sources before concluding that some utilization of the grapheme-phoneme route is typical of dyslexic children. It can however be concluded from the present group that the pattern of disabilities associated with dyslexia in children is not <u>necessarily</u> associated with a gross inability to use the grapheme-phoneme route, and in this respect it appears to differ from the phonemic dyslexia studied in Patterson and Marcel's adult patients.

At a speculative level, the difference between the acquired and developmental dyslexic syndromes might be explained as follows. When a child starts to read, he already has a substantial vocabulary of words he has heard, which can be accessed through the activation of an auditory input logogen (c.f. Morton, 1969, 1978). In learning to read he is likely to be taught grapheme-phoneme conversion rules which allow him to say the words to himself and thus activate the necessary auditory input logogen and hence understand the <u>written word</u>. It seems likely that the process of learning to read, with multiple presentations of particular words, will create a separate set of visual input logogens, which will allow the meaning of the word to be accessed without the necessity of going through the auditory logogen system.

Acquired dyslexics could read before their accident, and had thus presumably developed an extensive visual input logogen system. As a result of their accident there seems to be damage in the system translating the visual input into a phonological code via grapheme-phoneme conversion rules. It is this phonological code which allows activation of auditory input logogens, and as there is a deficiency in the system responsible for phonological encoding, the acquired dyslexic is forced to rely heavily on the direct route to meaning through the visual input logogen system. Hence they are able to produce a semantically appropriate response for words which they are unable to read out loud. Such semantic errors are not characteristic of developmental dyslexics, who are more likely to make 'visual' or 'phonological' errors. It seems likely that developmental dyslexics are slow in operating and developing the grapheme-phoneme conversion route, the link between the written word and the auditory input logogen system. If the visual logogen system develops from the auditory system, then it seems likely that this will also be underdeveloped, and will not be available for use as an alternative to the phonological encoding process. Hence developmental dyslexics will tend to show visual or phonological rather than semantic errors and produce a reading performance which resembles that of younger children, who are still in the process of building up the lexical route, viz. visual input logogen system via the grapheme-phoneme conversion route.

General Discussion of Expts. 4a - 4e

It has been concluded:

a) Dyslexic children are relatively slow at naming single letters. This deficiency appears not to reside at the level of pattern recognition or dealing with the visual aspects of the letters since the same children are as fast and as accurate in letter matching according to visual characteristics (OO, OZ, OQ) in Expt. 3a. The deficiency is thus assumed to be at the translation into a phonological or lexical representation, or in articulatory encoding from that representation.

b) Dyslexic children are relatively slow and inaccurate at naming pictures. Again this deficiency is not thought to reside at the pattern recognition stage since similar poor readers perform normally in a non-verbal pictorial task (Mackworth and Mackworth, 1974). This present finding, and those of Denckla and Rudel (1976), Spring and Capps (1976) and Audley (1976), of slow picture and colour naming in dyslexic children is of interest since it contradicts adequate object naming for the four dyslexic children studied by Seymour and Porpodas (1979) who conclude that any visual or naming deficits of dyslexic children are specific to the graphemic system.

c) Dyslexic children are relatively slow and inaccurate at naming words. They show large word length effects and are slower at naming words than pictures. Their reading is primarily orthographic and they are slow and inaccurate in using the grapheme-phoneme translatio route in reading. The limitation may occur either in the creation of the phonological representation or in articulatory encoding from that representation.

d) In contrast to phonemic dyslexic patients, developmental dyslex children show a non-word homphone effect in lexical decision. Therefore, whereas the phonemic dyslexic shows a gross deficiency in phonological encoding, the developmental dyslexics have some capability in using the grapheme-phoneme route, but are relatively slow and inefficient. It is again unclear whether the phonological representation in question is non-articulatory or articulatory.

e) In comparison to both CA and RA matched controls dyslexic children are relatively slow and inaccurate at the orthographic reading of non-words but do have some capability of using the grapheme-phoneme conversion route.

Over a broad range of visual stimuli (letters, pictures, words, non-words) dyslexic children typically demonstrate capability in dealing with the visual stimulus characteristics but appear slow and inaccurate in either accessing phonological or lexical representations of these stimuli, or in articulatory encoding for output.

EXPERIMENTAL CHAPTER 5

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CONTENTS

EXPERIMENTAL CHAPTER 5

In which the short-term memory span for verbal material is tested for dyslexic, CA control and RA control children - dyslexic children are demonstrated to be quite capable at articulatorily encoded rehearsal strategies - the dyslexic child appears 'normal' in his understanding of spoken speech - the lexical system is suggested to be deficient in the poor reader.

Introduction

The deficiency in dyslexics is not visual and is concerned with linguistic stimulus representation, manifesting itself in naming tasks, and in tasks involving the short-term retention of verbal material.

It is evidence of this type that has prompted the present thesis and that of a number of investigators to suggest that the poor reader differs from the good reader in his capacity for phonological encoding and that it is this disability which underlies both his poor reading and STM span (Conrad, 1972a; Baddeley, 1978; Baddeley and HItch, 1978; Ellis and Miles, 1978; Liberman et al., 1976). 'Phonological' is a blanket term, however, encompassing all internal representation of language sounds, be they either 'auditory images' (c.f. Conrad, 1972b; Sperling, 1967) or speech-motor (articulatory). It is important for clarity that this distinction between articulatory and non-articulatory linguistic representations be made. Within the context of the phonological deficit in dyslexia, Baddeley (1978) has been specific in suggesting it to be articulatory in nature; in contrast Ellis and Miles (1978, 1979) propose that it is a non-articulatory name or lexical code precursor to articulatory encoding.

It is the aim of this chapter to test these alternative possibilities with regard to the processing deficits underlying the poor memory span and poor reading found in dyslexic children.

Experiments 5a and 5b test the ability of these children to use articulatory encoded rehearsal, Experiments 5c(i) and 5c(ii) their speed of articulatory encoding from an auditory stimulus input, and Experiment 5d their ability to understand, retain, and act upon spoken instructions.

Perhaps the most easily testable interpretation of the relationship between memory span and dyslexia is that of Baddeley (1978) who has suggested that dyslexics are defective in their utilization of the articulatory loop. The articulatory loop is a concept devised by Baddeley and Hitch (1974) to account for the close association between memory span and speech coding. The loop is assumed to be one component of a composite short-term or working memory system. It is a system whereby the central component of working memory may supplement its limited storage capacity by subvocalization. The articulatory loop is assumed to be responsible for the phonemic similarity effect (poorer memory span for material that is phonemically similar), the word length effect (poorer span for longer words) and the effect of articulatory suppression (poorer span when the subject is prevented from rehearsing by the need to articulate some irrelevant item). Further evidence for the concept of the articulatory loop comes from the observation that in the case of visually presented material if the subject is prevented by means of articulatory suppression from using the articulatory loop this abolishes both the phonemic similarity and word length effects. Baddeley (1978) has suggested that the articulatory loop is important in learning to read since it allows the temporary storage of phonemic information during the reading process. If the articulatory loop is not used, Baddeley suggests that the central executive must be used both for storage and for decoding subsequent graphemes in the word being read. When the central executive becomes overloaded the reader must sacrifice either retention of what he has already decoded or his capacity for continuing to decode the remaining letters in the word. Such an interpretation is consistent with the previously cited relationship between speech coding, memory and dyslexia. It is also very easy to test since it produces a number of straightforward predictions. If dyslexic children do not use the articulatory loop, then pre-empting the loop by articulatory suppression should not affect their memory span. Similarly, they should show no evidence of either phonemic similarity or word length effects. Experiments 5:1 and 5:2 test these predictions.

EXPERIMENT 5a

Abstract

To investigate the use of articulatory encoded rehearsal in groups of 20 dyslexic, CA and RA matched control children, a digit span task was administered with and without articulatory suppression. The short-term memory (STM) span of dyslexic children was less than that of CA matched controls but was similar to that of younger children of a similar reading age. This limitation in memory span is not attributable to an inability on the part of poorer readers to use rehearsal strategies involving the articulatory loop since the three subject groups were equally (proportionately) affected by articulatory suppression.

Introduction

Articulatory suppression is a procedure whereby the subject is required to repeat continuously some redundant but irrelevant sound such as "the" or "hiyah", it has frequently been used to study the role of subvocal articulation in cognitive tasks (Baddeley and Hitch, 1974; Murray, 1967; Sokolov, 1972) and has typically been found to reduce memory span (Levy, 1971). The present experiment uses articulatory suppression to study the utilization of articulatory coding in performing the memory span task by dyslexic children and controls of either the same age or the same reading age.

Subjects

20 dyslexic boys, 20 chronological age (CA) matched control boys, and 20 reading age (RA) matched control boys were chosen from private schools. The dyslexic boys were attending a school which specialized in dyslexia and all met the criteria for dyslexic group membership as outlined before. All the subjects were of average or above average intelligence determined using a recognised intelligence test.

The mean CA for the Dyslexic group was 11 years 11 months (s.d. 0.65 years), the mean RA was 9 years 1 month and the mean spelling age (SA) was 8 years 3 months. The mean CA for the CA Control group was 12 years 0 months (s.d. 0.81 years), the mean RA was 12 years 10 months and the mean SA was 12 years 9 months. The mean CA for the RA Control group was 9 years 5 months (s.d. 0.72 years), the mean RA was 9 years 5 months.

Method

Arrays of random digits were presented on cards. The first card contained 3 items. Two seconds after a 'ready' signal, the card was exposed manually for a period in seconds which was equal to the number of items on that card. Two seconds after the card had been removed, the word 'now' was spoken, at which the child was to report the digits he had seen in the same order as they were in the array. There were three trials using different cards at each array size, after which the array size was incremented by one. This sequence was repeated until the child's responses were incorrect on three consecutive trials. Digit span was then calculated as being: 2 + (number of trials correct/3).

Each child was tested under the above control condition and under articulatory suppression, where he was to repeatedly recite the sequence "a b c, d", at the fastest rate compatible with clarity of pronunciation, continuously between the 'ready' and 'now' signals. The order of presentation of the 2 conditions was counterbalanced across subjects.

Results

The mean memory spans for the three subject groups on the two conditions are shown in Table 5:1.

A two factor ANOVA (3 groups x 2 conditions with subjects nested within groups) demonstrates that the groups factor ($F = 32.67$; d.f. 2,38; $p < .01$) and the conditions factor ($F = 111.35$; d.f. 1,76; $p < .01$) are significant. A Newman-Keuls test between groups showed that the CA Controls performed significantly better than both the RA Controls and the Dyslexics ($p < .01$), but that the performance of these latter two groups did not differ significantly. The condition x group interaction failed to reach significance ($F = 0.91$; d.f. 2,76) suggesting that the performance of all three groups was similarly impaired by articulatory suppression.

TABLE 5:1

The mean memory span of the Dyslexic, CA control, and RA control groups tested under the 2 conditions of Expt. 5a.

	CA Controls	Dyslexics	RA Controls
CONTROL CONDITION	6.70	5.37	5.48
ARTICULATORY SUPPRESSION CONDITION	5.17	3.70	4.27
d	1.53	1.67	1.21
$\bar{X}$	5.94	4.54	4.88

ANOVA Results

SOURCE OF VARIATION	d.f.	SSq	MSq	F	p
GROUPS (G)	2	42.62	21.32	32.67	**
SUBJECTS WITHIN G (S)	38	24.79	0.65		
CONDITIONS (C)	1	65.02	65.02	111.35	**
CG	2	1.07	0.53	0.91	NS
ERROR	76	44.38	0.58		

** : $p < .01$

NS : Not Significant.

Discussion

Children's memory span is reduced in this experiment under articulatory suppression, a finding which supports the claim of Levy (1971) and that of Baddeley, Thomson and Buchanan (1975) that articulatory encoding is involved in performance of some memory span tasks. This interfering treatment does not, however, totally prevent any stimulus memorisation, and this fact suggests that other non-articulatory codes are also used.

The lack of a significant condition x group interaction suggests that all the subject groups tested in the experiment were using articulatory coding. This implies that the low memory span that is typical of dyslexic children is not the result of a lack of articulatory encoding and rehearsal. Rather, as the groups still differ markedly in their span under articulatory suppression, this suggests a limitation for the dyslexic children in this 'other coding' used in the span task. The possible nature of such coding will be discussed later.

Although the memory span of the dyslexic group is significantly lower than that of their CA matched control group, it equates to that of younger children of similar reading ability. This accords with the findings of Baddeley, Thomson and Buchanan (1975) that memory span correlates with both the speed with which the subject can read the stimulus material and the speed with which a given type of material can be read. This suggests that the 'other coding' used in the memory span task may also be involved in the reading process.

EXPERIMENT 5b

Abstract

Expt. 5b is a further test of the articulatory loop hypothesis. Since Baddeley and Hitch (1974) attribute both the phonemic similarity effect and the word length effect to the operation of the articulatory loop, if dyslexic subjects fail to utilise the loop, they should show no evidence of either of these effects. 20 dyslexic and 20 CA controls were therefore tested for memory span of control, phonemically similar, and long-word-length items. The STM span of the dyslexic children was reliably less than that of the CA Controls, but the two groups showed equivalent detrimental effects of word length and phonemic similarity. It is concluded that the STM limitation of dyslexic children is not attributable to an inability to use rehearsal strategies involving articulatory encoding.

Introduction

Although the results of articulatory suppression eliminating word length and phonemic similarity effects are consistently found, there is some suggestion that rather than simply disrupting articulatory encoding, the effects of articulatory suppression are by no means simple or clear cut. For example Routh, Frosdick, Eddowes and Livesey (1979) demonstrate that a component of the interference effect of articulatory suppression originates in auditory feedback, and suggest that suppression tasks primarily generate interference by disrupting elaborative rehearsal and not by inhibiting articulatory processes or the formation of a phonological representation.

Since, therefore, there is some doubt as to the effects of articulatory suppression upon articulatory encoding, other tests of the use of articulatory encoding in dyslexic and control subjects should additionally be used.

Short-term memory span has been shown to be reduced when the stimulus items are phonemically confusable (Baddeley, 1966; Conrad and Hull, 1964). As phonemic confusability and long syllable length slow rehearsal rate (Chase, 1977; Clifton and Tash, 1973) it might be the case that the reduction in memory span for items of this nature is a result of this retarded rehearsal. Wickelgren's (1965) finding that phonemic similarity primarily disrupts the retention of order information, which is thought to be heavily dependent upon articulatory encoded rehearsal (Baddeley and Hitch, 1974), supports this notion. Baddeley, Thomson, and Buchanan (1975), using articulatory suppression, have demonstrated that word-length does indeed affect the rehearsal component of working memory, viz. the articulatory loop, and Murray (1968) and Estes (1973) have similarly shown this to be the level of the phonemic similarity effect, since there is no such effect if subjects are required to count during the presentation of the to-be-remembered items.

The present study uses the findings that word-length and phonemic similarity effects operate at an articulatory encoding level to further investigate the respective use of articulatory encoded rehearsal by dyslexic and control children: if the dyslexic children are unable to utilize articulatory encoding in the memory span task they should be less or not affected by stimulus word length or degree of phonemic similarity.

Subjects

The 20 dyslexic boys and 20 CA Controls of expt. 5a also served as subjects in this experiment.

Method

Four pools of stimulus items were prepared. A pool of short words (owl, crab, snake, chick, clown, sledge, branch, whale) was matched for frequency with a pool of long words (telephone, octopus, elephant, butterfly, parachute, kangaroo, envelope, crocodile). A pool of phonemically similar words (mat, bag, rat, tap, cat, man, hat, bat) was matched for frequency to a pool of phonemically dissimilar words (hand, fish, girl, spoon, train, horse, bus, clock). Lists, which varied in length from 1 to 7 items, were constructed from within these item pools.

For each of the four conditions the child was instructed that he would hear a list of words and that, on the command 'now', which followed list presentation, he was to repeat these words in the order in which he had heard them. Words were read to the child at a rate of one per second. The first trial for any condition was always of list length 1 item. There were three trials per list length, after which the length was incremented by one item. This procedure was repeated until the child made three consecutive errors. His span for that condition was then calculated as being: (number of trials correct/3). Each child was tested under all four conditions, the order of condition presentation being counterbalanced.

Results

Table 5:2 shows the mean span on each condition for the dyslexic and CA Control subjects.

A 2 factor ANOVA (2 groups x 4 conditions with subject nested within groups) showed significant group differences ($F = 5.77$; d.f. 1,38; $p < .05$), and condition differences ($F = 72.83$; d.f. 3,114; $p < .01$). The interaction of groups and conditions was not significant ($F = 0.88$; d.f. 3,114). Analysis of the conditions factor using a Newman Keuls test shows that the phonemically dissimilar words are recalled significantly better than all other word types ($p < .01$), the short words are recalled significantly better than either long or phonemically similar words ($p < .01$), and that recall of phonemically similar words does not differ significantly from that of long words.

Discussion

A similar patterning of results has been obtained to that of Experiment 5a. The Memory span of dyslexic children

TABLE 5:2

The mean memory span of the Dyslexic and CA Control Groups tested under the four conditions of Expt. 5b

	DYSLEXIC GROUP	CONTROL GROUP
Short Words	3.88	4.28
Long Words	3.33	3.65
d	0.55	0.63
Phonemically Dissimilar Words	4.25	4.70
Phomenically Similar Words	3.23	3.42
d	1.02	1.28
$\bar{X}$ Span	3.68	4.01

ANOVA Results

SOURCE OF VARIATION	d.f.	SSq	MSq	F	p
GROUPS (G)	1	4.56	4.56	5.77	*
SUBJECTS WITHIN G (S)	38	30.01	0.79	5.10	**
CONDITIONS (C)	3	33.96	11.32	72.83	**
GC	3	0.408	0.14	0.88	NS
ERROR	114	17.72	0.16		

**: $p < .01$

* : $p < .05$

NS: Not Significant.

is consistently less than that of CA matched controls. The detrimental effects of word length and phonemic similarity on memory span have again been demonstrated, and are present for dyslexic and control groups alike. The dyslexic child's smaller memory span is not, therefore, solely the result of an inability to use articulatory encoded rehearsal.

Further support of this finding comes from Cohen and Netley (1977) who compared two groups of reading disabled (RD) children with controls on a modified running memory test which used long lists of auditory digits presented at high rates. Both RD groups performed significantly worse than their controls at this task where effective use of a rehearsal strategy is, if not impossible, extremely difficult.

Given, therefore, that a rehearsal explanation is not valid in explaining span differences between good readers and poor readers (whether or not they be dyslexic), alternative explanations must be proposed and evaluated. Cohen and Netley (1977) suggest that "the RD children have an encoding deficit in the sense that they are slower than control children in identifying the incoming items", this idea will be assessed and expanded in the general discussion of this chapter.

EXPERIMENTS 5c (i and ii)

Abstract

Two separate experiments were performed to compare dyslexic and control children for the speed with which they could repeat auditorily presented words. The dyslexic children did not differ significantly from the controls in the speed or accuracy with which they made the words articulate. It is argued that this task involves articulatory encoding for output, yet by-passes the need to create non-articulatory lexical codes from visual input. It is concluded that dyslexic children are as efficient as controls at articulatory encoding single words after auditory input.

Introduction

The repetition of auditorily presented words must surely involve articulatory encoding for output. A comparison of dyslexic and control children on this task must therefore tap the articulatory encoding skills of these children.

In this situation the need to create a non-articulatory name or lexical code from graphemic stimuli is by-passed, but the stimuli still require articulatory encoding for output. Davis, Moray and Treisman (1961) used this task and concluded from data which showed no stimulus set size effects in highly skilled subjects that such imitative responses are produced "automatically" with little attentional demands.

EXPERIMENT 5 c(i)

Subjects

The subjects were 13 dyslexic boys (mean CA 11.8 years (range 11.0-12.9), mean RA 8.9 years and mean SA 8.0 years), from the same school as those of the earlier experiments, and 13 control boys of mean CA 11.8 years (range 10.9-13.0), mean RA 12.8 years and mean SA 12.8 years. The criteria for dyslexic and control group inclusion (average or above average intelligence etc.) were those detailed in Chapter 1.

Method

The following words were pre-recorded on a tape recorder: 'hot', 'big', 'cold', 'huge', 'bright', 'square', 'high','red', 'wrong', 'regular', 'purple', 'afternoon', 'rectangular', 'dangerous', 'transparent', 'elliptical', 'miscellaneous', and 'professional'. The first 9 are considered as being 'short', the latter 9 as 'long'.

The child was told that he was to hear some words on the tape recorder and that he was to repeat the words as quickly as he could. The onset of each word started a Dawes timer by means of a voice key, while the onset of the child's response stopped the timer by means of a second voice key whose microphone was positioned directly in front of his mouth. Errors and response times accurate to 10 ms were recorded.

It should be noted that the time taken to activate a voice key varies as a function of the initial phoneme of the word being spoken. Since the 'short' and 'long' words were not matched with respect to initial phoneme, comparisons of repetition latencies between 'short' and 'long' words are not strictly legitimate.

Results

For the dyslexic children there were 5 mispronunciations out of 234 trials, for the control children there were 3. The response time data were analysed as a 3-factor ANOVA: 2 groups (dyslexics, controls) x 2 word lengths x 9 words, with 13 subjects nested within each group. The groups factor ($F = 2.63$; $df = 1,24$) was insignificant, the mean response times on the 'short' words being 820 ms for the controls and 850 ms for the dyslexics, and on the 'long' words being 1010 ms for the controls and 1110 ms for the dyslexic subjects. The word length factor ($F = 299.8$; $df = 1,408$), words factor ($F = 14.6$; $df = 16,408$) and subjects-within-groups factors ($F = 9.2$; $df = 24,408$) all reached the .01 level of significance.

EXPERIMENT 5c(ii)

There is some hint in the results of Expt. 5c(i) that there is a trend, albeit far from significant, that the dyslexic children are slower on the longer words ($\bar{x}$ response latencies of 1010 ms for the controls and 1110 ms for the dyslexics). For this reason it was considered advisable to replicate the study. (Thanks to Rob Lenzie for running this replication).

Subjects

The subjects were 11 dyslexic boys ($\bar{x}$ CA 11 yrs. 5ms., s.d. 0.88 yrs.; $\bar{x}$ RA 9 yrs. 10 ms., s.d. 0.99yrs.) and 11 control boys ($\bar{x}$ CA 11 yrs 4 ms., s.d. 0.85 yrs.; $\bar{x}$ RA 12 yrs. 3ms., s.d. 2.08 yrs.). All subjects were of average or above average intelligence, were attending preparatory schools, and fulfilled the criteria for group membership outlined in the introduction.

Method

The method was identical to that of Expt. 5c(i) except different stimuli were used. Three conditions of 8 words were used: these were 5-, 3- or single-syllable words matched to a frequency of 1:1 million on the Thorndike and Lorge (1944) count. The stimuli were as follows:

5-syllable words	3-syllable words	1-syllable words
Bibliography	Legislate	Brusque
Capitalistic	Juryman	Leach
Hallucination	Inductive	Marl
Geometrical	Election	Quirk
Abbreviation	Bivouac	Prong
Ecstatically	Obdurate	Gist
Scholasticism	Jollity	Null
Versatility	Hebrides	Kurd

The order of presentation of conditions was randomized for each subject.

Results

The group mean response latencies on each of the conditions can be seen in Table 5:3. These data were analysed as a 3 factor ANOVA (2 groups x 3 word lengths x 8 words) with 11 subjects nested within each group. The Groups factor was insignificant ($F = 0.73$; d.f. 1,20). The Condition factor was significant ($F = 13.33$; d.f. 2,21; $p < .01$). A Newman Keuls test on this word-length difference demonstrated the 5-syllable words to have a longer response latency than either the 3-syllable words ($p < .05$) or the 1-syllable words ($p < .01$), and the 3-syllable words to have a longer latency than the 1-syllable words ($p < .01$). The Groups x Conditions interaction was not significant ($F = 1.44$; d.f. 2,230).

Discussion of Expts. 5c(i and ii)

In both of these tests of articulatory encoding for word repetition the Groups factor has failed to reach significance, there being large subject-within groups variability. In other words, when single words are presented auditorily the dyslexic children did not differ significantly from the controls in the speed or accuracy with which they made the words articulate. Whether this articulatory encoding is the same process as that involved in reading is a matter of debate: in adults its initiation is certainly very fast, automatic, and with practice, apparently independent of vocabulary size for nonsense syllables

TABLE 5:3

Mean Naming Response Latencies for the 2 Subject Groups (dyslexics, controls) tested on the 3 Conditions of Expt.5c(ii)(Latencies in sec.)

	DYSLEXIC SUBJECTS	CONTROL SUBJECTS
1-Syllable Words	1.17	0.94
3-Syllable Words	1.27	1.13
5-Syllable Words	1.40	1.22

ANOVA Data

SOURCE OF VARIATION	d.f.	SSq.	MSq.	F	p
GROUPS (G)	1	4.899	4.899	0.73	NS
SUBJECTS WITHIN G	20	133.6	6.68		
CONDITIONS (C)	2	5.447	2.72	13.33	**
WORDS WITHIN C	21	4.286	0.204		
GC	2	0.104	0.052	1.44	NS
ERROR	230	8.303	0.036		

**: $p < .01$

NS: Not Significant

(Davis, Moray, and Treisman, 1961). These findings may or may not apply with articulatory encoding in the postulated grapheme to lexical code to articulatory code pathway. There is, however, no doubt that articulatory encoding is necessary for speech output whether the input be visual or auditory, and the experiment shows that when the need to create a non-articulatory name or lexical code from graphemic stimuli is by-passed dyslexic children perform no differently from controls at articulatory encoding.

EXPERIMENT 5d.

Abstract

The possibility that dyslexic subjects are defective in the comprehension of spoken language was tested using the short form of the Token test (Warrington, Logue and Pratt, 1971). The dyslexic children showed a small deficit in performance, but their scores resembled those of children of the same reading age. The magnitude of this deficit implies that it is more likely to be a secondary result of impaired memory span rather than being primary evidence for a general comprehension deficit.

It is concluded that the dyslexic children under test have an adequate vocabulary development of their auditory input logogen system, and thus this area of possible deficiency is discounted as a possible cause of the dyslexic child's reading and verbal STM span problems.

Introduction

While addressing the verbal STM span deficiency in dyslexia, there is one possibility which remains open to test. This is not that the dyslexic children are deficient at articulatory encoding and use of the articulatory loop, but that the problem occurs at the stage of "loop unloading", where the articulatory encoded data is fed back into the working memory system refreshing the trace (c.f. Baddeley and Hitch, 1974). In other words, it is possible that the reduced memory span of dyslexic children may be a result of a 'receptive disorder': the children may show an impairment in understanding spoken speech and therefore the words, being less meaningful, will be less susceptible to grouping or chunking and thus less memorable. In formalized terminology this may be expressed as the dyslexic child having a less well developed auditory input logogen system (Morton, 1970; 1978). This concept might also carry explanatory power for other typical dyslexic symptoms such as their poor reading.

The parallels between dyslexia and aphasia have often been stressed. MacMeeken (1939, p.27) states that with dyslexia "There can be no doubt whatever that we are in touch with a pattern of difficulty aphasic in type". Rabinovitch et al. (1954) found receptive, expressive and nominal types of language difficulty such as occur in adult aphasics to be present in some of the dyslexic cases whom they studied, and De Hirsch, Jansky and Langford (1966) found auditory perceptual and oral language deficiencies in all their sample of children who subsequently failed at reading.

This point, however, appears to be in conflict with the anecdotal reports made by teachers who often say of a dyslexic child that he is one of the brightest in the form except when it comes to dealing with written material. Similarly there are many experimental studies which have failed to establish a relationship between impairment in the understanding of spoken speech and impairment at reading.

In reviewing 13 studies which compared good and poor readers on the subtests of the Illinois Test of Psycholinguistic Abilities (ITPA, McCarthy and Kirk, 1961), Spache (1976) finds there to be typical group performance differences on the auditory sequential memory (digit span), visual sequential memory, grammatic closure (sentence completion according to actions specificed in pictures) and auditory-vocal association (completion of incomplete analogies) subtests. In contrast the auditory decoding task (where simple sentences have to be answered 'yes' or 'no')failed to differentiate between the groups in 11 of the 13 studies. Silver (1968) similarly failed to find backward readers deficient in the understanding of word meanings as measured by ability to match pictures to spoken words. Vernon (1971) in reviewing studies of the relationship between linguistic impairment and reading disability concludes that the findings depend on both the sample tested and the degree of backwardness, and such a relationship will not appear in all cases of reading disability.

One aspect of comprehension which often does appear to be defective in dyslexic children lies in their ability to obey complex commands involving right-left discriminations. For example, dyslexic children often appear to make errors or at least hesitate in obeying an instruction such as "point to my left ear with your right hand" (Miles, 1978). This is typically attributed to problems of lateralization, but could also be attributed to a more general defect in comprehension, possibly based on reduced memory span. Patients with reduced memory span such as the patient K.F., described by Shallice and Warrington (1975) also show an impairment in comprehension when this is measured by means of the Token test. This test, which was originally developed by De Renzi and Vignolo (1962), involves presenting the subject with an array of shapes varying in size and colour and instructing him to perform various operations. These range in complexity from simple commands such as "Point to the green circle" up to much more complex instructions such as "Touch the large red circle with the small green triangle". While this is typically regarded as a test of "comprehension", patients such as K.F. may be grossly defective on this test and yet show no evidence of comprehension failure in either conversation or in processing normal prose. The most parsimonious interpretation of such results would seem to be to argue that the Token Test is particularly dependent on short-term memory. It is characterised by a very rapid input of information which must be interpreted very precisely. In the case of a normal subject he/she probably stores the input sentence while processing the semantics, in contrast to normal prose, which tends to be much more predictable and redundant.

What might one expect of dyslexics in a Token Test? If it is assumed that they are suffering primarily from a comprehension deficit, then one might expext a dramatic impairment. On the other hand, if one assumes that any deficit in comprehension is a result of their somewhat impaired memory span, then a much smaller decrement would be predicted. Finally if one attributes comprehension deficits such as those observed by Miles to left-right confusion resulting from inadequate lateralization, then a test which involves no left-right discrimination might be expected to produce no decrement in performance. A sample of dyslexic children was therefore tested and their performance was compared to that of the CA and RA control groups using the shortened form of the Token Test (Warrington, Logue and Pratt, 1971).

Subjects

The three groups of subjects were those used in Expt. 5a.

Results

The mean number of correct responses made by the CA control group was 14.25 (s.d. 0.79). The corresponding figures for the dyslexic group was 12.25 (s.d. 1.89) and for the RA control group was 1.200 (s.d. 1.86).

A Kruskal-Wallis one way ANOVA performed on these data demonstrated significant group differences (H = 17.84; d.f. 2; $p < .001$). Repeated Mann-Whitney U tests at the .001 significance level showed that whilst the CA controls answered significantly more questions correctly than both the RA controls and the dyslexics, the latter two groups did not differ significantly from each other ($p > .32$).

Discussion

On the token test there is a small but significant difference between the performance of the dyslexics and age matched controls. The mean difference in performance is however only in the order of two questions correctly answered and on a test which was originally designed to be a "sensitive tool to reveal slight disturbances in the understanding of speech" (our italics, De Renzi and Vignolo, 1962, p.667), this hardly suggests a major comprehension difficulty. A more plausible interpretation is offered by the short-term memory hypothesis: the dyslexic groups performed at the same level as the RA controls, who it will be recalled from Expt. 5a, have an equivalent memory span. The fact that a small but reliable effect was observed suggests in addition that the impaired ability of dyslexics to follow complex directional instructions may be attributable to a limitation in storage of the verbal instruction rather than to left-right confusion as such (compare Miles and Wheeler, 1974).

It is concluded that the dyslexic sample under test shows no major difficulty in the comprehension of spoken speech, and it therefore appears unlikely that the dyslexic child's verbal STM span deficiency is attributable to an ill-developed auditory input logogen system.

General Discussion

The experiments in this chapter continue to suggest that there is a clear association between developmental dyslexia and memory performance. The results of Expts. 5a,b,c(i and ii) clearly rule out the relatively peripheral articulatory loop as the source of the problem: the dyslexic child is quite capable at articulatory encoding and the use of articulatory encoded rehearsal strategies. The results of Expts. 5d suggests adequate understanding of spoken language and normal development of the auditory input logogen system(within the limits investigated in the experiment).

Given that deficiencies in articulatory encoding or the auditory input logogen system do not underlie the dyslexic child's poor reading and relatively poor STM span for verbal material, some other coding that is used in these tasks must be deficient. It is argued in Chapters 3 and 4 to be heuristic to view verbal short-term memory as the interaction between lexical and articulatory representation, and it is thus suggested (c.f. Chapters 3 and 4) that it is the lexical component of the working memory system which is deficient in dyslexic children.

EXPERIMENTAL CHAPTER 6

EXPERIMENTAL CHAPTER 6

CONTENTS

Introduction

Introduction

Dyslexic children's 'word finding' (i.e. lexical and articulatory encoding) skills have been investigated with visual input (letters, words, non-words, pictures, colours etc.) in Experimental Chapters 2,4 and 5 and with auditory input in Experimental Chapter 5. There is another common situation of word-finding which warrants investigation, however, and that is spontaneous word finding in order that speech might reflect thought. In terms of the model (Chapters 2 and 3) this reflects lexical and articulatory encoding from 'cognitive' or 'semantic' sources. (Alan Baddeley first suggested that this should be investigated).

EXPERIMENT 6

Experiment 6 therefore examines the performance of dyslexics on a verbal task involving no immediate input, namely that of category generation in which subjects are required to produce as many items from a given category as they can within a one-minute interval. This task has been studied extensively, typically using taxonomic categories such as birds or colours (e.g. Bousfield and Sedgwick, 1944; Indow and Togano, 1970). It probably involves at least two components, one being a semantic search of long-term memory for instances, the other being the access to the appropriate name code. In order to try and separate these, three types of category were used, one in which the conventional procedure was used of asking for items from taxonomic categories (e.g. birds), a second in which the category was defined phonologically (e.g. words rhyming with dog) and a third where the category was visually defined (e.g. green things). Any difference between these three types of category would have implications for the nature of the deficit.

Subjects

A sample of 18 dyslexic children from the same source as the earlier studies was tested. Their mean chronological age was 12.0, their mean reading age 9.2 and their mean spelling age 8.3. Control subjects were also boys and were taken from the same population as those used in the previous experiments; the chronological age control group had a mean age of 11.9, a mean reading age of 12.9 and a mean spelling age of 12.6, while the 18 boys in the reading age control had a mean age of 9.5 and a reading age of 9.4. All children tested were of average or above average intelligence.

Method

Each child was instructed to generate and call out as many category members as he could in one minute from the category name given. Nine categories were tested in all, three taxonomic: "birds", "boys' names", "animals"; three phonological: "words rhyming with dog" , "words rhyming with may", "words beginning with a g": and three visual: "green things", "red things", and "three-letter words". The order of presentation of the 9 categories was counterbalanced.

Results

The mean number of items generated for each category by the three subject groups are shown in Table 6:1. A two factor ANOVA (3 Groups x 9 categories, with subjects nested within groups) shows significant effects of Groups ($F = 12.8$; d.f. 2,51; $p < .01$), of Categories ($F = 168.6$; d.f. = 8,408; $p < .01$), and of the Groups x Categories interaction ($F = 3.72$; d.f. = 16,408; $p < .01$).

A Duncan's Multiple Range Test on the Groups shows that whilst the CA Controls reliably generate more category items than both the Dyslexics and the RA Controls (p .01), the performance of these latter two groups does not differ significantly The presence of a Category effect is of little theoretical significance since there is no reason to suppose that the various items are equally difficult. Of more apparent interest is the Category by Groups Interaction. Unfortunately, however, inspection of Table 6:1 suggests no obvious pattern of behaviour;

Categories	CA Control Group	Dyslexic Group	RA Control Grou
Birds	15.4	10.5	9.6
Boys' names	13.9	10.0	12.5
Animals	17.7	14.2	15.6
$\bar{X}$ "Semantic Categories"	15.7	11.6	12.6
'Dog' rhymes	4.9	2.9	3.6
'May' rhymes	8.2	4.7	5.6
'G-' words	9.7	7.7	6.2
$\bar{X}$ "Phonological Categories"	7.6	5.1	5.1
Green things	4.6	4.0	4.1
Red things	2.9	2.4	2.6
3 letter words	12.4	9.2	7.4
$\bar{X}$ "Visual Categories"	6.6	5.2	4.7
$\bar{X}$	10.0	7.3	7.5

Table 6:1

The mean number of items generated in one minute by each subject group for the 9 category names used in Experiment 6.

certainly there is nothing which would appear to merit drawing any very strong theoretical conclusions about qualitative differences between the various groups.

Discussion

The pattern of results suggests that dyslexic children are less fluent at category generation than normal readers of the same age. Their level of performance appears to be roughly what one would expect of younger children with similar reading ability. How should this be interpreted? One might suggest that it reflects an impoverished semantic memory in dyslexic children. While this is possible it seems to be inconsistent with reports of normal vocabulary in dyslexics, and might furthermore be expected to lead to a much more general pattern of decrement in performance.

An alternative explanation, which is more consistent with the results of the other experiments reported here, is to attribute the slow performance of the dyslexics on category generation to impairment in the generation or utilization of lexica or name codes. One feature of all the category generation tasks, whether based on phonological, semantic or colour criteria is that ultimately the subject must generate a word. If this process were in some way defective, then it follows that the performance would be impaired. Furthermore, since the hypothetical defect is in a final common path shared by all the generating tasks, one would not expect a clear difference between impairment on semantic, phonological or visual tasks; such an explanation is therefore consistent both with the positive differences between dyslexics and their chronological age controls and with the absence of a systematic relationship between type of item generated and amount of impairment.

EXPERIMENTAL CHAPTER 7

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EXPERIMENTAL CHAPTER 7

In which the interaction between the functions involved in visual information processing and short-term memory are investigated - item processing for short-term retention does not, but item-and-order processing optimally does, involve articulatory encoding - a static verbal memory preload interferes with the visual information processing of verbal material but a concurrent, running memory preload does not - it is suggested that digit array processing and the short-term memorization of verbal material compete for storage resource at a level of lexical representations - a nonsense visual preload also interferes with the visual information processing of verbal material and this is consistent with the two tasks competing for visual storage resource - those 'buffer processes' underlying the initial fast rate of acquisition for verbal material involve both post-iconic visual and lexical encoding - letter comparison by name in Posner type tasks involves non-articulatory name or lexical representations - a view of working memory is adopted which includes both storage and executive capabilities.

Introduction

The interpretation of the experiments which compare dyslexic and control children on performance at visual information processing to some extent rests upon some assumptions of the functions involved in the tasks used - digit array processing and letter matching in Posner tasks. The primary assumptions concerned are that (i) neither of these tasks involve articulatory encoding to any great extent and (ii) that the initial rate of information acquisition in digit array processing may reflect either visual encoding or lexical encoding operations. Although further experimentation with the dyslexic and control children yet

results in data which are consistent with, and which further differentiate between these assumptions (e.g. Experimental Chapter 5 which shows dyslexic children to be adequate at articulatory encoding even though their performance differs from controls on the digit array processing task), it is important to test these assumptions more thoroughly.

Similarly, in Chapters 3 and 4 a model is developed to account for some of the functions involved in single fixation reading and short-term memory as a result of an extensive literature review. It would be useful to put some of the suggestions and predictions of the model to the test.

The following experiments are designed to, at least in part, fulfil these aims by investigating the functions involved in the visual processing and short-term memory of verbal and visual information.

The experiments in Experimental Chapter 7 assume that function specific interference is to some extent possible. The use of interference tasks is one of the primary tools in the investigation of cognitive functions yet, to be realistic, there is nothing sure in the interpretation of experiments which use interference. If there is an interference effect, is it because the experimental and interference tasks compete for (i) attention, (ii) mental mechanism or processor or (iii) mental representation or code?

Yuille and Ternes (1975) in their analysis of interference in short-term verbal and visual retention found retention losses due to competing attention demands to be comparable in visual and verbal coding conditions regardless of the modality of an interpolated interference activity. In addition, however, retention losses were larger when the same modality was involved in the processing of the memory and interpolated tasks. From their series of careful experiments which were designed to separate out attention and modality specific demands of interference tasks they thus conclude that interference treatments cause short-term retention losses both due to (a) attention diversion, and (b) modality specific interference, but with attention diversion accounting for the larger part of the total retention loss. The notion of attentional processing introduced by Yuille and Ternes (1975) appears synonymous with that of a central processing resource or central executive (c.f. Atkinson and Shiffrin, 1968; Baddeley and Hitch, 1974) and as such the argument becomes more specific: is there (i) one processing resource capacity which is responsible for guidance of behaviour, deeper levels of processing (c.f. Craik and Lockhart, 1972), and maintenance of information by rehearsal, which can operate on different modalities of stored coded data (with interference treatments competing for either modality of store and/or central processing resource) or (ii) modality specific processors operating on data stored in one particular representation (with interference treatments competing for modality specific processor and storage)? As Phillips and Christie (1977b) state:

"The question as to whether there are separate mental mechanisms for thinking in words and pictures is sometimes approached by treating it as identical to the question as to whether words and pictures have separate forms or representation. This approach is attractive because there is a very large body of evidence for this latter distinction. The identification of the two issues, however, seems quite invalid. A single processor can operate upon different forms of representation, and many processors can operate upon one form of representation".

(Phillips and Christie, 1977, p.638)

Certainly there are many examples of modality specific interference, i.e. situations where tasks a priori assumed to involve storage or functions in one modality are more affected by interference tasks involving that same modality than those tapping other processes. Thus:

(i) den Heyer and Barrett (1971), Meudell (1972), and Murray and Newman (1973) have shown that visual interference tasks have a greater disruptive effect upon memory for spatial information than memory for item or verbal information.

(ii) Kroll, Parks, Parkinson, Bieber and Johnson (1970) have shown that if single target letters are presented either aurally or visually, with an interference task of shadowing an auditory message there is poorer report of the aurally-presented letters but not of the visually presented letters.

(iii) Lowe (1975) and Merickle (1976) demonstrate that if the partial report cue in a visual array processing task is presented visually, performance is inferior to that when the cue is auditory. In other words the visual cues produce modality-specific interference which operates (demonstrated by further experiment) at a post-iconic visual representation.

(iv) Segal and Fusella (1970) have shown that visual signal detection is more disrupted by imaging pictures than imaging sounds, while acoustic signal detection suffers more during auditory imaging.

(v) Brooks (1968) demonstrated that a task requiring visual imagery could be performed more easily while speaking than while pointing, whereas a verbal task could be performed more easily while pointing than while speaking.

(vi) Finally there are many cases where there is a greater retention loss when the same modalities are involved in both short-term memory and interference tasks (Cohen and Granstrom, 1970; Parks, Parkinson and Kroll, 1971; Wickelgren, 1965).

So yes, there are many instances of modality specific interference. What is difficult to determine, however, is where this is interference of modality specific code or modality specific processor. It might be argued that a static memory preload would answer this question since it will result in only code interference, however, this will not be the case since the maintenance of such preloads in memory appears to involve active rehearsal and associated processing or executive activity whether the preload be verbal (Peterson and Peterson, 1959; Atkinson and Shiffrin, 1971; Craik and Lockhart, 1972) or visual (Kelly and Martin, 1974; Tuersky, 1969; Phillips, 1974; Tversky and Sherman, 1975; Phillips and Christie, 1977a; Posner and Konick, 1966). It is only by very careful use of instructions (do not rehearse the preload/do rehearse it) or better still by careful manipulation of the experimental conditions with regard to active processing/static code retention (Yuille and Ternes, 1975) that such questions can be approached.

Lest the reader conclude from the above collection of readings that the principal interference effects are generally modality specific, there are similarly many examples of general, across the board effects of interference tasks whatever the modality. Thus:

(i) Posner and Konick (1966) found that the ability to remember the location of a point on a line (a priori a short term visual task) was interfered with by the requirement to process digits in the retention interval. The more demanding the processing, the greater the forgetting.

(ii) A verbal interference task interferes with short-term visual memory (Yuille and Ternes, 1975; Phillips and Christie, 1977a, b; Kelly and Martin, 1977) although there is a suggestion from the Kelly and Martin work that this occurs primarily with to-be-remembered shapes which were verbally codable.

Those experiments which specifically address the nature of interference (Yuille and Ternes, 1975; Phillips and Christie, 1977b) conclude that there is some modality specific interference (typically attributed to the modality coded data store) but that the major interference effect occurs through competition for central processing capacity ("Hence, STM phenomena can be interpreted as reflecting the results of the central processing capacity utilizing modality specific coding process to maintain information" ..." It is proposed that the maintence of information for short intervals relies on the availability of central attentional processes, with modality specific coding processes determining the most appropriate coding mode for a given stimulus situation" Yuille and Ternes, 1975, pp.372 and 360; "It is concluded that visualization requires general purpose resources"; "The kind of resources for which visualization and "(visual)" ... perception are in competition is not yet clear, but is seems possible that they are in competition for general purpose rather than special purpose resources". Phillips and Christie, 1977b, pp.637 and 649).

In the present chapter, we are to investigate functions underlying the visual perception of verbal material. One of the primary tools of investigation is the use of 'specific interference tasks'. The underlying hypothesis is that the cognitive apparatus of man can be subdivided with each subsystem devoted to a particular type of mental operation; these subsystems can operate without conflict and independently of each other (see e.g. Coltheart, 1978). It has been demonstrated that this is not entirely true, there appears often to be competition for attention and central processing resource between apparently disparate tasks, but it is typically the case that the more the a priori similarity of process or code involved in the primary and interference task, the more the interference effect. As such, therefore, the use of interference tasks can be considered a useful tool when the effects of different interference tasks are compared, but the use of one interference task alone is considered relatively useless since any effect cannot be definitely attributed to modality specific effects or general resource competition.

Those experiments in this vein which have been relatively successful (e.g. Phillips and Christie, 1977b; Yuille and Ternes, 1975; den Heyer and Barret, 1971; Allport, Antonio and Reynolds, 1972) have all, therefore, compared the effects of interference treatments which tap different functions. Even when this is the case, it is extremely difficult if not impossible to a priori equate the attentional demands of disparate interference treatments, and the general resource /general resource plus specific resource distinction is thus only approximated to at best.

Making the best of a bad job therefore, the visual information processing of digit arrays will be compared under articulatory suppression (Expt. 7a), static and running 6 consonant preloads (Expts. 7b and 7c), and visual preloads (Expt. 7d) to investigate the roles of articulatory, lexical and visual encoding functions in visual information processing. The nature of visual and name encoding in Posner type tasks will be investigated using articulatory suppression (Expt. 7e). Even with this design which compares interference effects, there arise problems in differentiating between general and modality specific interference effects, this being especially the case in Expt. 7d, but some speculative conclusions are eventually reached.

Experiment 7a

The Effect of Articulatory Suppression on digit processing

Abstract

The possible role of articulatory encoding in the visual information processing of verbal material is investigated by comparing digit array processing under backwards masking under a control condition and a condition involving articulatory suppression. The processing of items from the visual array is unaffected by the subject having to articulate concurrently a redundant message, but there is a detrimental effect of articulatory suppression on the processing of item-and-order information. Other evidence is reviewed which suggests a view of partially non-contingent short-term processing and memorization of item and order information, with item information accurately performed using lexical and visual representations whereas item-and-order retention additionally calls for articulatory encoding.

Introduction

Articulatory suppression (A.S.) (see Experimental Chapter 5) requires the subject to vocalize overlearned sequences e.g. "the, the, the ... " or "a b c d e f g a b c d ... ". Levy (1971) found that subjects in a probed recall task which used visually presented lists as stimlus showed reduced accuracy of performance under A.S., such that they were performing almost at chance level. This did not occur with auditory stimulus presentation.

This pattern of results is a common one: A.S., is effective with visual presentation, has much less effect with auditory presentation (see e.g. Baddeley, Thomson and Buchanan (1975) on A.S. and memory span; Richardson and Baddeley (1975) on A.S.

and Free Recall; and Baddeley and Hitch (1974).

Baddeley, Thomson and Buchanan (1975) therefore suggest that A.S. prevents usage of the speech-motor component of working memory, the articulatory loop. It is thought to do this by preventing the articulatory encoding of visual stimulus information in the central executive. This articulatory encoding is a necessary precursor to articulatory loop loading for visual stimuli; with auditory stimulus presentation, however, this articulatory encoding step appears not to be necessary.

Be this the case, the use of A.S. as an interference task whilst the subject is to process from 7 digit arrays at short exposure times should provide data which would allow interpretation of the role of the articulatory loop in the visual information processing involved in this task.

It is interesting that the data which lead Baddeley, Thomson and Buchanan (1975), to tentatively suggest that the articulatory rehearsal loop has "a capacity of about 3 items" are derived from span tasks which involve both the retention of item and order information. As Baddeley (1976) stresses the involvement of the articulatory loop in retention of order of verbal stimuli, the role of the loop in item retention alone is less clear. Richardson and Baddeley (1975) did find a decrimental effect of A.S. upon Free Recall performance where scoring is for item information only, however these experiments involve list presentation times ranging from 8 to 20 sec. thus involving considerable retention intervals. Therefore these findings may well not apply to the situation of visual information processing where retention intervals are to be minimized.

The role of articulatory coding in situations of visual information processing where arrays of items are presented simultaneously, processed from a single fixation, and reported immediately is thus less clear and warrants investigation. Some investigations into the role of implicit speech in visual information processing have been performed (Scarborough, 1972; Henderson, 1972; Scarborough and Scarborough, 1975) which suggests that generally it is not involved. The most thorough investigation, that of Scarborough (1972), is difficult to interpret, however, since shadowing constituted the implicit speech interference treatment and this task may well involve considerable 'processing' in addition to an articulatory suppression effect (see Baddeley and Hitch, 1975, where the less redundant the string used for suppression, the more the interfering effect). Similarly this study fails to investigate memory for order of visual stimuli, concentrating solely on item retention.

There is, however, general agreement that in verbal symbol array processing under backwards masking the steep first limb obtained in the items correct/exposure time function cannot reflect implicit speech since its rate is much too fast (see discussion Experimental Chapter 2; Sperling, 1967; Coltheart, 1972; Allport, 1973). In contrast, since the rate of the second limb above the dogleg point approximates to that of implicit speech at 150 ms/monosyllabic item (Landauer, 1962), there is a similar agreement that articulatory encoding may well be involved in this function (Coltheart, 1972; Scarborough, 1972).

In an attempt, therefore, to untangle these conflicting views, the role of articulatory encoding in single fixation array processing is investigated using A.S. as the interference treatment. Both 'limbs' are studied using a backwards masking paradigm at exposure times from 40-400 ms., and item and order retention subjected to independent scrutiny.

Method

7-quasi-randomly generated digits (no digit could appear more than once) constituted the test stimuli (T.S.) for any trial. These were printed on white card using 28 pt. Helvetia light letraset and were presented in an Electronic Developments 3 field tachistoscope at a distance of 508 mm. from the S's eyes giving an illumination at the eye of approximately 1 lux. Each condition involved 6 practice trials followed by 32 test trials. For the control condition a trial consisted of: the warning signal 'ready' followed after approximately 2 sec. by the fixation cross (1000 ms., 0.15 lux. subjective intensity), seven digit T.S. (exposure time either 40, 60, 80, 100, 150, 200, 300, or 400 ms., 0.6 lux. subjective intensity), pattern mask stimulus (M.S.) (1000 ms., 2.4 lux. subjective intensity). The M.S. was made up of randomly spaced and overlapping digit segments with a black: white ratio of approximately 50% which occupied the same spatial position as the previous T.S. It was known to be effective as when both M.S. and T.S. were presented simultaneously for 1 sec., no digits could be reported by the subject. Each condition used 4 trials at each exposure time presented in a randomized order.

In order to investigate the role of the articulatory loop in 1) item and 2) order processing the experiment must allow the subject to report items he has seen even though he is unsure of the order of those items. For this reason, subjects were required to report as many digits as they were sure they saw, in the correct order if possible, upon mask offset. It was stressed that if they knew they had seen an item but were unsure of its position they were to report it anyway. Excessive guessing was discouraged if necessary in the practice trials.

For the control condition the subjects were silent during the trial sequence. In the experimental condition, however, they were asked to say aloud the sequence "a b c d e f g" at a fast rate starting upon the ready signal and to continue uttering this sequence until M.S. offset when they were then to report the digits. Six first year undergraduates were the subjects, three were run: control condition then experimental condition, and three: experimental condition then control condition. The two conditions were separated by a rest period of 5 minutes.

The subjects' verbal responses were recorded for each trial and scored under two different procedures viz. 1) Identity scoring: the number of digits correctly reported was calculated for each trial: no account was taken of the order of items in the response. 2) Order scoring: a simple scoring system was used: starting at the beginning of any trial response one point was given if the first response item was the first test item, and additional points were added scoring through the response until the first error either of identity or of order.

Thus, for example, the response 7 6 2 0 4 9 1 given to the stimuli 7 6 2 4 0 8 1 would score 6 points under identity scoring and 3 points under order scoring.

Results and Discussion

1) Identity Scoring. The results were analysed as a three factor ANOVA (6 subjects x 8 exposure times x 2 condition with 4 blocks of replication). The subjects factor ($F = 80.1$, d.f. 5,288 $p < .01$), time factor ($F = 62.8$, d.f. 7,288 $p < .01$) and S x T interaction ($F = 4.39$, d.f. 35,288 $p < .01$) were significant. No other factor or interaction was significant. There was a possibility of non-normality of the data, thus a similar analysis was performed on the angular transformations.

This analysis, however, leads to the same patterns of significance.

Thus the condition factor (F = 0.12, d.f. 1,288) failed to reach significance - articulatory suppression has no effect on the processing of digit identity, as can be seen in fig. 7:1.

2) Order Scoring. The order-scored results were analysed in the same fashion as the identity scored results. The subjects factor ($F = 29.8$, d.f. 5, 288, $p < .01$), time factor ($F = 32.4$, d.f. 7,288, $p < .01$ and condition factor ($F = 6.44$, d.f. 1,288, $p < .05$) were significant. No other factor or interaction was significant except the S x T interaction in the angular transformation analysis ($F = 1.68$, d.f. 35,288 $p < .05$).

Thus while articulatory suppression has no effect on the processing of digits for identity, it can be seen from fig. 7:2 that the memory for order of the items in the stimulus array is disrupted by this procedure.

Discussion

It appears that with immediate response, articulatory encoding is not involved in the processing of visual item information. In the terminology of Baddeley and Hitch (1974), one would say that the 'central executive' of working memory was thus involved in item processing. If, more speculatively but also in more detail, we grasp the nettle and interpret in terms of the heuristic developed for short-term memory and reading detailed in Chapter 4, it would be concluded that either the information can be held in the non-maskable visual code prior to output, or that as a result of a scan process lexical codes for the items can be activated, and these representations can remain active and true over the short-term retention intervals involved without rapid decay and the need for refreshing by use

FIGURE 7:1

The Effect Of Articulatory Suppression On Digit Array Processing In Expt.7a; ITEM PROCESSING

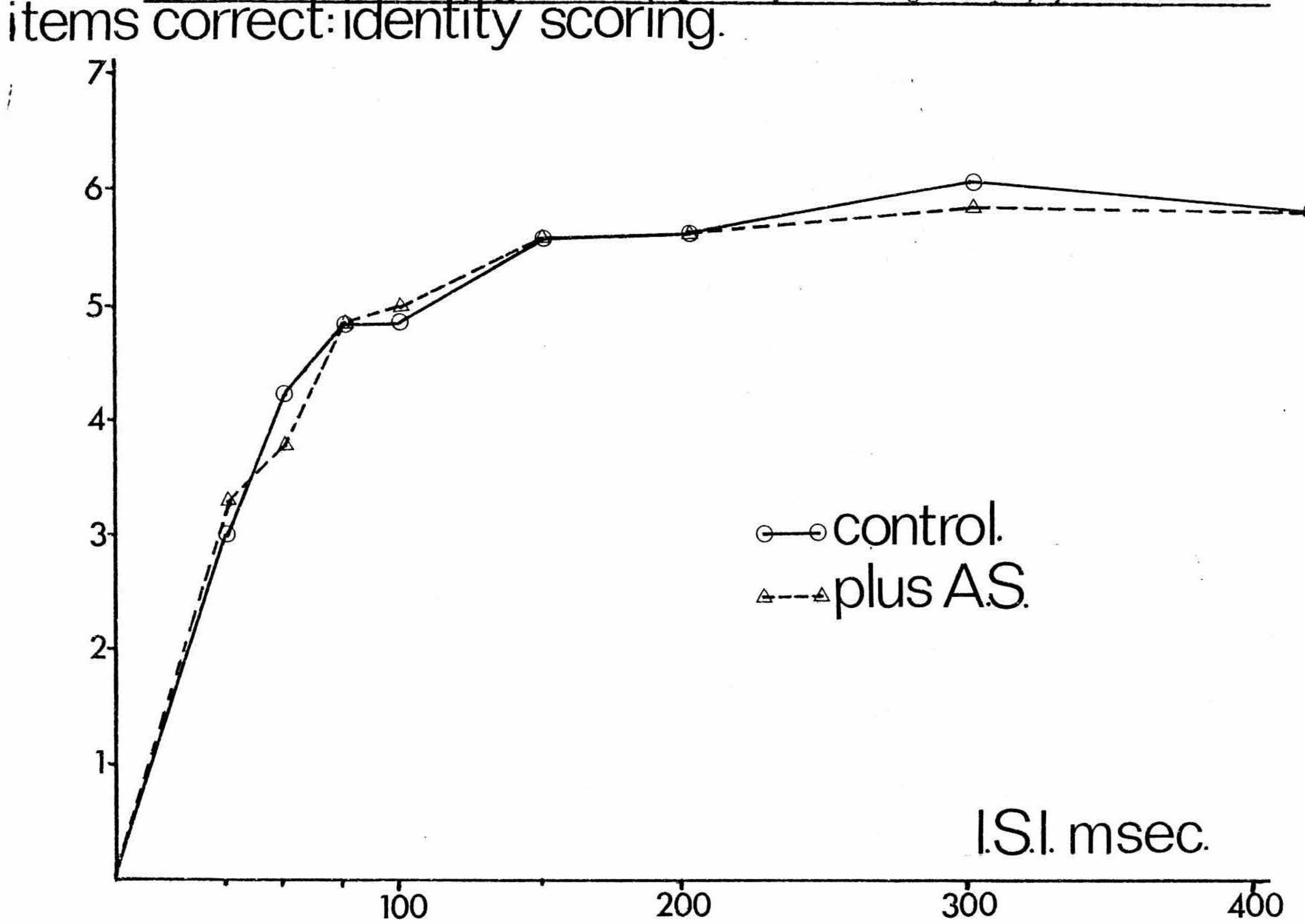

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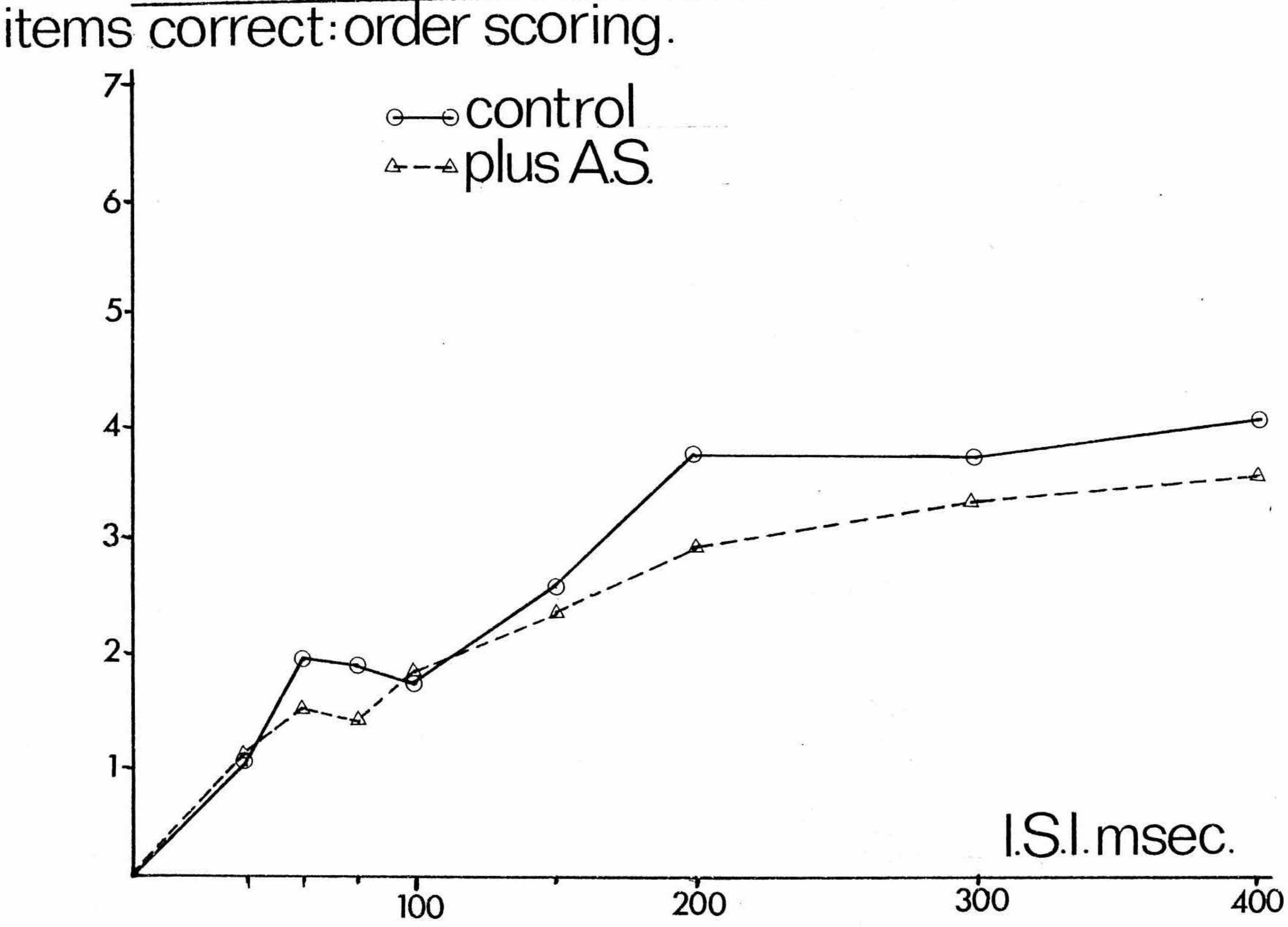
FIGURE 7.:2

The Effect Of Articulatory Suppression On Digit Array Processing In Expt. 7 a; ITEM-AND-ORDER PROCESSING



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of the articulatory loop for rehearsal.

In contrast to processing items, the visual processing of item-and-order information does appear to involve articulatory encoding: if the use of implicit speech (presumably as articulatory loop rehearsal) is prevented by A.S., so processing and retention of item-and-order information deter~~min~~iorates. Baddeley (1976) has suggested that the articulatory loop appears to be particularly useful in remembering sequences-of-items in memory span tasks which use sequential stimulus-item presentations, and from the present data it appears also to be a useful strategy in visual information processing of arrays of verbal stimuli.

This is especially interesting since it might have been expected that with visual arrays of symbols, order information would optimally be visually encoded.

A number of studies (e.g. den Heyer and Barrett, 1971; Meudell, 1972) have been carried out in which subjects are asked to report items (which letters or digits did you see?) and positions (in which locations did they occur?) from a two-dimensional matrix array. During a retention interval following exposure,subjects were given alternative 'load' tasks. In the den Heyer and Barrett study, for example, they either had to add up five digits (verbal task) or match dot-matrix patterns (visual task). Differential report deficits were found; the verbal task disrupted the report of items more than it did the report of positions; the visual task disrupted position report more than item report. These data suggest that items and positions are stored separately in memory, and so are open to interference from different kinds of competing material.

These results are in direct contradiction to those obtained in an earlier experiment by Cumming and Coltheart (1969) on the visual information processing of items and positions. They also used a matrix array. This was exposed for only a short time (70 and 80 m.sec.) and was followed by a mask. Subsequently subjects were shown a cue array and were asked to decide which of two cued digits occurred in the stimulus, and in which of two marked positions that digit had been located. Cumming and Coltheart examined response frequencies of items correct irrespective of position, positions reported correctly irrespective of item, and items correctly reported in the correct position, and their analysis of these data led them to conclude that item and position information is stored in an entirely contingent manner.

A study which pulls these findings together was performed by Stainton Rogers (1978). Subjects were asked to report item and position information from a visually displayed matrix array. The pattern of results obtained rejected both the model of full contingency and the model of full independence of item and position encoding. Instead, subjects seemed to alter their encoding strategies according to the response demands of separate and simultaneous report. Item and position are encoded together in acoustic-verbal form via the recognition buffer, but additional position reports can be derived from a post-VIS visual store. In other words it seems that position of items in an array (order information) can be represented either in a visually coded form and/or in a verbal form.

From the present results it can be seen that this verbal strategy for order retention is used in the digit processing task, and that, in terms of the model proposed in Chapter 4, it constitutes a lexical code/articulatory code interaction since A.S. decreases its effectiveness.

The retention of item information was discussed in terms of the activation of lexical representations and as such selection of remembered items might (in the traditional cognitive psychology format) be seen as a decision process of trace strength against a criterion threshold value. In memory span tasks the articulatory loop is involved in either refreshing the trace strength or in the maintenance of order retention, these processes are confounded. In Free Recall tasks the articulatory loop is involved in trace strength refreshment over relatively long retention intervals. The item scoring results of the present experiment demonstrates that decision of which items were seen is unaffected by prevention of articulatory encoding, in other words the trace strength of visual or lexical representations of seen items remain sufficiently strong without articulatory loop refreshment for accurate memorization over short time intervals.

For item retention the seen/not seen decision process is relatively simple - is the trace strength above a criterion value? The same mechanism would become much more complex, however, if order information were coded in this lexical fashion - one possibility, for example, is that in this case relative between-item lexical representation trace strengths would have to be assessed, and response output order ranked accordingly. Such considerations are highly speculative, however, and further discussion of the options for order retention is located in Chapter 4.

Certainly it is the case that item-and-order retention is more difficult than item retention alone. Certainly whereas visual or lexical representations are sufficient in short term retention of item information, they are relatively inaccurate in item-and-order retention and are supplementarily represented in articulatory form.

There is a vast amount of research into separation of item and order information in short-term memory and often the findings are at best equivocal, however it shall now be argued that the (short-term item retention = lexical representation, short-term item-and-order retention = lexical and articulatory representation interactions) view carries explanatory power for many of these findings:

1) It is argued in Experimental Chapter 2 and Chapter 4 that lexical encoding is fast (= rate of 1st limb in the masking experiments), articulatory encoding is slow (150 ms./ monosyllabic item). As presentation rate is increased in memory span tasks both item and order errors increase, but the rate of increase in order errors is much faster than that of item errors (see Mathews and Henderson, 1970). Articulatory encoding for order retention is slow and so is greatly affected by fast presentation rates; lexical encoding for item retention is fast and thus less affected.

Similarly Kolers and Katzman (1966) and Scarborough and Sternberg (1967) both report that if 6 digits are presented sequentially, at the same spatial locus of the visual field, at rates much higher than the estimated rates of implicit speech, subjects can report most of the symbols but are inaccurate in reporting the order in which the symbols were presented.

2) Phonemic similarity effects are thought to operate at an articulatory encoded level (see Experimental Chapter 5, expts. 5a, 5b) since they are reduced by A.S. Wickelgren (1965) demonstrated that acoustic similarity between to-be-remembered items in a short-term-memory task severely disrupted serial (order) recall but, if anything, improved item recall. In other words short-term item retention is not affected by a treatment which operates at an articulatory encoded level but short-term item-and-order retention is.

3) Hitch and Baddeley (1977) and Baddeley (1978) view the processes of chunking, grouping and sound blending to involve the articulatory loop. In contrast the view proposed in Chapters 3 and 4 is that the primary unit of lexical representation is the word. Wickelgren (1967) had subjects

rehearse in non-overlapping groups of various sizes and found that group size significantly influenced order errors (groups of 3 being the optimum size) while item errors were unaffected. Similarly, Ryan (1969) presented lists interrupted by pauses splitting the list into groups. This would presumably not greatly affect lexical code trace strength, but would affect the initiation of a fluent articulatory rehearsal strategy. Grouping improved performance compared to ungrouped lists, but the difference showed only in the order errors.

4) While it is difficult to come up with a plausible explanation of the findings, order and item errors are clearly differentiated in their serial position (SP) curves, the typically bowed SP curve appears to be typical only of order errors, the item errors showing little variation with SP (see Fuchs, 1969; McNicol, 1971; Aaronson, 1968).

All these findings support a view of non-contingent ST memorization of item and order retention, and 'fit' the suggestion that the short-term item retention involved in visual information processing can be accurately performed using lexical and visual representations, whereas item-and-order retention typically involves visual, lexical and articulatory representation. Although for completeness this discussion has included both th lexical and visual representation options for item recall, since short-term memory span is greater the more easily nameable the stimuli (Chi, 1976), it is considered that the major contribution of verbal item ST retention comes from lexical rather than visual representations.

To recapitulate: (i) Item-and-order processing and very short term retention is more difficult than that for items alone. (ii) The very short term item retention involved in this visual information processing task does not involve articulatory encoding and is considered to involve lexical representation. In the traditional short-term memory task where longer retention intervals are used and there would be considerable lexical trace decay, there is reason to believe that articulatory encoded lexical trace refreshment is involved, but this is difficulty to ascertain since item and order retention are confounded (Baddeley, Thomson and Buchanan, 1975). (iii) The item-and-order processing and retention involved in this task involves articulatory encoding in addition to those representations involved in item retention alone.

Experiment 7b

Effects of a 6 consonant static memory preload on digit processing

Abstract

The interaction between the visual information processing of verbal material and short-term working memory is investigated by comparing digit array processing under backwards masking under a control condition and under a static memory preload condition where subjects were to remember a 6 consonant, auditorily presented, preload whilst processing the digit arrays. Fewer digits are consistently reported in the consonant preload condition. The need for consonant preload storage also reduces the number of digits remembered in the correct order. The results are interpreted in terms of the two tasks competing for lexical representations.

Introduction

If interested in the interrelations between the visual perception and processing of verbal material and verbal STM, one method of investigation is to pre-empt some STM 'capacity' and see how visual processing is affected. STM, or more specifically, the short-term store (STS), has often been viewed as a working memory, an executive system controlling many subroutines of information processing involved in tasks such as problem solving, language comprehension and long term learning (Hunter, 1964; Rumelhart, Lindsay, and Norman, 1972; Atkinson and Shiffrin, 1968, 1971). With such a view the speculation of its role in the control of the visual information processing of verbal material follows naturally. To test this hypothesis, the most obvious approach is to limit available STS.

Baddeley and Hitch (1974) performed a number of experiments investigating the role of the STS in reasoning, free recall, memory span, and comprehension. To interfere with the STS they used a variety of interference treatments based on a definition of the STS which included the statements that the STS can hold material in memory span tasks, is limited in capacity, is concerned with the retention of order information, and is closely associated with the processing of speech. To pre-empt STS capacity they had subjects retain a concurrent memory preload while performing tasks under investigation such as reasoning, language comprehension or learning. The concurrent memory load ranged from one to 6 verbal items (letters or digits), and they found a consistent pattern of additional memory load effects on all the tasks, thus inferring that each of these tasks involves a span-like component which they refer to as working memory. These interference techniques have a sound theoretical basis and have been shown to be a useful tool in the investigation of the role of the STS in information processing tasks, and thus seem suitable for use in the present investigation which questions the role of the STS in the visual information processing of verbal material. Digit array processing under backwards masking will thus be compared with and without the subject having to hold a six consonant memory preload.

Baddeley and Hitch (1974) note that subjects can use different strategies in remembering the auditorily presented preload. One possibility was that "Ss dealt with the memory preload by quickly rehearsing the items, to "consolidate" them in memory before starting the reasoning problem" (Baddeley and Hitch, 1974, p.53) in which case there appears to be initial rehearsal followed by non-rehearsal of the preload during the reasoning task, there being static preload retention: this will be called the static preload condition. An alternative is that the subjects continuously rehearse the preload throughout the reasoning task: this will be called the concurrent or running preload condition. In the static condition, with subjects not rehearsing while reasoning, the preload must be held as a non-articulatory representation, and in terms of the model proposed in Chapter 4, this representation can be seen to be primarily lexical. In the concurrent preload condition the preload can be seen to be held as lexical/articulatory code interactions. Baddeley and Hitch explicitly investigated the effects of a concurrent preload by comparing reasoning under no interference, simple articulatory suppression (articulation of overlearned and simple sequences such as 'the, the, the ... ' 'one, two, three ... ') and concurrent preload (articulation of a random 6-digit number). They found an effect of articulatory suppression, and this effect was much greater in the concurrent preload condition. They conclude that interference in verbal reasoning is not entirely to be explained in terms of competition for the articulatory system, rather there is a much more important factor: the availability of spare short-term storage capacity determines the rate at which verbal reasoning processes are carried out. Again to rephrase in terms of the Chapter 4 model, it would be concluded that the more the retention of lexical code representations, the greater the interference effect. If, as the models of Baddeley and Hitch (1974) and Chapter 4 suggest, the articulatory loop can be used to store some short-term memory span items and to refresh their non-articulatory (lexical) representations, the static holding strategy, with no articulatory loop rehearsal, will necessitate a greater involvement of lexical code representations than will the concurrent or running strategy where some span items are held as articulatory representations (Baddeley and Hitch suggest that approximately three items can so be held) and the use of this articulatory "slave" system for rehearsal will cause refreshment of those lexical representations used (in contrast to the static strategy where the activated lexical codes are not refreshed and are thus subject to passive trace decay).

Since there are, at least, these two available strategies for preload retention, and since they appear to be tapping different functions, they will be independently investigated: digit array processing will be studied under a static preload in Expt. 7b and under a running preload in Expt. 7c.

It should be noted that, although this introduction started with the notion of interfering with central processing or central executive resource, this idea has been refined and the discussion is now phrased in terms of specific interference of code and function: the memory preload is not viewed as interfering with central executive resource in working memory but rather as interfering with the functions involved in the maintenance of lexical and/or articulatory representations depending upon whether the preload is static or concurrent.

Procedure and Subjects

The method was identical to that of experiment 7a for the control condition. For the experimental condition, however, the warning signal 'ready' was replaced by the experimenter reading aloud six randomly chosen consonants at a rate of one consonant per sec... 2 sec. after the last letter the fixation cross, the test stimulus-mask sequence was started. The subjects (six undergraduates different from those used in Expt. 7a) had been instructed to remember the consonant sequence throughout the trial and to report them, in the correct order, upon mask offset. Having reported the consonants they were then required to report what digits from the T.S. they had seen, again in the correct order if possible. Different 6 consonant sequences were used on each trial. Three of the subjects were first tested on the control condition and then the experimental condition; the other three subjects were run under the reverse order of condition presentation.

Upon conclusion of the experimental condition the subjects were asked their strategies in this part of the experiment. All the subjects reported memorizing the letters by subvocal naming. They all used chunking procedure; these, however, were not constant across S's - the most popular chunkings of the six letters being 3:3 or 2:2:2 or 4:2. When questioned further about their strategies they all reported that, upon the experimental reading the last consonant, they would cycle the six consonants either one or two times (depending on subject) AND THEN 'SHELVE' THEM whilst the T.S. appeared. Upon T.S. offset the consonants were then retrieved and reported before T.S. digits were similarly produced. In no case did the subjects, using a remembering strategy which they had chosen themselves, articulate the consonants right through the T.S. exposure to remember them. Thus the reported introspective sequence appeared to consist of the switching strategy of storage as previously reported for static preloads by Baddeley and Hitch (1974). This was:

Exptal. sequence	consonants presented	- 2 sec -	fixation cross 2 sec.	- T.S. var. e.t.	- M.S. 1 sec.	
Subject's strategy		cycle the 6 consonants subvocally once or twice. Then allow consonants into a storage mechanism which requires no active subvocal processing		"look at" the 7 digit T.S. Then allow digits into storage mechanism which requires no active subvocal processing	retrieve consonants from storage and report	retrieve digits from storage and report

The subjects' responses were again scored under both the identity and the order scoring procedures described in Expt. 7a.

Results

1) Identity scoring

Results were analysed as in Expt. 7a. The Subjects factor ($F = 60.9$, d.f. 5,288, $p < .01$), Time factor ($F = 67.2$, d.f. 7,288, $p < .01$) and Condition factor ($F = 65.7$, d.f. 1,288, $p < .01$) were all significant, as were the S x T interaction ($F = 1.8$, d.f. 35,288, $p < .01$) and the S x C interaction ($F = 3.5$ d.f. 5,288, $p < .01$). No other interaction was significant. Again, due to the possibility of non-normality of the data, an angular transform of the data was also used. This yielded the identical pattern of significance to the raw data ANOVA and thus will not be discussed.

Thus the condition factor is highly significant. It can be seen in fig. 7:3 that fewer digits are consistently reported in the consonant preload condition than in the control condition.

2) Order scoring

The same ANOVA design was used for the order scored data. The Subjects factor ($F = 18.7$, d.f. 5,288, $p < 01$), Time factor ($F = 25.5$, d.f. 7,288, $p < .01$) and Condition factor ($F = 30.1$, d.f. 1,288, $p < .01$) were again significant. The only significant interaction was the T x C one ($F = 3.0$, d.f. 7,288, $p < 0.1$).

The analysis of the angular transformation of the data again produced the identical patterning of significance.

Thus the storage of a consonant preload also reduces the number of T.S. items remembered in the correct order, as is seen in fig. 7:4.

3) Error rates on consonant sequences

The experimental condition consisted of 32 trials. The

FIGURE 7:3

The Effect Of A Static 6 Consonant Memory Preload on Digit Processing in Expt.7b; ITEM PROCESSING

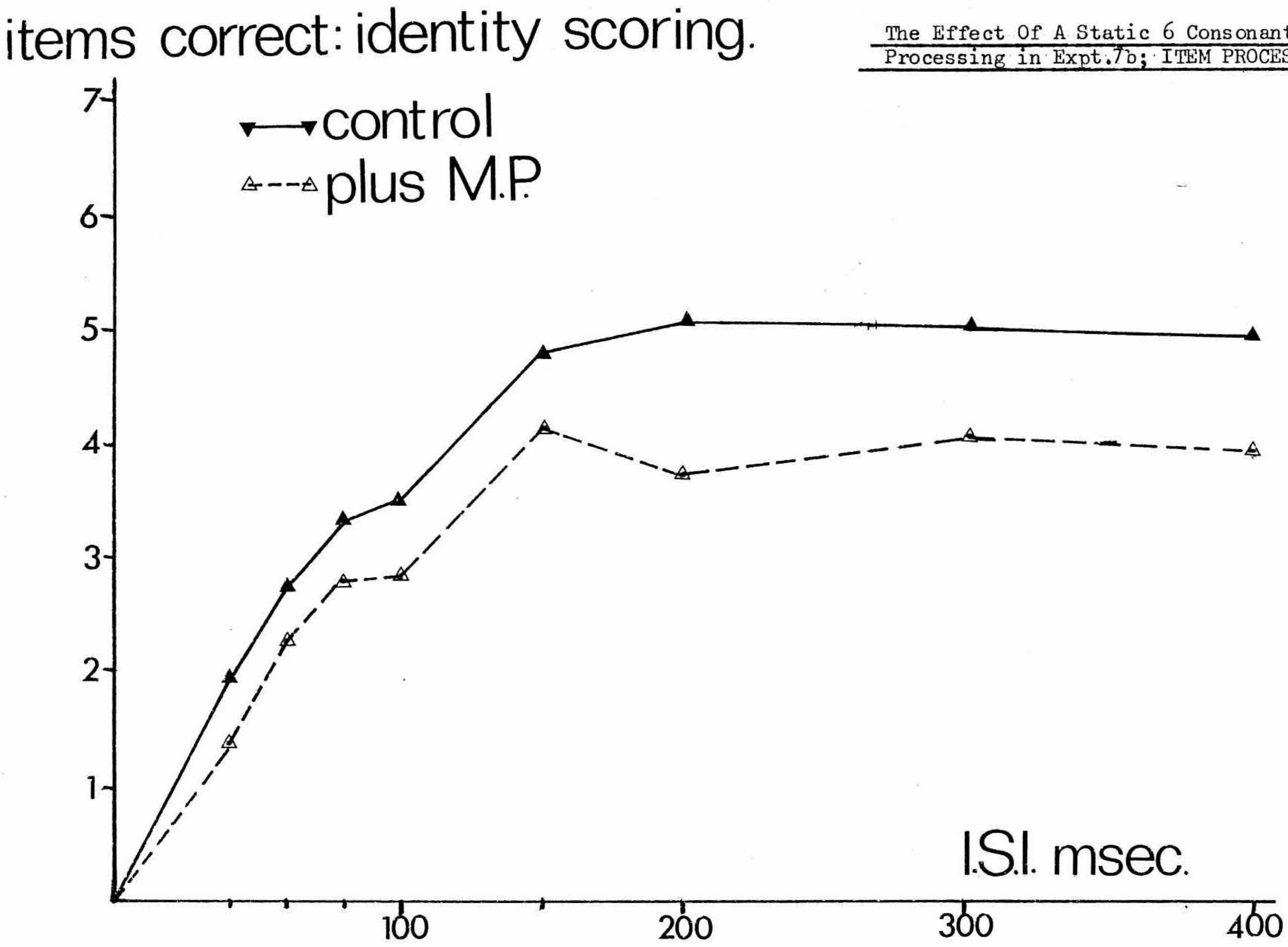

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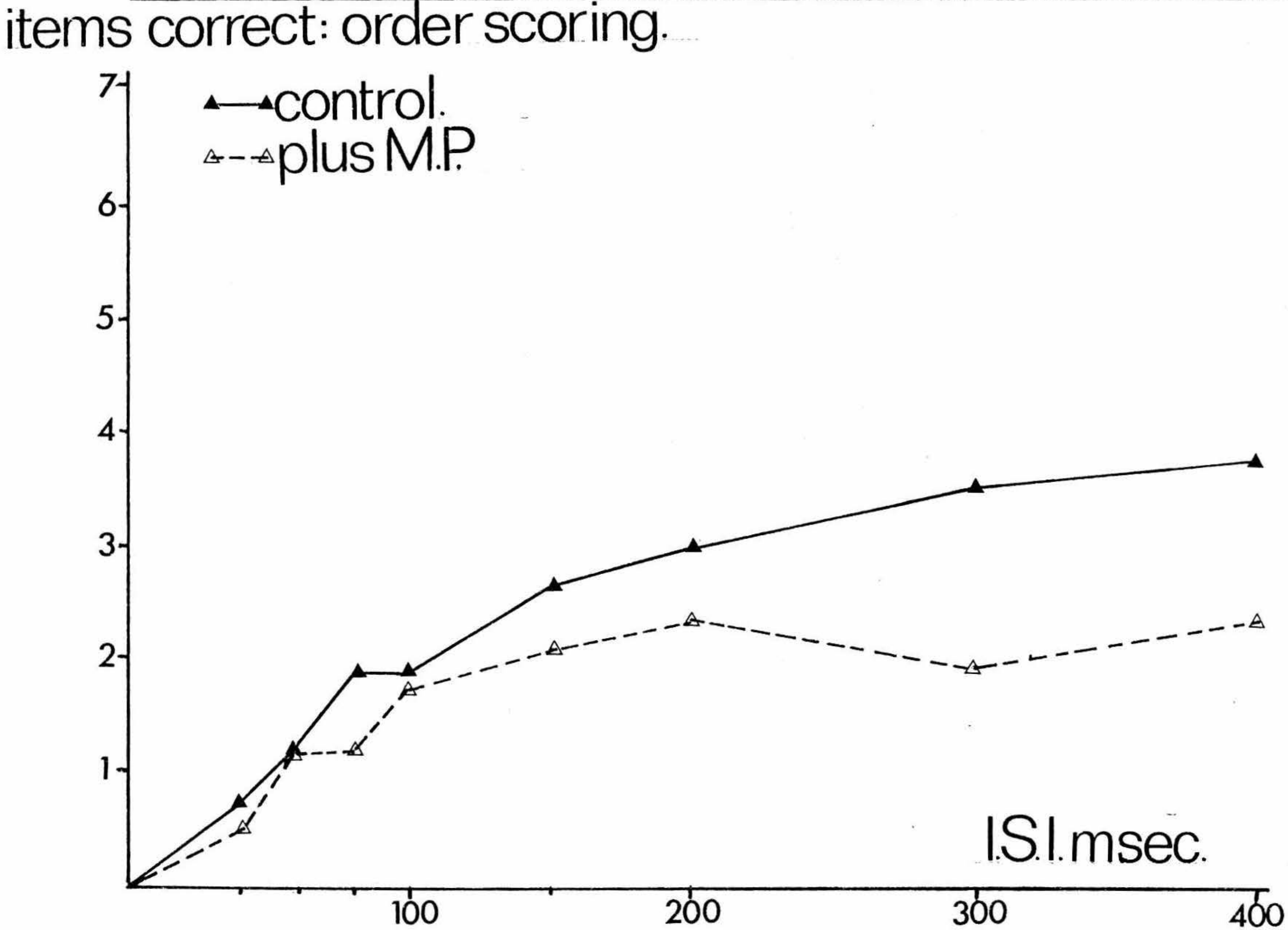
FIGURE 7:4

The Effect of a Static 6 Consonant Preload on Digit Processing in Expt.7b; ITEM-AND-ORDER PROCESSING



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subject scores for correct consonant sequences using this storage switching strategy were (out of 32): 31, 27, 27, 25, 15, 21. This yields an error rate of 24%. Thus this switching strategy, which it must be stressed the subjects chose for themselves as optimal, not only leads to a decriment in recall performance of the digit T.S. but also is a relatively inefficient means of remembering the consonant preload.

Discussion

In order to store the preload the subjects have adopted what is presumably the most natural strategy, also adopted by the subjects of Hitch and Baddeley (1974).

In terms of the model developed in Chapter 4, the consonant preload is held initially (in the rehearsal stage) primarily in terms of a lexical code/articulatory code representation interaction. The subjects then stop rehearsal with the stimuli being held primarily as activated lexical representations (with presumably some contribution from the PAS, Crowder and Morton, 1969). The level of activation of these lexical representations is presumably subject to trace decay.

The subject is then required to process as many digits as he can from 7-digit arrays presented at short exposure times under backwards masking. The fact that he/she is already holding in short-term memory the representations of 6 consonants, presumably as lexical codes, results in a significant reduction in the number of digits processed at all exposure times. It is concluded that the maintenance of activated lexical representations in short-term memory interferes with digit processing, and this may either be a result either of the two tasks competing for central processing resource, or a result of both tasks requiring a number of independent lexical representations to be activated, with a 'capacity limitation' of the number of such representations available at any one time, and thus the two tasks compete for lexical code representation.

If it is speculated that the only way in which a lexical representation can be rehearsed or maintained activated is by refreshment by cycling through the articulatory loop, it follows that in this situation there is no active processing involved in the maintenance of the lexical representations of the preload stimuli, and thus the tasks compete for lexical code representation. If we further speculate quantitatively with a simple version of this notion, it follows that the maintenance of (primarily) lexical representations for the 6 preload stimuli causes a reduction in the number of digits processed at 400 ms. from (roughly) 5 items to 4 items. 6 consonants stored at a cost of one digit certainly doesn't tally at a 1:1 correspondence. Whilst, at this extreme level of speculation, it is possible to construct many possible explanations for this lack of quantitative correspondence, one possibility is that the digit stimuli can be held in a post iconic, pre-lexical, visual or graphemic buffer representation, and there is some support for this to be found in Expt. 7d.

The processing of item and order information is also reduced by the static preload treatment. It is unclear whether this represents loss of order information, or simple loss of item information with concomitantly fewer items to be recalled in their correct order.

The levels of speculation in this discussion have become too extreme for comfort. In Expt. 7c, which follows, the effect of a concurrent, running memory preload is investigated.

Experiment 7c

The effect of a concurrent memory preload on digit processing

Abstract

The interaction between the visual information processing of verbal material and short-term working memory is investigated by comparing digit array processing under backwards masking under a control condition and under a concurrent memory preload condition when subjects had to cyclically utter a randomly chosen, 6 consonant, auditorily presented, preload whilst processing the digit arrays. There was no detrimental effect of preload on the processing of items. The results are similar to those found with articulation of a redundant ~~method~~ message and suggest that the processing demands and functions involved in lexical code/articulatory code rehearsal of the preload do not compete with the functions involved in digit array processing.

Introduction

To compare static and running preload effects upon the visual processing of verbal material, digit array processing was investigated under a control condition and under a running memory preload condition where the subject was to repeatedly whisper a randomly chosen 6 consonant sequence throughout the digit array exposure.

Procedure and Subjects

The control condition was again that of Expt. 7a. The experimental condition used the same consonant sequences and T.S. as that of Expt. 7b. However, a processing strategy was predetermined for the subjects in order to prevent the storage switching behaviour which was chosen by the subjects in Expt. 7b. Thus as soon as the experimenter had finished reading the consonant sequence the subjects articulated the sequence in a whisper and continued this articulation cyclically. After two cycles of articulation the fixation cross, T.S., M.S. sequence was started. Upon M.S. offset the subjects finished articulation, their final cycle of consonants being recorded, and then the subjects reported what digits they saw in the T.S., in the correct order if possible. Six new undergraduates were the subject who were run under this procedure which is otherwise identical to that of Expt. 7b.

Results

1) Identity scoring

The data were analysed as in Expt. 7b. The subjects factor ($F = 114.9$, d.f. 5,288, $p < .01$), Time factor ($F = 101.1$, d.f. 7,288, $p < .01$) and Condition factor ($F = 14.7$, d.f. 1,288; $p < .01$) were all significant. The only significant interactions were S x T ($F = 2.4$; d.f. 35,288; $p < .01$) and S x C ($F = 2.7$; d.f. 5,288; $p < .05$). Analysis of the angular transformation of the raw data yields the same patterning of significance.

The Condition factor is significant. However, it can be seen in fig. 7:5 that the condition means differ in the opposite direction to that expected. Concurrent articulation of the 6 consonant preload certainly does not impair performance on the digit processing task (c.f. results of Expt. 7b). Whereas in Expt. 7b the subjects remembered more T.S. items in the control condition (mean = 3.90 items over all trials, exposure times and subjects) than in the static preload condition (mean = 3.14

items), in Expt. 7c the subject remembered more T.S. items in the concurrent preload condition (mean = 4.31 items) than in the control condition (mean = 3.96 items).

2) Order scoring

The same ANOVA design was used for the order scored data. The Subjects factor ($F = 23.6$; d.f. 5,288, $p < .01$), Time factor ($F = 46.6$, d.f. 7,288, $p < .01$) and S x T interaction ($F = 2.26$, d.f. 35,288, $p < .01$) were the only significant sources of variance. This pattern of results is also found with the angular transformed data. The order scoring results can be seen in fig. 7:6.

Thus there is no significant difference between the number of items in the correct order reported in the control condition (mean = 2.08) and that in the experimental condition (mean = 1.97). However, when it is noted that there was a significant difference between item information reported in the experimental condition (mean = 4.31) and that in the control condition (mean = 3.96). It can be seen that there is indeed a loss of order information relative to the number of items reported in the experimental condition.

3) Error rates on consonant sequences

The subject scores for correct consonant sequences in the concurrent articulation of the memory preload were (out of 32): 22, 27, 32, 28, 29, 31. This yields an error rate of only 12%. Thus the concurrent articulation strategy appears more accurate as far as remembering the consonants than the strategy adopted by the subjects with the static preload in Expt. 7b (error rate 24%), although this difference fails to reach significance (Mann Whitney U test, $n_1 = n_2 = 6$, $U = 8.5$, $p = .07$).

FIGURE 7:5

The Effect Of A Concurrent Memory Preload on Digit Processing in Expt.7c; ITEM PROCESSING

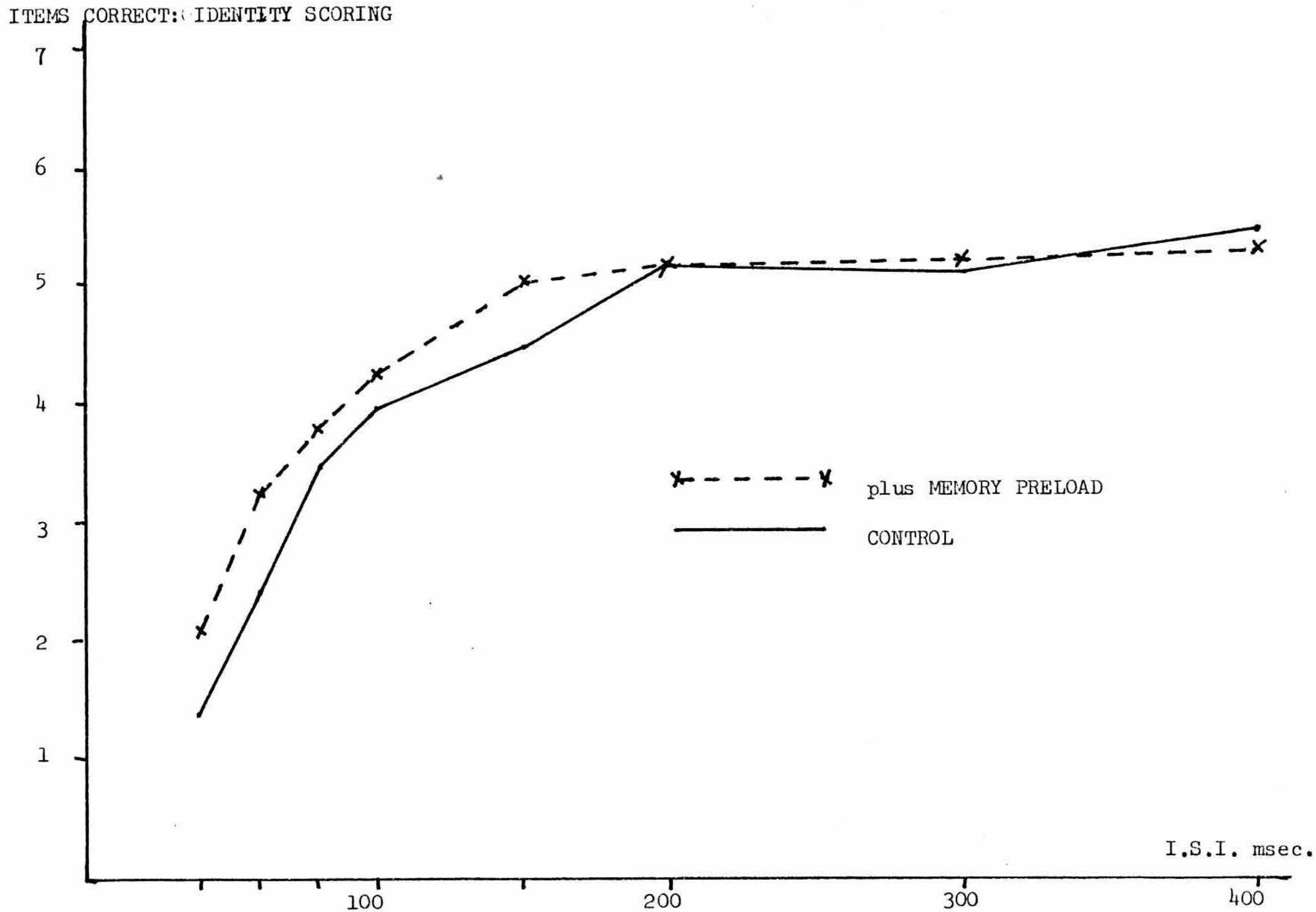

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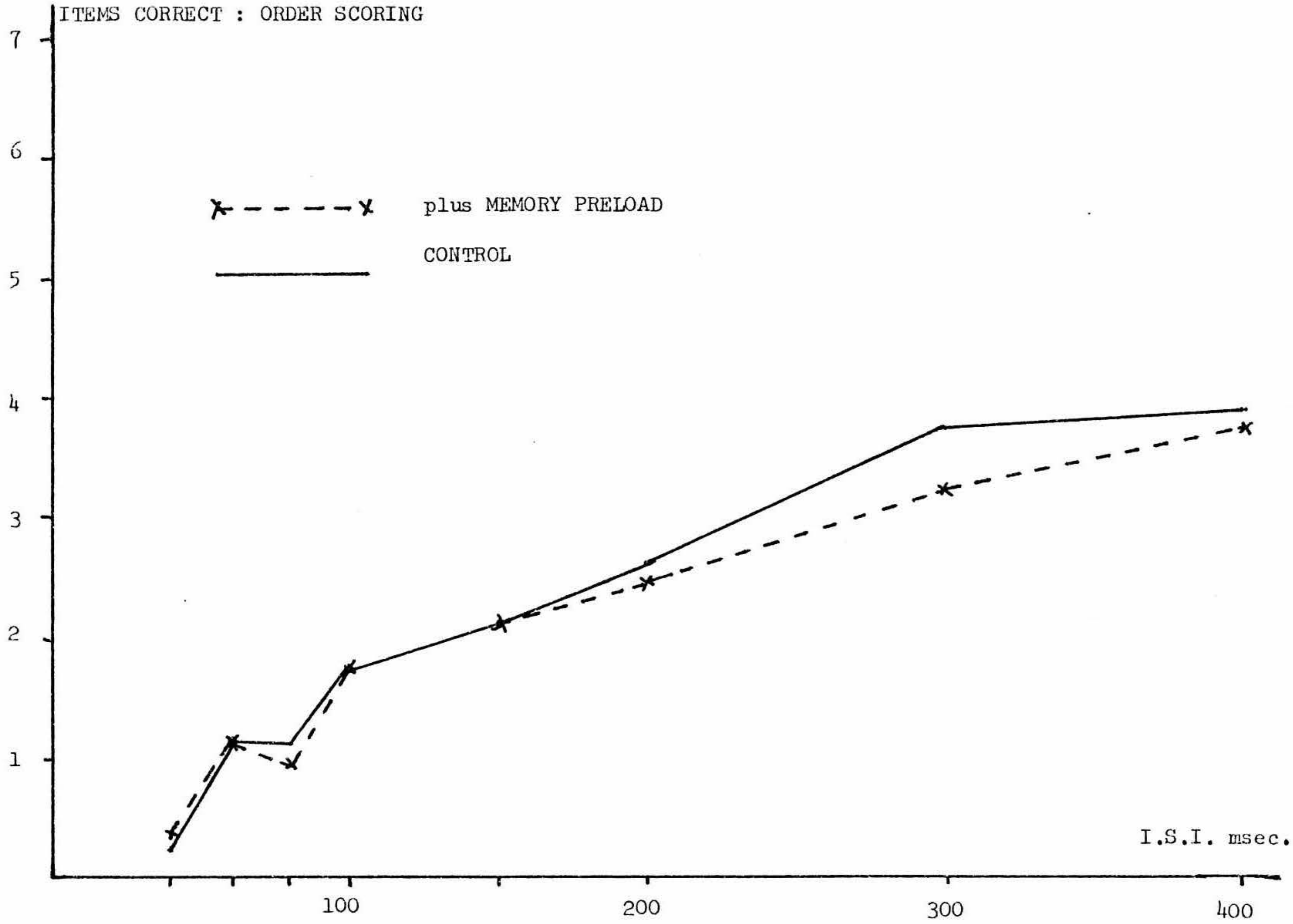
FIGURE 7:6

The Effects Of a Concurrent 6 Consonant Memory Preload on Digit Array Processing in Expt. 7c; ITEM-AND-ORDER PROCESSING



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Discussion

The patterning of results with respect of effect of interference treatment is much more similar to those found with articulatory suppression (Expt. 7a) than those found with a static memory preload (Expt. 7b). There is no detrimental effect of a constantly rehearsed 6 consonant concurrent memory preload on item processing from digit arrays but there is some reason to believe that the articulation of the preload reduces item-and-order processing from the digit arrays.

In terms of the Chapter 4 model, the difference between the static memory preload and the concurrent memory preload in terms of retention function is that the former is held primarily statically in terms of lexical representations whilst the latter is held actively as lexical code/articulatory code interactions. As such it may be suggested that the static preload results in greater competition for lexical representations than does a concurrent preload. Since the concurrent preload incurs less competition for lexical representations, and since it has no detrimental effect upon item processing from digit arrays, this strengthens the argument that at some stage the visual information processing of verbal material makes use of lexical representations. Since the concurrent preload incurs competition for articulatory representation, and since it has a detrimental effect upon item-and-order processing from digit arrays, this strengthens the notion that the articulatory loop is involved in the maintenance of the order of representations of otherwise discrete verbal stimuli.

Hitch and Baddeley (1974) tested verbal reasoning ability (speed of sentence verification e.g. A is not followed by B; A.B. → 'False' response) under a control condition and under experimental conditions where the subject had to remember a six item memory preload. When the subjects were instructed to give equal stress to the span and verification tasks there was no effect of preload; in contrast those subjects instructed that their sentence verification performance could only be considered if they recalled all six letters of the preload correctly (memory stress group) showed a large effect of preload on verification speed. The subjects under the memory stress instruction all reported that they quickly rehearsed the memory items before attempting the verification trials, presumably not rehearsing during verification. In contrast none of the'equal stress' subjects reported tackling one task before the other. It is unclear whether these subjects continuously rehearsed the preload during reasoning. In order to test the effects of static/running preload retention strategies in Expt. III verification performance was investigated under control, simple articulatory suppression, and concurrent articulation of a 6 digit preload, conditions. Rapid articulation of well-learned or simple messages have little effect on verification speed. However, the 6 digit running memory preload slowed verification considerably. This result contrasts with the 'equal stress' performances in Expt. II where perfect recall of a 6 item preload was not associated with any slowing of verification. Since one important difference between the two procedures is that the static preload technique does not force the subject to process the preload and verification tasks simultaneously, Hitch and Baddeley conclude that the "processing oeprations associated with STM storage rather than storage per se are critical in producing interference" in the verification task (Hitch and Baddeley, 1974, p.616). Since memory span for letters is between six and seven items (Cavanagh, 1972), it would appear that the short-term storage requirement of the verification task is minimal. Since the preload only had an effect on verification when it was actively processed, Hitch and Baddeley conclude that the storage demands of the verification task are much less important than its processing demands, and in this context working memory is seen as a limited capacity executive processing system rather than a scratch-pad store.

In contrast to these findings the opposite pattern of results of effects of different preload condition has been found here: the static memory preload had a consistent detrimental effect on digit processing whereas the concurrent memory preload (which required active processing but less lexically represented scratch-pad store) had none. It should be remembered, however, that the main experimental tasks differed: whereas the verbal reasoning task made little storage demands but large processing demands, the digit processing task is, from introspection, highly automatic and as such may be considered low in cognitive processing demand, but does involve considerable short-term storage. It appears, therefore, that a processing demand task (sentence verification) is being interfered with by a processing demand interference treatment (concurrent preload), whereas a storage demand task (digit processing) is being interfered with by a storage demand interference treatment (static preload).

To view working memory as <u>either</u> a scratch-pad store involved in memory span tasks <u>or</u> a central executive processing system involved in practically all else appears misguided. The older views of Baddeley and Hitch (1974) of working memory as a highly flexible limited-capacity system having both storage and executive capabilities is here favoured over the updated Hitch and Baddeley (1976) analysis which favours working memory as a limited capacity central executive system.

Support for the generality of the present findings can be drawn from Scarborough (1972). Performance on an auditory retention task (mean sequence length 7.5 numbers) and on a tachistoscopic report task (6 letters or digits presented under backwards pattern masking for 250 ms.) when administered separately, was compared with performance when the two tasks were combined. In the combined task the subject first heard a sequence of numbers (auditory load). Shortly after the last number, a visual display was presented (visual load), and this was followed by an auditory signal (cue) that designated either the auditory load or the visual load for report. When the report cue immediately followed the visual display there was no interaction between the two visual modalities: report of either the visual input or the auditory input was about as accurate as report of either input when presented alone.

When the report cue was presented 2 sec. after the visual display offset, report of the auditory symbols was still unaffected although report of the visual display dropped by 20%.

Scarborough assumes that the auditory load is stored as implicit speech and thus concludes that since about four visual-display symbols could be reported after a 2 sec. delay without affecting auditory report visual symbolic material can be retained without recoding the visual display symbols into implicit speech (articulatory representations). Besides concluding that the visual display symbols are not retained iconically in his experiments, Scarborough does not address the question whether these symbols are stored as visual code representations or as abstract, non-articulatory name code rperesentations (lexical referents or 'programs of motor-instruction'). It cannot be determined from his article whether the subjects in these experiments were consistently cycling the auditory preload in implicit speech, or whether they were'shelving' them as in Expt. 7b, but since Scarborough gives evidence of implicit speech coding of the auditory load, and since there is little or no interaction between retention of the auditory and visual loads, a repeated implicit speech rehearsal strategy seems more likely, as in Expt. 7c here.

Chow and Murdock (1976) again asked the question "does memory load affect the rate of readout from iconic memory?". The subjects were presented with a string of alphanumeric items immediately followed by pattern masks, and had to recall as many items as they could under different memory preload conditions. Memory preloads affected rate of readout from iconic memory in a systematic manner, with pictorial (nonsense geometric forms) and verbal memory items producing the same effect. The preloads were presented visually prior to the alphanumeric arrays. The method of recall of the preload stimuli was to verbalize the verbal stimuli or to draw the geometric patterns. There was no overt rehearsal of the preload stimuli during the array processing task, and it appears, since the verbal and non-verbal preloads both produced an effect, with these effects being quantitatively similar, that the preload stimuli were held using the 'switch and shelve' strategy of Expt. 7b. Since verbal and non-verbal preloads produced essentially the same effect, it follows that the preload effect is not necessarily language specific (lexical or articulatory) and suggests in this case either (i) the interference is due to the preloads being held as their visually encoded representations or (ii) the effect of a verbal preload is due to interference at a lexical level, that of a non-verbal preload is due to interference at a visual level, with the two treatments causing a similar amount of competition for central processing capacity resource.

Since, however, similar levels of interference are found in Expt. 7b where the preload is presented auditorily, it can be concluded that the interference does not solely reside at a visual level, and the maintenance of non-articulatory linguistic stimulus representations also reduce the rate of readout from iconic memory.

The post hoc conclusion which is most consistent with these findings appears to be that memory preloads which have large storage demands interfere with digit array processing, those which incur little non-articulatory storage demands but high processing demands have no effect. The interference effect can operate due to competition for visually encoded storage (Chow and Murdock, 1976 and Expt. d following) or lexically encoded storage (Expt. 7b), but, unless the alphanumeric stimuli are to be remembered in order, not articulatory encoded storage (Expts. 7a, 7c, and Scarborough, 1972).

Experiment 7d

The role of the visual code in the initial acquisition of stimulus information

Abstract

The effect of a visual code interference treatment upon digit processing is investigated. In conjunction with a review of pertinent literature it is concluded that there is considerable reason to believe that visual encoding is one of the functions involved in 'buffer processing'.

Introduction

To repeat in synopsis some of the arguments already outlined (see especially Chapter 4 and Experimental Chapter 2). In the development of cognitive models with an aim to represent the functions involved in the initial information acquisition for visually presented verbal stimuli the debate has primarily concentrated upon the nature of the 'buffer'. It is widely agreed that there is a precategorical visual information store which is of short duration (of the order of ½ sec.), which is subject to masking, and from which the subject can choose to preferentially process items on the basis of simple physical characteristics such as physical location, colour, size or shape (Sperling, 1960, 1963; Clark, 1969; Turvey and Kravetz, 1970; von Wright, 1968, 1970). This is the starting point of the functional pathway. As an end-process it is commonly assumed that the stimulus information is represented in an articulatory form in "short-term memory". But the initial rate of acquisition of stimulus information is considerably faster than the rate of implicit speech and this it is argued (Sperling, 1963, 1967; Coltheart, 1972; Allport, 1973) that there is some intervening process or store of information: the buffer store.

Since there appears to be a visual short-term memory system, the visual code, which is of longer duration than the iconic store and which is not subject to masking (Posner, 1969; Mitchell, 1972, Phillips, 1974; Phillips and Baddeley, 1971; Phillips and Christie, 1977), theorists such as Coltheart (1972) and Mitchell (1976) have argued that the visual code, a representation of the visual features of the stimulus, may act as this buffer store, with articulatory encoding eventually acting directly upon this data base. In contrast Sperling (1967) has suggested that the 'recognition buffer' might hold representations of the stimuli in terms of 'programs of motor instructions' for later articulation - a sort of non-motor or abstract name code, and in a somewhat similar vein Allport (1973, 1977) discusses an abstract name code buffer of lexical representations.

There is no denying that the naming process must make use of the visual features at some stage, but the following alternatives must be evaluated:

(i) The only language representation involved is motor articulatory and occurs from a visual code representation. It is these processes: fast visual coding followed by relatively slow speech motor encoding from this visual representation which underlies the rate of initial stimulus information acquisition.

(ii) The stimuli are encoded in an abstract linguistic or lexical form prior to speech-motor encoding. Lexical encoding operates directly upon iconic information.

(iii) Stimuli are represented lexically prior to articulatory encoding but lexical encoding operates on visually encoded information. This alternative is, in effect, a merger of the different views whereby visual encoding and lexical encoding both underly the properties of the 'buffer'; viz. iconic information → visual code → lexical code → articulatory code. Such a conceptualization has previously been suggested by, for example, Seymour and Porpodas (1979), who envisage a post iconic visual code for graphemic information, the grapheme register, prior to semantic or phonological encoding.

How might these alternatives be investigated or evaluated? Since tasks involving short-term memory (i) typically result in better performance for verbal items than for non-verbal visual forms, (ii) result in performance which is superior the more nameable the stimuli are, (iii) result in considerable memorization performance even under articulatory suppression and, this being the case also from auditory stimulus presentation where, presumably, visual encoding is not involved (or if it is, is involved to a lesser degree than when following visual stimulus presentation), we can be fairly sure that there is a non-articulatory linguistic representation. But does the production of this lexical code occur direct from an iconic representation or from a visual representation? Perhaps it is possible to test this by interfering with the visual code whilst asking the subject to process visually presented verbal material. "If remembering in visual imagery utilizes somewhat the same central mechanisms as are used in visual perception, competition for this limited capacity will result when the person must both visually guide his hand (to indicate answers to various questions about the memorized diagram) and simultaneously remember the spatial diagram in visual imagery. The general idea, therefore, is that two activities in the same modality will compete for a limited analyzer or processing capacity, whereas two activities in different modalities will tend to be less competitive, less disruptive and less interfering." (Bower, 1970, my italics). Following this line of reasoning, just as digit processing has been investigated under articulatory suppression (to investigate the role of articulatory encoding in this task) in Expt. 7a, and just as it has been investigated with static and cycled memory preloads (to investigate the role of the CPU and lexical representations) so digit processing can be studied under a visual interference treatment to investigate the use of visual encoding.

What sort of task should be used to interfere with the visual code? Brooks (1967, 1968) performed a series of experiments investigating the interference between visual imagery and visual perception, demonstrating, for example, that a task requiring visual imagery could be performed more easily while speaking than wile pointing, whereas a verbal task could be performed more easily while pointing than while speaking. His tasks have since been used as standard visualization interference tasks (see e.g. Baddeley, Grant, Wight and Thomson, 1975), and include presenting the subject with a block capital letter, removing it, and the subject visualizing it whilst working in a clockwise direction classifying the corners into 'coming from top or bottom of the figure' or otherwise. It would be neater and clearer cut, however, if a standard 'visual code' task were used itself as a visual code interference treatment. For this reason the paradigm of Phillips and Baddeley (1971) and Phillips (1974) was initially chosen: a random chessboard (4 x 4 cells with half the cells filled in at random) was to be shown at the top of the tachistoscope field for a short exposure duration (1000 ms.) so as to allow no time for verbal encoding, this was followed by the digits array midscreen, and then a third card was presented which had a pattern mask midscreen occupying the spatial location previously filled by the digits, and a second matrix was shown bottom-screen. A visual code representation had thus to be created for the first matrix, held whilst the digits were presented, and then compared with that of the second matrix. When, and only when this judgement had been performed could the digits be reported. It seemed like a good interference task since it was certain that the visual code was preloaded throughout digit presentation. This technique was thus piloted on six subjects and the flaws became apparent. Only three of the subjects could report any digits at all. In addition this result may have been a result of overt inattention since eye-movements were involved - subjective reports were that they looked high for the first stimulus then low for the second matrix. There were reports of non-fixation of the digits since the visual code task was stressed as the first priority.

The technique was promising, but in need of modification, simplification, and elimination of eye movements. The procedure outlined in the method section was the replacement. This involved the midscreen presentation of two nonsense forms which were difficult to name. This was followed by the digit arrays (also midscreen) which were in turn replaced by a central pattern masking stimulus which was surrounded by eight nonsense forms. The visual code task was to judge whether the two nonsense forms of card 1 occurred adjacently anywhere in the array of 8 such forms on card 3. The advantages of the modified Phillips procedure still hold, the forms of card 1 had to be visually encoded and this representation had to be held throughout digit presentation. The new procedure had the additional advantage of no eye movements being necessitated. This unfortunately carried the disadvantage of considerable masking: backwards masking of card 1 by card 2 (the digits); forwards masking of the digits by the card 1 forms; lateral masking of the nonsense-forms arrays on card 3 by the central pattern mask (Visual Noise Causes Tunnel Vision; Mackworth, 1965). However, if the trials remain the same over the three conditions to be used (visual code matching only (VC Match), Report digits only (Digits alone), and Visual code matching and digit processing (VC Match and Digits)) the amount of masking will remain the same across the three conditions, and the effects of task demands can be compared directly, uncontaminated by potential masking independent variable.

Subjects

Six first year undergraduates acted as subjects. Each subject served under all three conditions.

Method

There were three conditions to the experiment, each condition constituted 6 practice trials followed by 30 test trials. Each trial followed the following sequence: verbal warning signal 'ready': 2 sec. delay: card 1 presented on Electronic Developments 3 field tachistoscope at 508 mm. from the subject's eye, 0.9 lux intensity, 1000 ms.: card 2 presented on the tachistoscope, 0.9 lux intensity, variable exposure time (either 50, 100, 150, 200, 400 or 600 ms.): card 3 presented on the tachistoscope, 2.7 lux. intensity, 2000 ms.: subject's report.

Examples of cards 1, 2 and 3 can be seen in fig. 7:7. Card 1 always contained two nonsense forms printed centrally in blue ink. These forms were of the size shown in fig. 7:7 and each form subtended approximately 0.75° visual angle. Card 2 always contained an array of 7 quasi-randomly generated digits. These were printed in black 28 pt. Helvetica light letraset with the whole array subtending approximately 4.1° visual angle. The digit array replaced and overspread that

		STIMULUS	INTENSITY	EXPOSURE TIME
CARD 1		Nonsense Forms (Blue)	0.9 lux	1000 ms.
CARD 2	9074631	7 Digit Array (Black)	0.9 lux	Variable (50, 100, 150, 200, 400, or 600 ms.)
CARD 3		Mask and Nonsense Forms Array (Black Mask Blue Nonsense Forms)	2.7 lux	2000 ms.

TRIAL SEQUENCE OF EXPERIMENT 7d.

POOL OF NONSENSE FORMS USED IN EXPERIMENT 7d.

FIGURE 7:7

visual space previously occupied by the nonsense forms on card 1. Card 3 constituted a central masking stimulus: a jumble of digit parts generated from that same letraset used on card 2. This mask occupied the spatial location previously containing the digit array of card 2. Above and below the mask were arranged an array of four visual nonsense forms printed in blue ink. The pool of nonsense forms can be seen in fig. 7: 7.

Throughout the condition the stimulus cards varied. The only otehr variable was card 2 exposure time, there being 5 trials at each exposure time, these being presented in a randomized block design.

The three conditions were identical with respect to the stimuli and stimuli presentations. They differed only in respect to the instructions given to the subjects.

In the VC Match condition the subject was instructed to concentrate on the nonsense forms. At the end of the trial he was to report 'yes' if the array on card 3 contained in adjacent positions the two stimuli shown on card 1. Otherwise he was to report 'no'.

In the Digits Alone condition the subject was told to concentrate on the digits. At the end of the trial he was to report as many of the digits as he was sure he saw in the correct order if possible.

In the VC Match + Digits condition the subject was instructed to report firstly whether the array on card 3 contained in adjacent positions the two nonsense forms of card 1 (VC Match instructions). This was his first priority. Then he was to report as many of the digits as he was sure he saw on card 2. (Digits Alone instructions).

Three subjects were run under the following condition presentation order: VC Match, VC Match + Digits, Digits Alone. The remaining 3 subjects were run Digits Alone, VC Match, VC Match + Digits

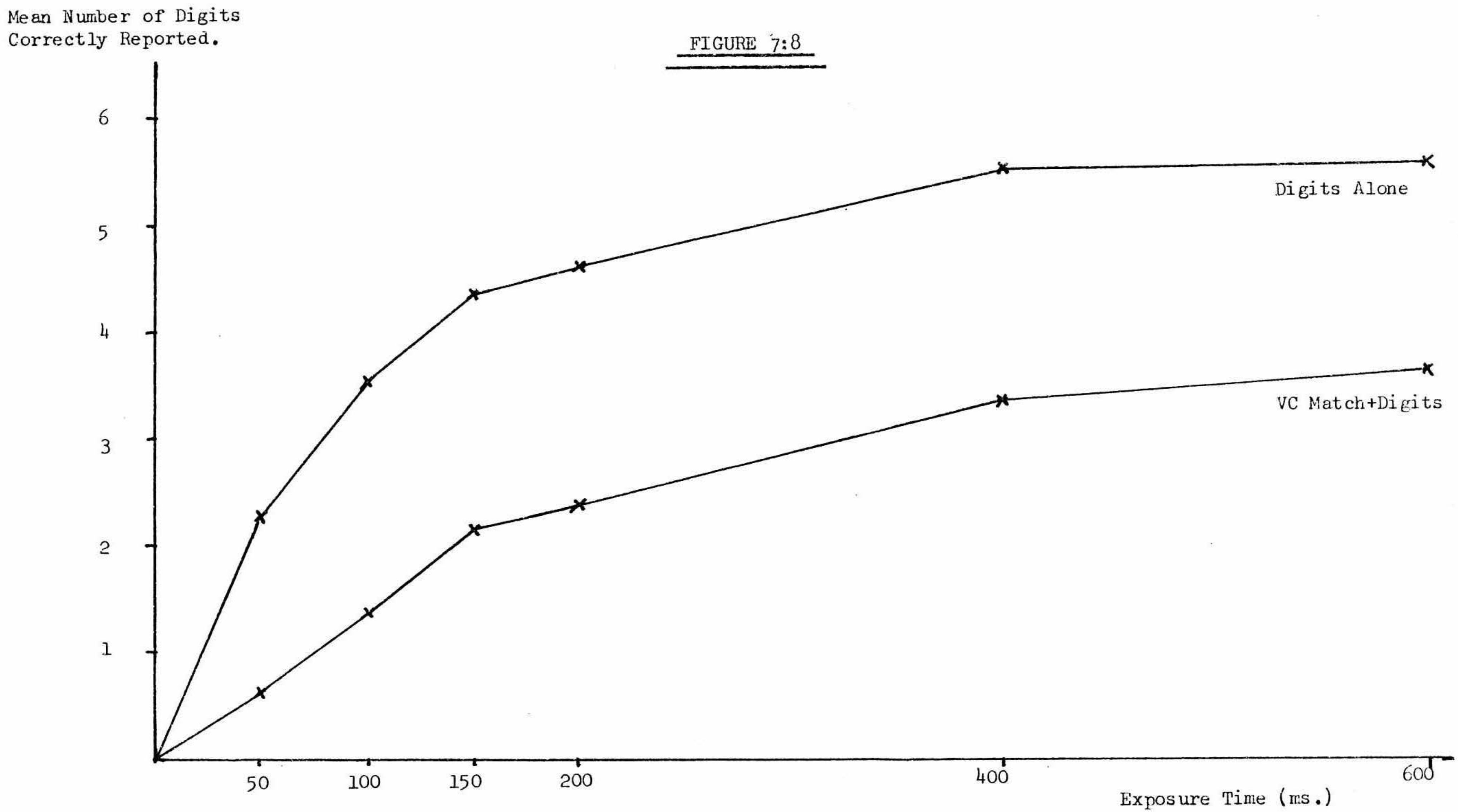
Results

The VC Match error rate was 7.8% under VC Match instructions and 19.4% under VC Match + Digits instructions. These means differ significantly if rates are compared across subjects ($T = 6$, $L = 0$, $p < .05$, Sign test).

The digits data were scored as number of digits correctly reported regardless of order. The average number of digits correctly reported at each exposure time under Digits Alone and VC Match + Digits instructions can be seen in Table 7:1 and Fig. 7:8. These data were analysed as a 3 factor ANOVA (2 Conditions (Digits Alone, VC Match + Digits) x 6 Exposure times x 6 Subjects) with 5 blocks of replications. The ANOVA data can also be seen in Table 7:1. The conditions factor was highly significant ($F = 524.0$; d.f. 1,288; $p < .001$), the average number of digits correctly reported under Digits Alone and VC Match + Digits instructions being 4.34 and 2.27 respectively. The Time factor was highly significant ($F = 119.2$; d.f. 5,288; $p < .001$). The Conditions by Time two-way interaction was insignificant ($F = 0.99$; d.f. 5,288). The subjects factor, subject x condition and subject x time interactions were all significant at the 1% level.

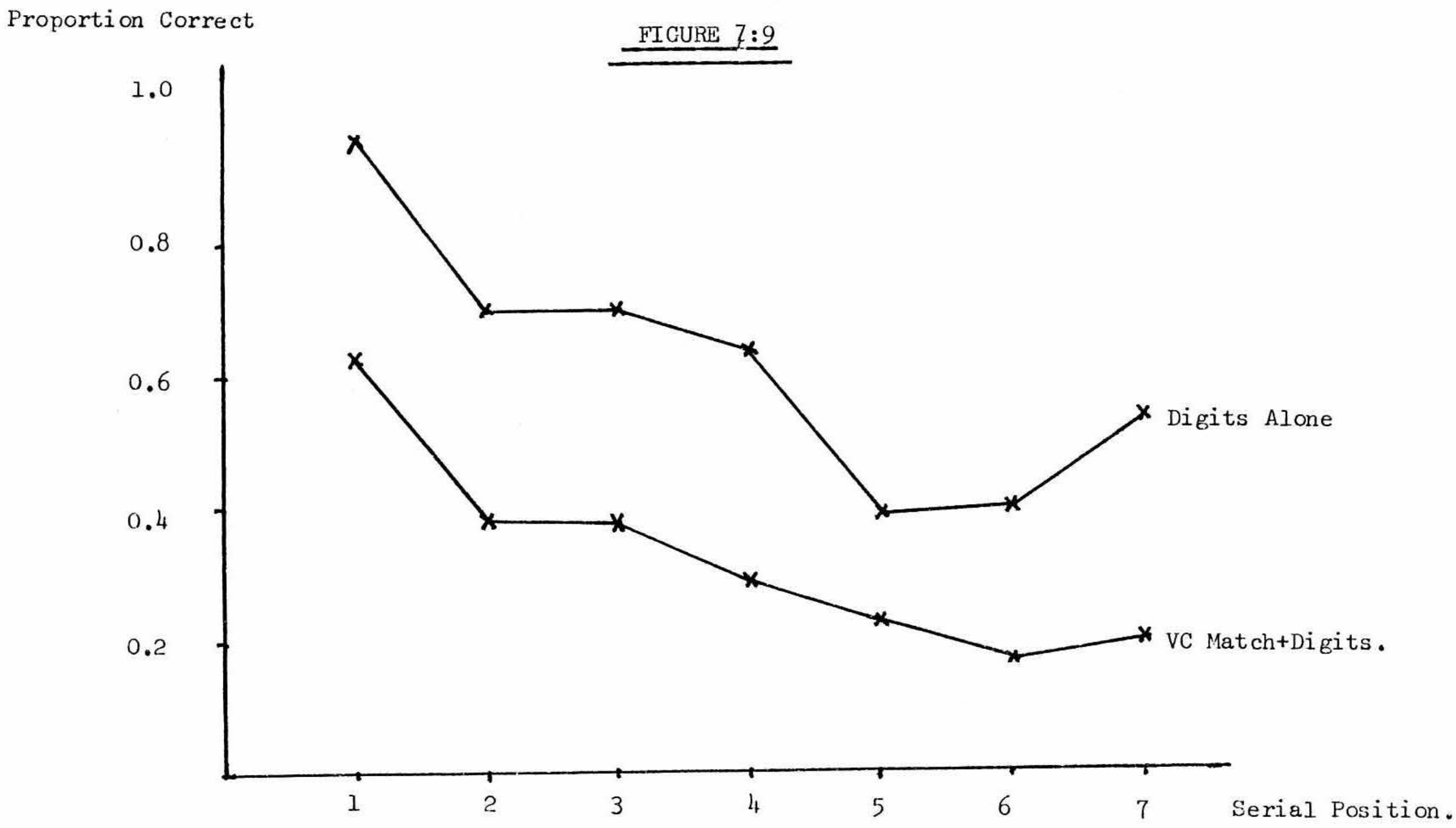
The digits data were also subjected to a serial position analysis: they were scored as the proportion of the 5 trials correct at each serial position for each exposure time/subject. The mean proportions correct for each serial position under the Digits Alone and VC Match + Digits instructions are shown in Fig. 7:9. These data were analysed as a 4 factor ANOVA (7

FIGURE 7:8



Mean Number of Digits Correctly Reported Under the Digits Alone and VC Match+Digits Instructions in Experiment 7d.

FIGURE 7:9



Mean Proportion Correct at each Serial Position over all Subjects and Exposure times Under the Digits Alone and VC Match+Digits Instructions in Experiment 7 d.

TABLE 7:1

MEAN NUMBER OF DIGITS CORRECTLY REPORTED UNDER THE DIGITS ALONE AND VC MATCH + DIGITS CONDITIONS OF EXPERIMENT 7d.

EXPOSURE TIME (ms.)	DIGITS ALONE	VC MATCH + DIGITS
50	2.30	0.63
100	3.57	1.37
150	4.37	2.17
200	4.63	2.17
400	5.57	3.40
600	5.63	3.67

ANOVA DATA FOR THE DIGITS CORRECT DATA OF EXPERIMENT 7d.

SOURCE OF VARIATION	SSq.	df	MSq.	F	p
Condition (C)	386.47	1	386.47	524.0	**
Time (T)	439.55	5	87.91	119.2	**
CT	3.65	5	0.73	0.99	NS
Subjects (S)	254.63	5	50.93	69.05	**
CS	44.65	5	8.93	12.11	**
TS	47.09	25	1.88	2.55	**
CTS	26.34	25	1.05	1.43	NS
ERROR	212.40	288	0.74		

** : $p < .01$
NS : Not Significant

Serial Positions x 2 Conditions x 6 Exposure times x 6 Subjects). All the main factors were significant at the 1% level. The Serial Position x Condition two way interaction was insignificant as were the Serial Positon x Time and Condition x Time interactions. The ANOVA Table and Serial Position Data can be seen in Table 7:2.

Discussion

From the visual code matching results it can be seen that instructions to process the digits causes a reduction in visual code matching accuracy: there is competition between the two tasks. In a similar experiment which concentrated upon interference with visualization by the processing of visually presented verbal material (rather than as here the interference of visualization upon visual processing) Phillips and Christie (1977b) had subjects compare two successively presented 4 x 4 'random chessboard' separated by ISIs up to 4s. If 5 single digits were visually presented successively during the retention interval with the subjects reading them aloud, there was a non-significant performance decrement on the visual matching task. If, however, the digits had to be held and summed, with the subject stating the result of this addition, the performance decrement on the visual matching task was significant. There was no difference between the decrement caused by adding visually presented digits and that resultant from adding auditorily presented digits. If, however, the ISI between the 1st and 2nd matrices was filled by the presentation of two more to-be-compared matrices, there was a large and significant performance decrement, this being especially the case if the two intervening matrices were separated by an interval (750 ms.) greater than iconic storage duration, in which case these intervening matrices themselves required visual code comparison. From these results Phillips and Christie conclude "Visualization was greatly interfered with by adding five digits but not

TABLE 7:2

MEAN PROPORTION OF TRIALS CORRECT ON EACH SERIAL POSITION OVER THE 6 EXPOSURE TIMES AND 6 SUBJECTS OF EXPERIMENT 7d. DIGITS ALONE AND VC MATCH+DIGITS DATA.

SERIAL POSITION	DIGITS ALONE	VC MATCH+DIGITS	d
1	0.96	0.63	0.33
2	0.70	0.38	0.32
3	0.70	0.38	0.32
4	0.64	0.29	0.36
5	0.39	0.23	0.17
6	0.40	0.17	0.23
7	0.54	0.20	0.34

ANOVA TABLE FOR THE SERIAL POSITION DATA OF EXPERIMENT 7d.

SOURCE OF VARIATION	SSq.	df	MSq.	F	p
SERIAL POSITION (P)	13.23	6	2.20	43.1	**
CONDITION (C)	10.98	1	10.98	215.2	**
PC	0.54	6	0.09	1.7	NS
SUBJECTS (S)	7.23	5	1.45	28.4	**
TIME (T)	12.51	5	2.50	49.0	**
PT	2.56	30	0.09	1.7	NS
CT	0.10	5	0.02	0.4	NS
PCT	3.06	30	0.10	2.0	**
Error	21.18	415	0.05		

** : $p < .01$
NS : Not Significant

by reading them. Presentation modality of the digits did not affect the interference they caused. Where the intervening activity involved processing patterns similar to those being visualized, the amount of interference depended upon whether the subject had to form and use representations that outlined the icon. Perception caused interference when it involved formation of a maintainable representation, but not when it required only sensory storage.

It is concluded that visualization requires general purpose resources, and that interference between visualization and perception could be due to competition for these resources." (Phillips and Christie, 1977b; my italics).

They interpret the findings almost entirely in terms of competition for general purpose, central-executive-type resources; and these would apply to the current findings. However, so would the proposals outlined in the short-term memory heuristic developed in Chapter 4. Simple reading of single digits (one at a time) in their experiment caused no significant visual code performance decrement, but holding of those 5 digits and addition which must presumably involve the manipulation of lexical and articulatory representations (see Hitch, 1978; Ellis and Hennelly, 1979; Ellis and Kettle, in preparation) did interfere. Since this occurred with auditory digit presentation as well, the competition for CPU resources does seem the most obvious conclusion. In the present experiment, however, it is shown that processing as many digits as possible while visualizing does result in a visualization performance decrement. Is this a result of the digits being held as lexical/articulatory representations (the lexical buffer notion) with CPU resource competition similar to that found with the cognitive task of mental addition in the Phillips and Christie experiment? Or is it a result of the digits being held as visually encoded representations (the visual code notion)? The nonsense form stimuli are of similar size and feature complexity and the digits, and the digit processing intervening activity thus fits with Phillips and Christie's visual code interpretation, "when the intervening activity involved processing patterns" (digits) "similar to those being visualized" (nonsense forms) " the amount of interference depends upon whether the subject had to form and use representations that outlined the icon".

So the present findings fit those of former studies. Unfortunately they fit too well (!) in that they are compatible with both the notions of a lexical code buffer and that of a visual code buffer and the main purpose of the present experiment was to differentiate between these options.

If, however, attention is turned to the effect of visual matching task upon digit processing the picture becomes clearer, since, in contrast to the digits which can be both visually and lexically encoded, the visual nonsense forms can only, presumably, be represented according to their visual representations.

From the ANOVA on the digit processing data (Table 7:1) it can be seen that there is a severe decrement in digit processing caused by having to perform the visual coding of nonsense forms task. It is also apparent (see Table 7:1 and Fig. 7:8) that the condition x time interaction is insignificant - having to do the visual coding task causes an 'across the board' of exposure times digit report decrement of roughly two items (yes, two items: the number of visual nonsense forms to be visually encoded; but surely this must be a coincidence).

Storing the nonsense forms in the visual code thus interferes with processing of visual digits the lack of treatment x time interaction is consistent with the idea that, in the digit processing task, the digits are held at some early stage as their visually encoded representations: if the visual code is preloaded with two items (nonsense forms) there is then a decrement in visual code resource available to the digit processing. N.P. Arguments concerning treatment x time interactions have been formalized in Chow and Murdock (1976): "The Baxt paradigm could be helpful in determining how memory load affects the rate of readout from iconic memory. Four alternative ways can be anticipated and they are diagrammatically represented in Fig.1. If visually presented memory load taxes the visual system or the central processor in a way analogous to using visual noise in the preexposure field, one would expect that the onset of the readout process would be delayed when there is memory load (See Figure 1(a)). If memory load reduces the number of items which can be read into short-term memory, one would expect that the recall function would have a lower asymptote when there is memory load (see Figure 1(b)). If memory load reduces the rate of readout, one would expect a shallower slope for the recall function when there is memory load (see Figure 1(c)). Finally, if memory load affects both the number of items that can be transferred into a short-term memory store and the rate of readout, one would expect a recall function like the one in Figure 1(d). To test these four alternatives, various amounts of memory load were imposed upon the subjects when they were given the Baxt-type task".

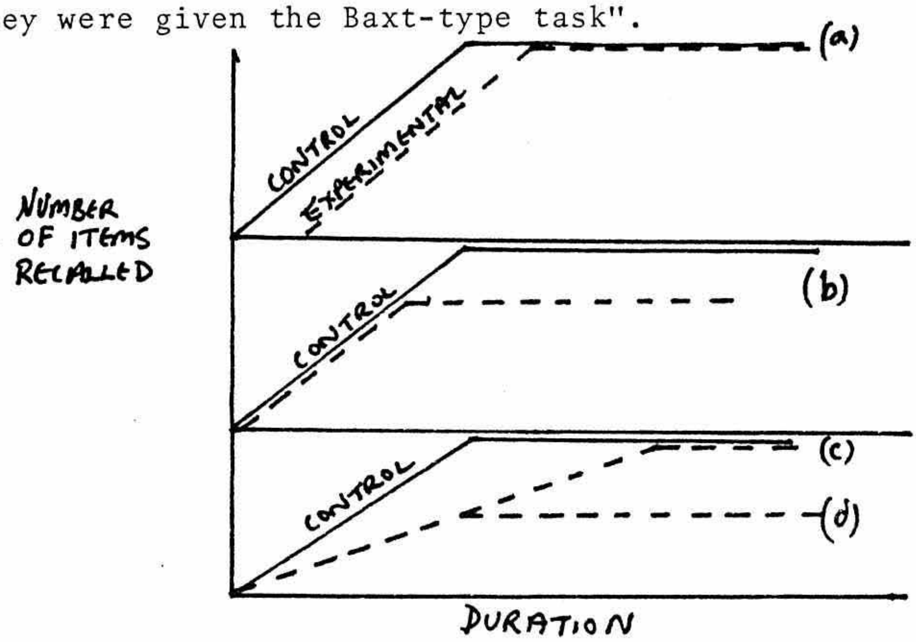


Figure 1. Alternative ways in which memory load could limit iconic memory: (a) memory load delays the onset of the readout process; (b) memory load reduces the number of items which could be read into short-term memory; (c) memory load reduces the rate of readout; (d) both (b) and (c).

From Chow & Murdock (1976)

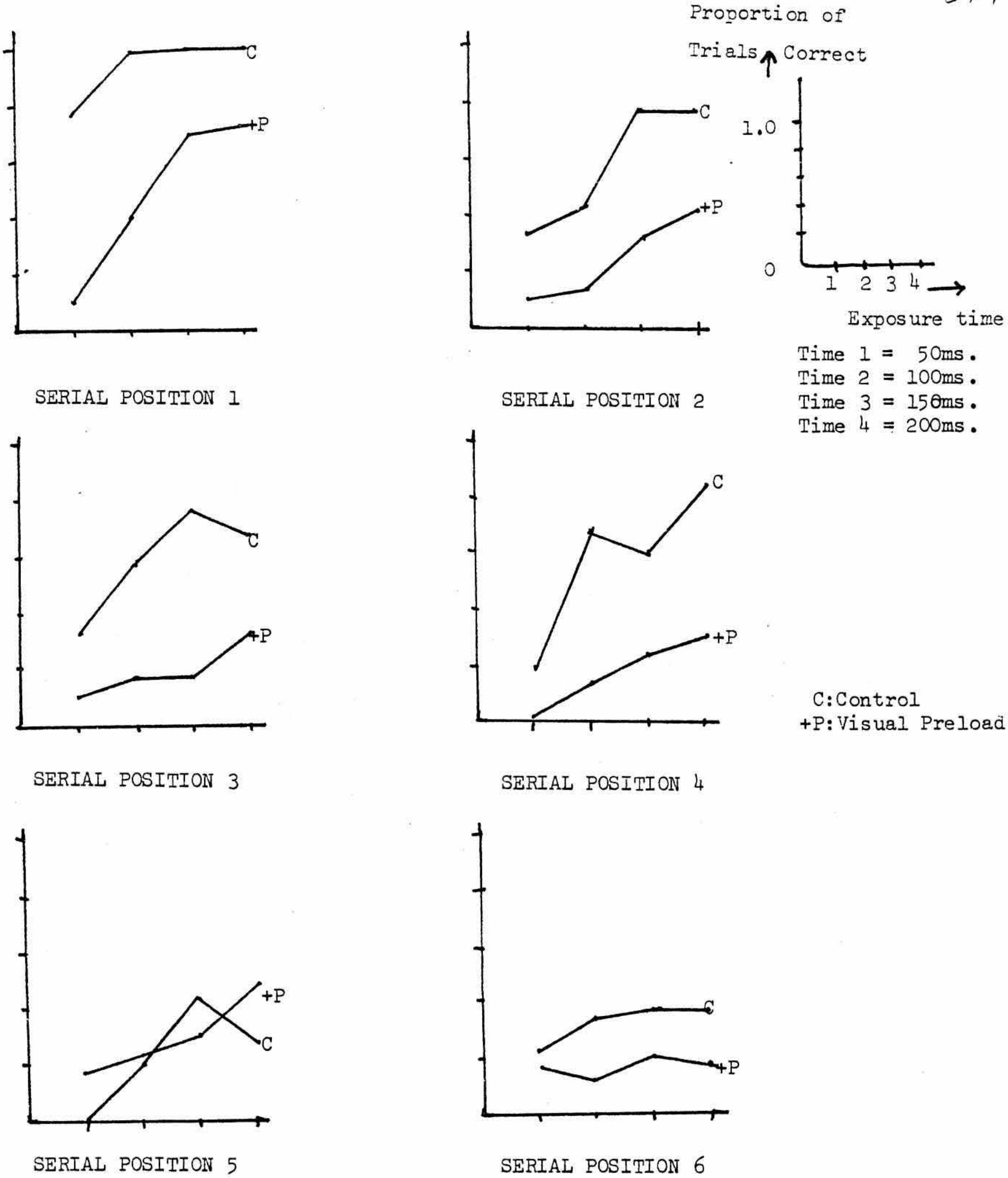
In a similar fashion, but interpreting according to the heuristic developed in Chapter 4, the argument runs as follows: consider interference in memory storage, rather than 'central executive resource', with the following available storage functions: iconic - visual code - (lexical code - articulatory code). The lexical and articulatory encoded representations are bracketed together since, as in Chapter 4, the interaction between these two representations is considered to be a useful way of considering verbal short-term memory. If an interfering treatment affects a stage in the functional process which is after the preferential 'buffer' functions, it is to be expected that the initial rate of processing which is a result of the 'buffer' functions will be relatively unaffected (see e.g. the effects of articulatory suppression on item and order processing, Expt. 7a). If, however, the interference treatment affects a function at a stage early in the processing chain then the limitation in resource should be found at all exposure times since the treatment interferes with one of the buffer functions as well. It is this latter result that is found in the present experiment, and this lends support to the notion that visual encoding is one function underlying preferential buffer performance.

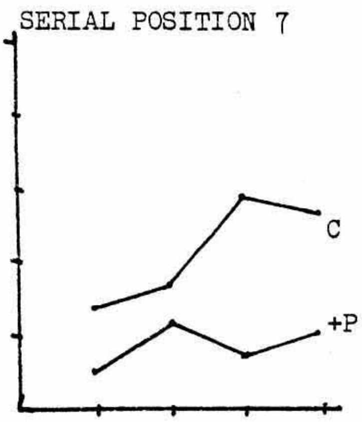
Can we be sure, however, that the nonsense form interference treatment is a result of visual code preload rather than a more general central executive resource limitation which is a result of having to visualize, with the nonsense form visualization using a system independent of that used in digit processing (itself perhaps iconic - (lexical code - articulatory code))? There is certainly abundant evidence to support the idea that a visual interference treatment has a greater effect upon visual information processing than interference treatments which involve, presumably, auditory and lexical-articulatory processes. Thus Merickle (1976) tested probed report of single letters from centrally fixated, seven letter, target rows presented for 100 ms. The probe cue was either a visually or an auditorily presented digit which indicated the spatial location of the to-be-reported letter. Over a series of experiments, report was always better with the auditory cues. He concludes that the visual cues produce modality-specific interference which operates at a level of processing beyond iconic representation. In the heuristic developed in Chapter 4 the only verbal short-term memory system which is specific to the visual modality and which is post iconic is the visual code. It appears, therefore, from Merickle's experiments that the analysis of visual probes requires at least part of the limited information-processing capacity underlying the storage of information in the visual code.

In addition to these conclusions Chow and Murdock (1976) found that memory preloads of either 5 non-verbalizable geometric patterns or 5 alphanumeric stimuli equally affected alphanumeric processing under masking: the two types of memory items had the same effect quantitatively as well as qualitatively on slowing the rate of readout from iconic memory. To rephrase, this suggests that the visually encoded preload for the geometric patterns has the same effect as the alphanumeric preload: is this because the alphanumeric preload is similarly visually encoded? Again the results are consistent with the notion that visual encoding is a function involved in the 'buffer processes' underlying the fast initial rate of information acquisition.

Relevant also are the experiments which investigate item and position information processing from visual arrays (den Heyer and Barrett, 1971; Meudell, 1972; Cumming and Coltheart, 1969; Stainton-Rogers, 1978; see review in discussion of Expt. 7a). In her series of experiments investigating the item and position processing contingent/non-contingent debate, Stainton-Rogers concludes that "item and position are encoded together in acoustic-verbal form via the recognition buffer" (lexical representation in the present terminology)"but additional position reports can be derived from a post-VIS visual store" (the visual code) (Stainton-Rogers, 1978; my italics). Whether, however, this post-iconic visual store can act as a data base for either lexical or articulatory encoding is unclear from Stainton-Rogers' results - in her model of STM (Fig.4) whereas VIS (iconic store) and scan/ recognition buffer processes (lexical encoding) are linked by thick, firm arrows, as are the VIS and post-iconic visual store (visual code), the links between post-iconic visual store and scan and between post-iconic visual store and translator (articulatory encoding) are more tentative arrows bisected by question marks. Such, I fear, is the nature of conclusions from experiments such as these. The present experiment similarly suggests that visual coding is one of the buffer processes, but the possibility of visualization competing for pcentral executive resources' and thus interfering with digit processing which doesnot use this visual code system cannot be totally disproved.

To address the visual code buffer model of Coltheart (1972) more directly, the serial position effects will be considered. When a row of eight letters is presented for 100 ms., followed either by a pattern mask or a blank white field, and subjects are asked to report as many letters from the row as possible, performance is worse in the mask condition than in the no-mask condition. However, Merickle, Coltheart and Lowe (1971) showed this to be true only for letters near the centre of the row; the report of the letters at either end of the row is unaffected by the mask. Merickle et al. (1971), and Coltheart (1972) suggest thatthis is a result of the ends-of-the-row items being visually encoded. Further support for this idea comes from Merickle and Coltheart (1972) who demonstrate that the end-items are selectively more affected by forwards masking: the first, preferentially fast rate of information acquisition is assumed to reflect visual encoding, forwards masking is assumed to affect more the early processing functions, the end serial positions are assumed to be selectively processed by the preferential early processing functions. This is certainly evidence that the ends-of-the-row-items are first processed, but does not prove that this first process is visual encoding. If, however, the results of the present experiment are scored for serial position we can go some way in evaluating whether the end-items are indeed visually encoded. Does the visual code preload (the nonsense forms) selectively affect the processing of the ends-of-the-array digits, as would be predicted by Coltheart's hypothesis? The ANOVA (Table 7:2) for the serial position data shows a significant effect of visual preload ($F = 215.2$; d.f. 1,415; $p < .001$), a significant serial position effect ($F = 43.1$; d.f. 6,415; $p < .001$), but an insignificant serial position by treatment and interaction which suggests that over all exposure times the visual preload affects the processing of all digit serial position equally (even so, inspection of the d scores in Table 7:2 does suggest a trend which accords with the prediction with the Coltheart (1972) model whereby mid serial positions 5 and 6 seem less affected by the visual code interference than are end serial positions). The hypothesis of Coltheart (1972), however, leads to the more specific prediction that it is the end serial positions that will be more affected at short exposure times when 'visual encoding' is supposed to be occurring. The three way interaction of treatment by serial position by time is relevant, therefore, and this is indeed significant ($F = 2.0$; d.f., 30,415; $p < .01$). If Figure 7:10 is considered there is some tentative support for this prediction: certainly in comparison with the other serial positions, serial position 1 is drastically affected by the visual code interference treatment at





The effect of a Visual Code Preload upon the proportion o[f] correctly reported digits at each of the 7 Serial Positi[ons] of the digit arrays used in Experiment 7d.

FIGURE 7:10

at the two shortest exposure times. This is shown more clearly in Figure 7:11 where the proportion correct decrement as a result of the interference treatment is shown over the 7 serial positions at the shortest exposure times where visual encoding is speculated to be occurring and the effect at the 200 ms. exposure time is also shown. Some tentative support for serial position 1, but no support from the other end, serial position 7. No firm theoretical conclusions can be drawn, however, from the serial position effects.

Overall therefore, the results of Expt. 7d lend some support to the role of visual coding functions in the 'buffer processes'. This support is at best tentative, but in the light of evidence (Phillips and Christie (1977, Chow and Murdock (1977), Merickle (1976) and Stainton-Rogers (1978) which is reviewed here, it can certainly be concluded that the possibility of visual encoding being involved in the initial assimilation of visual information cannot be discounted.

Finally, with regard to the digit processing data for the dyslexic and control children of Experimental Chapter 2, it can be seen that the functions with and without visual code interference closely mimic those of control and dyslexic children respectively (as did the functions with and without a static memory load, Expt. 7b). This parallel might suggest a visual code deficiency in dyslexic children, but, in the light of the follow up experiments (Experimental Chapters 3, 4, and 5) which demonstrate adequate visual encoding ability but deficiencies in the production of lexical referents in these children, it must be concluded that while one of the processes underlying the initial rate of information acquisition may well be visual encoding, lexical encoding is also involved, and it is a deficiency in this latter function which limits the dyslexic child's visual information processing ability.

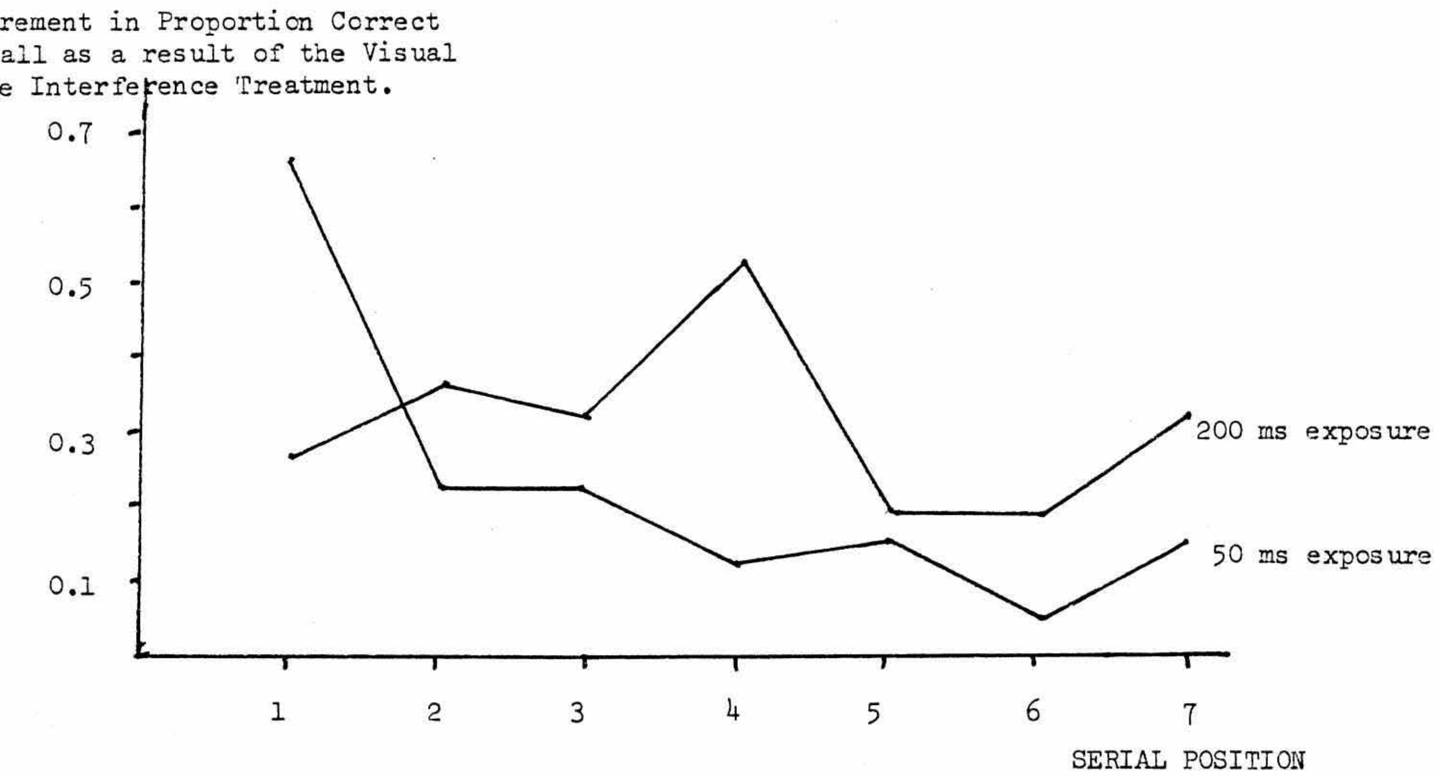


FIGURE 7:11

The decrement in proportion correct recall at each serial position in the digit processing task as a result of the visual code interference task used in Expt.7d.

Experiment 7e

Is articulatory coding involved in Posner tasks where letter matching is by name?

Abstract

Eight undergraduates were tested on the Posner letter matching task used with dyslexic and control children in Expt. 3a. The procedure was modified, however, such that response was by button press rather than verbal, and the experiment was run both with and without articulatory suppression (A.S.). A.S. had no effect on response latencies for any of the conditions. It is concluded that the representations used for letter comparisons by name are non-articulatory.

Introduction

In Expt. 3a, the Posner letter matching task, the dyslexic children performed at the same speed and accuracy as control children with letter pairs to be matched according to their visual characteristics (OO, OQ, OB) but were significantly and reliably over 100 ms. longer in adjudging letters to be same of different on the basis of name or lexical features (Gg, Gd, Gw). It was concluded that either (i) dyslexic children are relatively slow at accessing non-articulatory name or lexical representations of letters, or (ii) they are relatively slow at accessing articulatory representations of letters. This indecision of conclusion was a result of a lack of clarity about whether the internal representations used in letter matching by name are articulatory or otherwise. This question is addressed in this experiment with the use of articulatory auppression which is assumed to prevent articulatory encoding for visual stimuli (See Expts. 5a; 7a; Baddeley and Hitch, 1975; Baddeley, Thomson and Buchanan, 1975).

If letter-matching by name utilizes articulatory representations then either response latencies should increase on these conditions under A.S. or, alternatively, A.S. will result in an increased error rate.

Method

The stimuli and method of presentation were identical to those of Expt. 3a. The method of response was charged from verbal yes/no to button press yes/no to allow for articulatory suppression. The subject sat before the tachistocsope with a button in each hand. The 'yes' button was placed in his/her non-dominant hand.

Eight undergraduates served as subjects. They were instructed to press the 'yes' button if the letters were the same and the 'no' button if different, and they were to make their responses at the fastest rate compatible with low error rates. Each subject performed under two experimental treatments, viz. control and + A.S. Four subjects were run under the A.S. condition first, four under the control condition first. Each treatment used those 8 practice stimuli and 32 test stimuli of Expt. 3a. The test stimuli constituted the following pairs:

	e.g.	response
8 Visually identical letter pairs	OO	'yes'
4 Visually different letter pairs	OB	'no'
4 Visually similar letter pairs	OQ	'no'
8 Phonologically identical letter pairs	Gg	'yes'
4 Phonologically different letter pairs	Gw	'no'
4 Phonologically similar letter pairs	Gd	'no'

In the A.S. condition the subject was to whisper the sequence '1, 2, 3, 4, 5, 6, 7, 8, 9' cyclically and repeatedly at the fastest rate compatible with clarity of pronunciation starting at the ready signal which preceded each trial (ready - 1 sec. fixation cross - start timer, 2 sec. letter pair) and finishing after response production which stopped the timer.

Results

Mean condition/treatment response latencies can be seen in Table 7:3. They are shown graphically in Fig. 7:12. These data were analysed as a 4 factor ANOVA (8 Subjects x 2 Treatments (control, + AS) x 2 Letter pair types (visual, phonological) x 4 conditions (run 1 identical, run 2 identical, different, similar)) with four replications per condition. The ANOVA table can be seen in Table 7:4.

The treatments factor is insignificant ($F = 0.117$; d.f. 1,384), the mean response latency under the control procedure being 643 MS., that under suppression being 647 ms. The subjects factor ($F = 21.3$; d.f. 7,384; $p < .01$) was significant as was the subjects/treatments interaction ($F = 6.82$, d.f. 7,384; $p < .01$). The conditions factor was significant ($F = 14.17$, d.f. 3,384; $p < .01$), as in Expt.3a the similar condition produced the longest latency (704 ms.), next were the different and run 2 same latencies (634 ms. and 638 ms. respectively); the shortest latency was that of the run 1 same condition (604 ms.). The letter-pair-type factor was significant ($F = 60.15$; d.f. 1,384; $p < .01$), the visual pairs mean latency being 601 ms., that for the phonological pairs being 689 ms. The condition/letter-pair-type interaction was significant ($F = 4.54$, d.f. 3,384; $p < .01$) such that phonlogical pairs produced considerably longer response latencies (653 and

TABLE 7:3

Mean Treatment/condition Response Latencies in Experiment 7e

	CONTROL TREATMENT	
	VISUAL PAIRS	PHONOLOGICAL PAIRS
Run 1 Identical	549.7	658.1
Run 2 Identical	577.8	717.3
Different	609.4	638.1
Similar	668.8	725.9
	ARTICULATORY SUPPRESSION TREATMENT	
	VISUAL PAIRS	PHONOLOGICAL PAIRS
Run 1 Identical	559.8	647.8
Run 2 Identical	547.1	708.9
Different	611.0	678.3
Similar	687.6	735.3

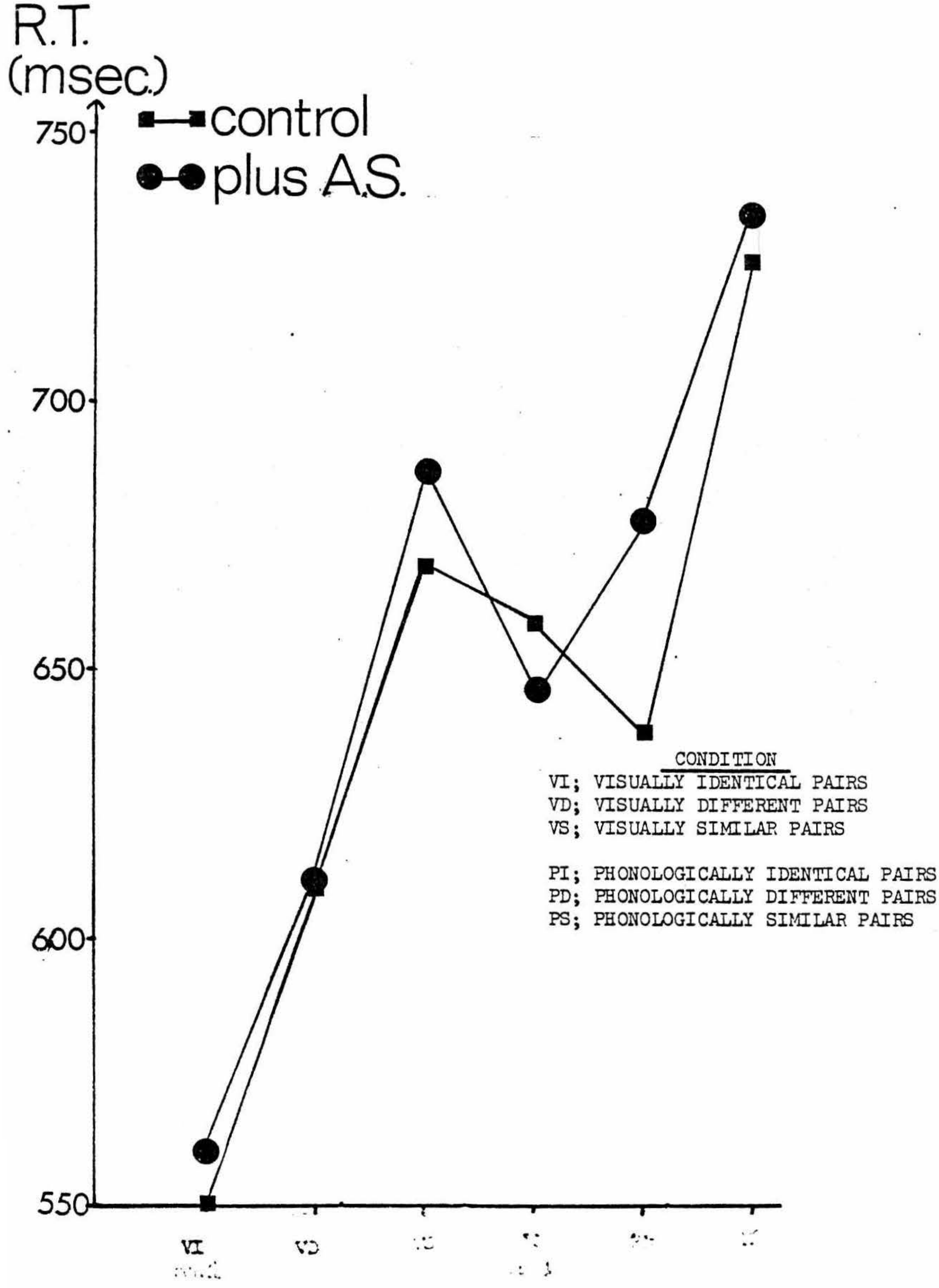
TABLE 7:4

ANOVA Table, Experiment 7e

SOURCE OF VARIATION	SSq.	DF .	MSq.	F	p
TREATMENTS (Control, A.S.) (T)	1898.82	1	1898.82	0.117	NS
SUBJECTS (S)	2419950.6	7	345707.24	21.30	**
TS	775217.46	7	110745.35	6.82	**
CONDITION (Runs 1,2 identical, different, similar) (C)	689583.35	3	229861.11	14.17	**
TC	30764.08	3	10254.69	0.63	NS
SC	658398.96	21	31352.33	1.93	**
TSC	216336.32	21	10301.73	0.63	NS
LETTER PAIR TYPE (L) (visual, phonological)	976153.78	1	976153.78	60.15	**
TL	1906.54	1	1906.54	0.12	NS
SL	86511.87	7	12358.84	0.76	NS
TSL	44074.15	7	6296.31	0.39	NS
CL	220771.78	3	73590.59	4.54	**
TCL	18021.80	3	6007.27	0.37	NS
SCL	227137.81	21	10816.09	0.67	NS
TSCL	251453.82	21	11973.99	0.74	NS
ERROR	6230971.5	384	16226.48		

FIGURE 7:12

The Effect Of Articulatory Suppression Upon Letter Matching In A Posner Type Task.



713 ms.) than visual pairs (555 and 562 ms.) on runs 1 and 2 same conditions, but only slightly longer response latencies on the different and similar conditions (phonological pairs 658 and 731 ms. respectively, visual pairs 610 and 678 ms. respectively). There was a significant subjects x conditions interaction ($F = 1.93$; d.f. 21, 384; $p < .01$).

No other factors or interactions reached the .05 level of significance.

Error rates were 6% under the control treatment and 10% under A.S. These are not significantly different (Wilcoxon test, $N = 8$, $T = 6.5$).

Discussion

The discussion of Expt. 3a with regard to the condition and letter-pair-type factors also applies here.

With regard to the main theme of this experiment, the treatments factor is insignificant: articulatory suppression has no significant effect upon response latencies in this task. The treatemnts/letter-pair-type factor is also insignificant: there is no hint that A.S. has any more effect on phonological pair matching than on visual pair matching performance.

It is concluded that articulatory representations are used neither in letter matching to visual features nor in letter matching to name features. Phonological letter pair matching is carried out using non-articulatory name or lexical representations.

Scarborough and Scarborough (1975) performed reaction time experiments where subjects searched visual displays of one to three letters for the presence of one or two auditorily presented target letters. Since implicit speech conditions (where the subjects named the visual arrays to themselves prior to lever pressing) showed a function of lever response times against display size of about twice the slope of that found in the target search conditions, they conclude, as in the present experiment, that the memory comparison process in this and related (Posner type) tasks does not involve implicit speech representations: "The 'name code' in the Posner paradigm and in the first four sessions of the present experiment does not involve implicit speech" (op. cit. p.696). They discuss the representation used in the "name code" conditions in terms of Anderson and Bower's (1973) distinction between the mnemonic representation of a spoken word or symbol and the concept represented by that symbol. That is the representation of a letter that is involved in the memory comparison process may be independent of the way in which the symbol is presented, i.e., visually or auditorily. This proposed abstract code representing the concept of the symbol and being intermediate between visual input and vocal report shares all the properties of the lexical code representation suggested to be involved in this task both in Expts. 3a and 7e and in Chapters 3 and 4.

This being the case, we have a problem! Both in Expt. 3a, and in those of Dainoff and Haber (1970) and Dainoff (1970) there is evidence that acoustic similarity of letter names has an effect on response times in such tasks: if letter pairs are presented with different, but similar sounding, names (e.g. Gd, Bt), subjects are slower in responding than if the names of the letters are acoustically dissimilar. However phonemic similarity effects are supposedly occurring at an articulatory level (it is the deaf children, who are rated 'good speakers' or 'articulators', who make the 'acoustic errors' in Conrad's 1970 experiments; Murray (1968) and Estes (1973) have shown acoustic similarity effects are eliminated if subjects are required to count (AS) during presentation of the to-be-remembered material in span tasks). Contradictions are rife: AS eliminates phonemic similarity effects, yet such effects on response latency are seen clearly in the present experiment under AS (Fig. 7:12); the code in question in the name-matches of the Posner task are non-articulatory yet clear phonemic similarity effects are seen.

I'm really not sure how one argues one's way out of this one. It might be suggested that the lexical representations used in name-matching do show phonological properties and are subject to some phonemic confusability effects; or alternatively that AS is not totally efficient in the prevention of implicit speech. If the former hypothesis applies, it suggests that there is a pre-articulatory phonological store which can be directly accessed from visual input. Indeed maybe the 'lexical code' is not as abstract as we may believe, but rather is more phonological in nature, our word-knowledge in the lexicon initially having been acquired auditorily. This idea is incompatible, however, with the body of evidence for the lexical code's abstractness (e.g. no visual word-length effects under A.S., Baddeley et al., 1975; no word length effects in lexical decision, Frederiksen and Krell, 1976) and with the evidence from the aphasics that the phonology necessary for orthographic reading cannot be accessed in patients with expressive speech disorders (Sasanuma and Fujimura, 1971, see Chap.4).

No firm conclusions are proposed therefore, except that the weight of the evidence suggests that the internal representation used in 'name-matching' in Posner-type tasks is abstract, non-articulatory and perhaps lexical in nature. Since dyslexic children are relatively slow at such tasks (Expt.3a) and since there is abundant evidence that they are proficient at articulatory encoding (Experimental Chapter 5) there are thus further grounds for believing that they are deficient in creating, manipulating or comparing lexical representations.

CONCLUSIONS

The experiments detailed in this chapter investigate the interactions between those functions involved in visual information processing and short-term memory.

Expt. 7a demonstrates that articulatory encoding is not involved in symbol array processing for item information when retention intervals are short. Order information, however, seems optimally to involve articulatory encoding. A view of partially non-contingent item and order processing and short-term retention is thus suggested.

Expt. 7b demonstrates a reduction in the amount of processing of visual information when a static verbal memory load has to be retained in short-term memory.

This is shown not to be the case in Expt. 7c when the preload is concurrently articulated. It is thus suggested that verbal memory preloads and the visual processing of verbal information compete primarily for storage rather than central processing resource. This storage competition is suggested to occur at a level of lexical representations.

The results of Expt. 7d show that a non-verbal visual preload can interfere with the visual information processing of verbal material. Although the results might be a result of competition for central processing resource, they are again more consistent with the notion of the two tasks competing for storage. This storage competition is suggested to occur at a level of post-iconic visual representations.

It is thus demonstrated that visual information processing, the rate of readout form iconic memory, can be interfered with by prempting visual or lexical storage resource but not articulatory storage resource. It is suggested, therefore, that the 'buffer processes' underlying the initial fast rate of information acquisition for verbal material involves both post-iconic visual and lexical functions. This is considered far from surprising. The functions which interface the iconic representation of a visually presented verbal stimulus and its articulatory representation must surely include a pattern recognition stage where the visual representations are analysed (logogen or LLL activation), and, as a result, the accessing of non-articulatory name or lexical representations.

In Expt. 7e it is concluded that the name representations used in letter pair comparison by name characteristics in Posner type tasks are non-articulatory or lexical.

Since there is considerable evidence of visual information processing and working memory competing for storage resource, the view of Baddeley and Hitch (1974) of working memory as a highly flexible limited -capacity system having both storage and executive capabilities is adopted.

References

Aaronson, D. (1968). 'Temporal course of perception in an immediate recall task. Journal of Experimental Psychology, 76, 129-140.

Allen, T.W. (1975). 'Patterns of attention of Temporal stimulus sequences and their relationship to reading achievement. Child Development, 46, 1035.

Allport, D.A. (1968). 'The rate of assimilation of visual information'. Psychonomic Science. 12, 231-232.

Allport, D.A. (1973). 'Recognition units in reading: backwards masking experiments'. Unpublished.

Allport, D.A. (1978a). 'On knowing the meaning of words we are unable to report: the effects of visual masking'. In. S. Dornic (Ed.) Attention and Performance 6, Hillsdale, N.J.: Erlbaum Associates.

Allport, D.A.(1978b). 'Word recognition in reading: a tutorial review. In H. Bouma; P.A. Kolers and M. Wrolstad,(Eds.) Processing of Visible Language

Allport, D.A.; Antonis, B., & Reynolds, P.(1972). 'On the division of attention: a disproof of the single-channel hypothesis. Quarterly Journal of Experimental Psychology, 24, 225-235.

Anderson, I.H. (1937). 'Eye movements of good and poor readers. Psychological Monographs, 1937, 48 (3), 1-35.

Anderson, I.H., Hughes, B.O. & Dixon, W.R. (1957). 'The rate of reading development and its relation to age of learning to read, sex and intelligence'. Journal of Educational Research, 50, 481.

Anderson, J. & Bower, G. (1973). Human Association Memory. Washington, D.C.: Winston and Sons.

Annet, M. (1970). 'Handedness, cerebral dominance and growth of intelligence'. In D.J. Bakker & P. Satz (Eds.) Specific Reading Disability. Rotterdam University Press.

Apter, M.J. & Barrett, S. (1973). 'The computer in education and training'. in M.J.Apter & G. Westby (Eds.) The Computer in Psychology. London:Wiley.

Atkinson, R.C. (1968).'Computerized instruction and the learning process'.American Psychologist, 1968, 225-239.

Atkinson, R.C. & Shiffrin, R.M. (1968). 'Human memory: A proposed system and its control process. In K.W. Spence & J.T. Spence (eds.) The Psychology of Learning and Motivation: Advances in research and theory. Vol. 2 pp. 89-198. New York: Academic Press.

Atkinson, R.C. & Shiffrin, R.M. (1971).'The control of short-term memory'. Scientific American, 225, 82-90.

Audley, R.J. (1976). 'Reading difficulties: the importance of basic research in solving practical problems'. Presidential Address to the meeting of the British Association for the Advancement of Science.

Baddeley, A.D. (1966).'Short-term memory for word sequences as a function of acoustic, semantic and formal similarity'. Quarterly Journal of Experimental Psychology, 18, 362-365.

Baddeley, A.D. (1968). 'How do acoustic similarity influence short-term memory?'. Quarterly Journal of Experimental Psychology, 20, 249-264.

Baddeley, A.D. (1976). 'The psychology of memory'. Basic Books, Inc. Harper International.

Baddeley, A.D. (1979) 'Working memory and reading'. In H. Bouma, P.A. Kolers, and M. Wrolstad (eds.), Processing of Visible Language. Proceedings of a conference held at the Institute for Perception Research, IPO, Eindhoven, 1977.

Baddley, A.D., Ellis, N.C., Miles, T.R. and Lewis, V. Developmental and Acquired Dyslexia: A Comparison. In preparation.

Baddeley, A.D., Grant, G., Wight, E., & Thomson, N.(1975). 'Imagery and visual working memory'. In P.M.A. Rabbitt, & S. Dornic (Eds.) Attention and Performance V, pp. 205-17. London: Academic Press.

Baddeley, A.D. & Hitch, G. (1974). 'Working Memory'. In G.H. Bower (ed.), The Psychology of Learning and Motivation, Vol. 8, pp. 47-90. New York: Academic Press.

Baddeley, A.D. & Hitch, G. (1978). 'Working memory and information processing'. Open University Cognition Course D303.

Baddeley, A.D. & Scott, D. (1971). 'Short-term forgetting in the absence of proactive inhibition'. Quarterly Journal of Experimental Psychology, 23, 275.

Baddeley, A.D., Thomson, N., & Buchanan, M. (1975). 'Word length and the structure of short-term memory'. Journal of Verbal Learning and Verbal Behaviour. 14, 575-589.

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

Bakker, D.J. (1972). Temporal Order in Disturbed Reading. Rotterdam University Press.

Bakker, D.J. & Schroots, H.J. (1980). 'Temporal Order in Normal and Disturbed Reading'. In G.Th. Pavlidis & T.R. Miles (Eds.), Dyslexia: Experimental Research and Educational Implications. London: Wiley and Sons.

Bakwin, H. (1973). 'Reading disability in twins'. Developmental Medicine and Child Neurology, 15,184. S

Bannatyne, A.(1968). 'Diagnosing learning disabilities and writing remedial prescriptions'. Journal of Learning Disabilities, 1, (4), 28-35.

Bannatyne, A. (1971). Language, Reading and Learning Disabilities. Springfield, Charles C. Thomas.

Baron, J. (1973). 'Phonemic stage not necessary for reading'. Quarterly Journal of Experimental Psychology, 25, 241-246.

Baron, J. & Strawson, C. (1976). 'Use of Orthographic and Word-Specific Knowledge in Reading Words Aloud'. Journal of Experimental Psychology: Human Perception and Performance, 2, 386-393.

Baron, J. & Thurston, I. (1973).'An analysis of the word-superiority effect'. Cognitive Psychology, 4, 207.

Bartlett, F.C. (1932) Remembering. Cambridge, Mass: University Press.

Bateman, B. (1977).'Teaching reading to learning disabled children. In L. B. Resnick & P.A.Weaver (Eds.) Theory and Practice of Early Reading. Hillsdale, N.J.: Erlbaum. S

Baxt, N. (1871). 'Ueber die Zeit welche notig ist, damit ein Gesichtseindruck zum Bewusstein Kommt und uber die Grosse der bewussten Wahrnehmung bei einem Gesichtsei- ndrucke von gegenbener Daver'. Pfluger's Arch. ges. Physiol., 4, 325-336. S

Beaumont, J.G. & Rugg, M.D. (1978).'Neuropsychological Laterality of Function and Dyslexia: Dyslexia Review'. 1, (1).

Belmont, J.M. & Butterfield, E.C. (1971). 'What the development of short-term memory is'. Human Development, 14, 236.

Benton, A.L. (1975).'Developmental dyslexia: neurological aspects'. In W.J. Friedlander (Ed.) Advances in Neurology, 7, New York: Raven Press.

Benton, A. (1978)'Some conclusions about dyslexia'. In A.L. Benton & D. Pearl (Eds.) Dyslexia: An Appraisal of Current Knowledge. New York: Oxford University Press.

Birch, H.G. & Belmont, L. (1965). 'Auditory-visual integration, intelligence and reading ability'. Perceptual and Motor Skills, 20, p.295.

Blair, F.X. (1957).'A study of the visual memory of deaf and hearing children. American Annals of the Deaf, 102, 254-263.

Blank, M. & Bridger, W.H. (1966). Deficiences in verbal labelling in retarded readers. American Journal of Orthopsychiatry, 36, 840-847.

Blank, M., Weider, S., & Bridger, W.H. (1968). 'Verbal deficiences in abstract thinking in early reading retardation'. American Journal of Orthopsychiatry 38, 823-834.

Bleisner, E.P. & Yarborough, B.H. (1965). 'A comparison of ten different beginning reading problems in first grade. Phi. Delta Kappan, 1965, June, 500. S

Blumenthal, A.L. (1977). The Process of Cognition. Englewood Cliffs, N.J.:Prentice-Hall Inc.

Boden, M. (1977). Artificial Intelligence and Natural Man. Hassocks, Sussex: Harvester Press.

Boder, E. (1971) 'Developmental dyslexia: Prevailing concepts and a new diagnostic approach'. In H.R. Myklebust (ed.), Progress in Learning Disabilities, vol. II New York: Grune and Stratton.

Boies, K.G. (1971). 'An experimental study of aphasia: An investigation of the naming process in brain damaged populations'. Doctoral dissertation, University of Oregon. S

Bousfield, W.A. & Sedgewick, C.H. (1944). 'An analysis of sequences of restricted associative responses'. Journal of General Psychology , 30, 149-165.

Bower, G.H. (1970). 'Analysis of mnemonic device'. American Scientist, 58, 496-510.

Bower, G.H. (1972).'A selective review of organizational factors in memory'. In E. Tulving & W. Donaldson (Eds.) Organization of Memory, New York: Academic Press.

Bower, G.H. & Winzenz, D. (1969). Group structure, coding, and memory for digit series. Journal of Experimental Psychology Monograph, 80, (2, Part 2).

Bradley, L. & Bryant, P.E. (1978). 'Difficulties in auditory organization as a possible cause of reading backwardness'. Nature, 270.

Bradshaw, J.L. (1975).'Three interrelated problems in reading: A review'. Memory and Cognition, 3, 123-134.

Breitmeyer, B.G. & Ganz, L. (1976). 'Implications of sustained and transient channels for theories of visual pattern masking, saccadic suppression, and information processing'. Psychological Review, 83, 1.

Brener, R. (1940). 'An exper-mental investigation of memory span'. Journal of Experimental Psychology, 26, 467-482.

Brewer, W.F. (1963). 'Specific language disability: Review of the literature and a family study'. Honors thesis. Harvard University. S

Broadbent, D.A. (1971). Decision and Stress, New York & London: Academic Press.

Broadbent, D.A. (1977). 'The hidden preattentive processes'. American Psychologist, 32, 109.

Brooks, L.R. (1967). 'The suppression of visualization by reading'. Quarterly Journal of Experimental Psychology, 19, 289-299.

Brooks, L.R. (1968). 'Spatial and verbal components of the art of recall'. Canadian Journal of Psychology, 22, 349-368.

Brown, R. & McNeill, D. (1966). 'The "tip of the tongue" phenomenon'. Journal of Verbal Learning and Verbal Behaviour, 9, 190-196.

Bryden, M.P. (1970). 'Laterality effects in Dichotic Listening: Relations with Handedness and Reading Ability in Children'. Neuropsychologia, 8, 443.

Calfee, R.C., Chapman, R.S. & Venezky, R.L. (1970). 'How a child needs to think to learn to read'. Technical report No. 131, Wisconsin Research and Development Centre for Cognitive Learning. S

Callaway, E. (1975). Brain Electrical Potentials and Individual Psychological Differences. Grune & Stratton.

Cashdan, A. (1970). 'Backward readers - research on auditory/visual integration'. in J.F. Reid (ed.). Reading Skills: Problems and Practices . Ward Lock Educational.

Cavanagh, J.P. (1972). 'Relation between the immediate memory span and the memory search rate'. Psychological Review, 79, 525-530.

Cavanagh, J.P. (1976). 'Holographic and trace strength models of rehearsal effects in the item recognition task'. Memory & Cognition, 4, 186.

Chall, J. (1967). Learning to read - The great debate. S
New York: McGraw Hill.

Chi, M.T.H. (1976). 'Short-term memory limitations in children: Capacity or processing deficits?' Memory and Cognition, 4, 559-572.

Chow, S.L. & Murdock, B.B. (1976). 'Concurrent Memory Load and the Rate of Readout from Iconic Memory'. Journal of Experimental Psychology: Human Perception and Performance, 2, 179-190.

Clark, S.E. (1969). 'Retrieval of color information from pre-perceptual memory'. Journal of Experimental Psychology. 82, 263-266.

Clements, S.D. (1967). Some aspects of the characteristics, management and education of the child with minimal S brain dysfunction . Glen Ellyn, Illinois: West Suburban Association for the Other Child.

Cohen, G. (1969) 'Some evidence for parallel comparisons in a letter recognition task'. Quarterly Journal of Experimental Psychology, 21, 272-279.

Cohen, G. (1978) 'Speech perception and reading'. Open University Cognitive Psychology Course, Units 9-10. Milton Keynes: Open University Press.

Cohen, R.L. & Granstrom, K. (1970). 'Reproduction and recognition in short-term visual memory'. Quarterly Journal of Experimental Psychology, 22, 450-457.

Cohen, R.L. & Netley, C. (1977). 'Short-term memory deficits in poor readers, under conditions of minimal rehearsal'. Paper presented at Canadian Psychology Association meeting Ottawa, June, 1977.

Cole, R.A. & Scott, B. (1974). 'Toward a theory of speech perception'. Psychological Review, 81, 348-374.

Collins, A.M. & Quillian, M.R. (1970). 'Does category size affect categorization?' Journal of Verbal Learning and Verbal Behaviour, 9, 432-438.

Coltheart, M. (1972). 'Visual information processing'. In P.C. Dodwell (ed.) New Horizons in Psychology II, Penguin Education, 62-85.

Coltheart, M. (1978). 'Experimental design: a case study. Block 1, Unit 2 Open University Course D303, Cognitive Psychology, Milton Keynes: Open University Press.

Coltheart, M. (1979) 'Mysteries of reading in brain defects'. New Scientist, 81, (1141), 368-370.

Coltheart, M., Davelaar, E., Jonasson, J.T. & Besner, D. (1977). 'Access to the Internal Lexicon'. In S. Dornic (ed.), Attention and Performance VI,Hillsdale, New Jersey: Lawrence Erlbaum.

Coltheart,M. & Glick, M.J. (1974). 'Visual imagery: a case study'. Quarterly Journal of Experimental Psychology. 26, 438-453.

Coltheart, M., Patterson, K.E. & Marshall, J.C. (Eds.)(1979). Deep Dyslexia. Routledge & Kegan Paul: London.

Conners, C.K. (1978). 'Critical Review of "Electroncephalographic and Neurophysiological Studies in Dyslexia'. In A.L. Benton & P. Pearl (Eds.) Dyslexia: An Appraisal of Current Knowledge, New York: Oxford U.P.

Conners, C.K., Kramer, K. & Guerra, F. 1969. 'Auditory Synthesis and dichotic listening in children with learning disabilities'. Journal of Special Education, 3, 163.

Conrad, R. (1964). 'Acoustic confusion in immediate memory'. British Journal of Psychology, 55; 75-84.

Conrad, R. (1971). 'The chronology of the development of covert speech in children'. Developmental Psychology, 5, 398.

Conrad, R. (1972(a)). 'Speech and reading'. In J.F. Kavanagh & I.G. Mattingley (eds.) Language by eye and by ear. Cambridge, Mass.: MIT press.

Conrad, R. (1972(b). 'The developmental role of Vocalizing in Short-Term Memory'. Journal of Verbal Learning and Verbal Behaviour. Il, 521-533.

Conrad, R. (1972(c). 'Short-term memory in the deaf: a test for speech coding'. British Journal of Psychology. 63, (2), 173-180.

Corkin, S. (1974). 'Serial-ordering deficits in inferior readers'. Neuropsychologia, 12, 347.

Cotterell, G.C. (1970). 'Teaching procedures' 49-70 in Assessment and Teaching of Dyslexic Children ed. Franklin, A.W. and Naidoo, S. London: Invalid Children's Aid Association.

Craik, F.I.M. & Lockhart, R.S. (1972). 'Levels of processing: a framework for memory research'. Journal of Verbal Learning and Verbal Behaviour, 11, 671-684.

Crannel, C.W. & Parrish, J.M. (1957). 'A Comparison of immediate memory span for digits, letters and words'. Journal of Psychology, 44, 319-327.

Critchley, M. (1970). The dyslexic child London: Heinemann Medical Books.

Critchley, M. & Critchley, E.A. (1978) Dyslexia Defined London: Heinemann Medical Books.

Crowder, R.G. & Morton, J. (1969). 'Precategorical acoustic storage (PAS)'. Perception and Psychophysics, 5, 365-373.

Cumming, G. & Coltheart, M. (1969). 'Short-term memory: Are item and position information stored independently?' Psychonomic Science, 15, 216-218.

Daehler, M.W., Horowitz, A.B., Wynns, F.C. & Flavell, J.H. (1969). 'Verbal and non-verbal rehearsal in children's recall'. Child Development, 40, 443.

Dainoff, M.J. (1970). 'Time course of visual and auditory encoding'. Journal of Experimental Psychology, 86, 214-224.

Dainoff, M.J. & Haber, R.N. (1970). 'Effect of acoustic confusability on levels of information processing'. Canadian Journal of Psychology, 24, 98-108.

Davidenkov, S.N. (1956). 'Visual Agnosias'. State Publishing House of Medical Literature, 2. S

Davis, R., Moray, N., & Treisman, A. (1961). 'Imitative responses and the rate of gain of information'. Quarterly Journal of Experimental Psychology, 13, 78-89.

De Hirsch, K., Jansky, J.J. & Langford, W.S. (1966). Predicting Reading Failure. New York: Harper and Row.

De Leeuw, M. & De Leeuw, E. (1969). Read Better, Read Faster. Penguin.

Dember, W.N. & Neiburg, A.(1966). 'Individual differences in susceptibility to backward masking'. Psychonomic Science, 6, 2, 48-50.

Denckla, M.B. (1972). 'Color naming in dyslexic boys'. Cortex, 8, 164-176.

Denckla, M.B. & Rudel, R.(1974).'"Rapid "automized" naming of pictured objects, colours, letters and numbers by normal children'. Cortex, 10, 186-202.

Denckla, M.B. & Rudel, R. (1976). 'Naming of object-drawings by dyslexic and other learning disabled children'. Brain and Language, 3, 1-15.

Den Heyer, K. & Barrett, B. (1971). 'Selective loss of visual and verbal interpolated tasks'. Psychonomic Science, 25, 100-102.

De Renzi, E. & Vignolo, L.A. (1962). 'The Token test: a sensitive test to detect receptive disturbances in aphasics'. Brain, 85, 665-679.

Ditchburn, R.W. (1955). 'Eye movements in relation to retinal action'. Optica Acta, 1, 171-176.

Doehring, D.G. (1978). 'The tangled web of behavioural research on Developmental Dyslexia'.In A.L. Benton & P. Pearl (Eds.) Dyslexia: An Appraisal of Current Knowledge, New York: Oxford University Press.

Doehring, D.G. & Hoshito, I.M. (1977). 'Classification of Reading Problems by the Q-Technique of Factor Analysis'. Cortex, 13, 281.

Donders, F.C. (1868). 'Die Schnelligkeit psychischer Processe'. Archives of Anatomy and Physiology. pp 657-81. Translated by W.G. Koster (1969). Acta Psychologica, 30, 412. S

Done, D.J. & Miles, T.R. (1978). 'Learning, Memory and Dyslexia'. In: M.M. Gruneberg, P.E. Morris & R.N. Sykes (Eds.) Practical Aspects of Memory Academic Press: London.

Doost, R. & Turvey, M.T. (1971). 'Iconic Memory and Central Processing Capacity'. Perception and Psychophysics, 9, 269-274.

Drew, A.L. (1956). 'A neurological appraisal of familial congenital word-blindness'. Brain, 79, 440.

Earnst, G.W. & Newell, A. (1969). GPS: A Case Study in Generality and Problem Solving. New York: Academic Press. S

Ebbinghaus, H. (1885) Uber das Gedacht nis Leipzig: Dunker. H. Ruyer & C.E. Bussenius (trans.), Memory, New York: Teachers College Press, 1913. S

Efron, R. (1969). 'What is perception?' In R. Cohen & M. Wartofsky (Eds.), Boston studies in the philosophy of science, New York: Humanities Press.

Egeth, H.E. (1966). 'Parallel versus serial processes in multi-dimensional stimulus discrimination'. Perception and Psychophysics, 1, 246-252.

Eisenberg, L. (1978) 'Definitions of Dyslexia: Their Consequences for Research and Policy'. In A.L. Benton & P. Pearl (Eds.) Dyslexia: An Appraisal of Current Knowledge. New York: Oxford University Press.

Ellis, A.W. (1980). 'Developmental and acquired dyslexia: some observations on Jorm (1979)'. Cognition, in press.

Ellis, N.C. (1979). 'A model for the Reading/STM Correlation'. Paper presented to the British Psychological Society's (Cognitive Section) Conference on "Cognitive Models". London. December, 1979.

Ellis, N.C. Baddeley, A.D., Miles, T.R. Lewis, V. Limitations in Reading Ability and Short-Term Memory Span. In Preparation.

Ellis, N.C. & Miles, T.R. (1977a). 'Visual and name coding in dyslexic and non-dyslexic subjects'. Paper presented to the Experimental Psychology Society.

Ellis, N.C. & Miles, T.R. (1977b) 'Dyslexia as a limitation in the ability to process information'. Orton Society Bulletin, XXVII, 72-81.

Ellis, N.C. & Miles, T.R. (1978a) 'Visual information processing as a determinant of reading speed'. Journal of Reading Research, 1, (2) 108-120.

Ellis, N.C. & Miles, T.R. (1978b) 'Visual Information Processing in Dyslexic Children'. In M.M. Gruneberg, P.E. Morris & R.N. Sykes (Eds.) Practical Aspects of Memory. Academic Press: London.

Ellis, N.C. & Miles, T.R. (1978c). 'Visual Information Processing in Dyslexic Children'. Dyslexia Review. 1,(2) 10-12.

Ellis, N.C. & Miles, T.R. (1980). 'A Lexical Encoding Deficiency I: Experimental Evidence'. To appear in G. Pavlidis & T.R. Miles (Eds.) Dyslexia Research and its Application to Education. Chichester: Wiley.

Eriksen, C.W. & Collins, J.F. 1968. 'Some temporal characteristics of visual pattern perception'. Journal of Experimental Psychology, 74, 476-484.

Estes, W.K. (1973). 'Phonemic coding and rehearsal in short-term memory'. Journal of Verbal Learning and Verbal Behaviour, 12, 360-372.

Farnham-Diggory, S. (1978) Learning Disabilities. London: Fontana/Open Books.

Fenelon, B. (1968). 'Expectancy waves and other complex cerebral events in dyslexic and normal subjects'. Psychonomic Science, 13, 253.

Finucci, J.M., Guthrie, J.T., Childs, A.L., Abbey, H.&Childs,B. (1976). 'The genetics of specific reading disability'. Annals of Human Genetics, 40, 1. S

Firth, I. (1972). Components of reading disability. Unpublished doctorate dissertation, University of New South Wales, Australia. S

Fletcher & Atkinson, R.C. University of Stanford CAI Reading Project Technical Reports, 74, 111, 119, 158, 168 and 216. S

Fraisse, P. & Blancheteau, M. (1962). 'The influence of number of alternatives on the perceptual recognition threshold'. Quarterly Journal of Psychology, 14, 52.

Frederiksen, J.R. & Kroll, J.K. (1976). 'Spelling and Sound: Approaches to the Internal Lexicon'. Journal of Experimental Psychology: Human Perception and Performance, 2, 361-379.

Fries, C.C. (1962) Linguistics and Reading. New York: Holt, Rinehart & Winston.

Fry, D.B. & Whetnall, E. (1954). 'The Auditory approach in the training of deaf children'. Lancet, 1, 583.

Fry, D.B. & Whetnall, E. (1964). The Deaf Child. London: Heinemann Medical Books.

Fuchs, A.H. (1969). 'Recall for order and content of serial word-lists in short-term memory'. Journal of Experimental Psychology, 82, 14-21.

Furth, H.G. (1964). 'Research with the deaf: Implications for language and cognition'. Psychological Bulletin, 62, 145-164.

Geschwind, N. (1964). 'The Development of the Brain and the Evolution of Language'. In C.I.J.M. Stuart (Ed.) Monograph Series on Language and Linguistics. Washington: Georgetown University Press.

Geschwind, N. (1965). Disconnexion Syndromes in Animals and Man. Brain, 88, 237 and 585.

Geschwind, N. (1968). 'Isolation of the Speech Area'. Neuropsychologia, 6, 327.

Geschwind, N.(1969). 'The Alexias'. In P.J. Vinken & G.W. Pruyn (Eds.) Handbook of Clinical Neurology Vol. 4 Amsterdam: North Holland.

Geschwind, N. (1974). Selected Papers on Language and the Brain. Boston studies in the Philosophy of Science, Vol. XVI, Dordrecht, Holland: D. Reidel Publishing Co.

Gibson, E.J., Bishop, C., Schiff, W., & Smith, J. (1964). 'Comparison of meaningfulness and pronunciability as grouping principles in the perception and retention of verbal material'. Journal of Experimental Psychology, 67, 173.

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

Gibson, E.J. & Guinet, L. (1971). 'The perception of inflections in brief visual presentations of words'. Journal of Verbal Learning and Verbal Behaviour, 10, 182.

Gibson, E.J. & Levin, H. (1975). The Psychology of Reading. Cambridge, Mass.: M.I.T. Press.

Gilbert, L.C. (1959 a). 'Speed of processing visual stimuli and its relation to reading'. Journal of Educational Psychology, 55, 1, 8-14.

Gilbert, L.C. (1959b). 'Saccadic movements as a factor in visual perception in reading'. Journal of Educational Psychology, 55, 1, 15-19.

Gillingham, A. & Stillman, B.W. (1956). Remedial training for children with specific disability in reading, spelling and penmanship. Educators Publishing Service. Cambridge: Mass.

Gillingham, A., Stillman, B.W., & Childs, S.B. (1970). 'The Gillingham-Childs Phonic Proficiency Scales'. Cambridge, Mass: Educators Publishing Service.

Gleitman, L.R. & Rozin, P. (1973). 'Teaching reading by use of a syllabary'. Reading Research Quarterly, 8, 447-483.

Gleitman, L.R. & Rozin, P. (1977). 'The structure and acquisition of reading I: relations between orthographies and the structure of language'. In A.S. Reber & D.L. Scarborough (eds.), Towards a Psychology of Reading. New York: Lawrence Erlbaum Associates.

Gloning, I., Gloning, K., & Hoff, H. (1963). 'Aphasia - a Clinical Syndrome'. In Problems of Dynamic Neurology. L. Halpern (Ed.) Jerusalem Post Press: Jerusalem.

S

Glushko, R.J. (1978). 'The organization and activation of orthographic knowledge in reading aloud'. Occasional papers No. 1. Center for Human Information Processing, University of California, San Diego.

Goldberg, H.K. (1968). 'Vision, perception and related factors in dyslexia'. In A.H. Keeney & V.T. Keeney (eds.), Dyslexia. St. Louis: Mospy.

Goldstein, K. (1948). Language and Language Disturbance. New York.

Goldstein, K. & Scheerer, M. (1941). Abstract and Concrete Behaviour. Psychological Monographs, 53, (2). Illinois: American Psychological Association Inc.

Gough, P.B. (1972). 'One second of reading'. In J.F. Kavanagh & I.G. Mattingly (eds.) Language by ear and by eye. Cambridge: Mass., MIT Press.

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

Greene, J. & Holloway, C. (1978). 'Models and Methodologies'. Cognitive Psychology, Block 1, Unit 1. The Open University: Milton Keynes.

Griffiths, J.M. (1976). 'Dyslexia and dyscalculia'. Unpublished paper delivered at a conference organized by the University College of North Wales Dyslexia Unit.

Groenendaal, H.A. & Bakker, D.J. (1971). 'The part played by mediation processes in the retention of temporal sequences by two reading groups'. Human Development, 14, 62.

Gruber, E. (1962). 'Reading ability, binocular co-ordination and the opthalmograph'. Archives of Opthalmology, 67, 34-42.

Gummerman, K. & Gray, C.R. (1972). 'Age, iconic storage, and visual information processing. Journal of Experimental Child Psychology, 13, 165-170.

Guthrie, J.T. (1978). 'Principles of instruction: a critique of Johnson's "Remedial approaches to dyslexia"'. In A.L. Benton & P. Pearl (Eds.). Dyslexia: An Appraisal of Current Knowledge. New York: Oxford University Press.

Guzman, A. (1969). 'Decomposition of a Visual Field into Three-Dimensional Bodies'. In Automatic Interpretation and Classification of Images. Ed. A. Grasselli. New York: Academic Press.

S

Haber, R.N. 'Visual information storage'.In: National Research Council, Division of Behavioural Sciences: Visual Search: Symposium conducted at the Spring Meeting 1970. Washington D.C.: National Academy of Sciences 1973.

Haber, R.N. & Nathanson, L.S. (1968). 'Post retinal storage Park's camel as seen through the eye of a needle'. Perception and psychophysics, 3, 349-355.

Haber, R.N. & Standing, L. (1969). 'Direct measures of short term visual storage'. Quarterly Journal of Experimental Psychology, 21, 43-54.

Hardyck, C.D. & Petrinovich, L.F. (1970). 'Subvocal speech and comprehension level as a function of the difficulty of reading material'. Journal of Verbal Learning and Verbal Behaviour, 9, 647-652.

Harris, G.J. & Burke, D. (1972). 'The effects of grouping on short-term serial recall by children: Developmental trends'. Child Development, 43, 710.

Hayes, P. (1979). 'On the difference between Psychology and Artificial Intelligence'. Artificial Intelligence and the Simulation of Behaviour Quarterly, 34,8.

Head, H. (1926). Aphasia and Kindred Disorders of Speech. Macmillan: London.

Hecaen, H., De Ajuriaguerra, J. & David, M. (1957). 'Les troubles de la lecture dans le cadre des modifications des fonctions symboliques'. Psychiat. Neurol. (Basel), 134, 97. cited in Geschwind, 1969. S

Hecaen, H. & Kremin, H. (1976). 'Neurolinguistic research disorders resulting from left hemisphere lesions: aphasic and "pure" alexias In H. Whitaker & H. A. Whitaker (eds.), Studies in neuro-linguistics, Vol. 2. New York: Academic Press. S

Henderson, L. (1972). 'Visual and Verbal codes: spatial information survives the icon. Quarterly Journal of Experimental Psychology, 24, 439-447.

Henderson, L. (1977). 'A word superiority effect without orthographic assistance'. Quarterly Journal of Experimental Psychology.

Hermann, K. (1959). 'Reading disability: a medical study of word-blindness and related handicaps'. Copenhagen: Munksgaard.

Hermann, K. & Norrie, E. (1958). 'Is congenital word-blindness a hereditary type of Gerstmann's syndrome?' Psychiatrica ac Neurologica, 136, 59-73.

Hickey, K. (1976). Dyslexia. A Language Training Course for Teachers and Learners. Manual. London: Hickey.

Hinschelwood, J. (1917). Congenital Word Blindness. S
London: Lewis.

Hitch, G.J. & Baddeley, A.D. (1976). 'Verbal reasoning and working memory'. Quarterly Journal of Experimental Psychology, 28, 603-621.

Holmes, J.M. (1973). Dyslexia: a neurolinguistic study of traumatic and developmental disorders of reading. Unpublished Ph.D. thesis, University of Edinburgh.

Hornsby, B. & Miles, T.R. (1980). 'The effects of dyslexia in centred teaching programme'.In Preparation.

Hornsby, B. & Shear, F. (1974). Alpha to Omega. Heinemann: Guildford.

Howes, D. & Solomon, R. L. (1951). 'Visual duration threshold as a function of word probability'. Journal of Experimental Psychology, 41, 401.

Huey, E.B. (1908). The psychology and pedagogy of reading. New York: Macmillan. Republished by the MIT Press, Cambridge, Mass., 1968.

Huggins, A.W.F. (1964). 'Distortion of the temporal pattern of speech: interruption and alteration'. Journal of the Acoustical Society of America, 36, 1055-64. S

Hughes, J.R. (1978). 'Electroencephalographic and Neurophysiological Studies in Dyslexia'. In A.L. Benton & D. Pearl (Eds.), Dyslexia: An Appraisal of Current Knowledge. New York: Oxford University Press.

Hunter, I.M.L. (1964). Memory. Harmondsworth: Penguin.

Hurlock, E.B. & Newmark, E.D. (1931). 'The memory span of pre-school children'. Journal of Genetic Psychology, 39, 157-173.

Huttenlocker, J. & Burke, D. (1976).'Why does memory span increase with age?' Cognitive Psychology, 8, 1.

Indown, T. and Togano, K. (1970) 'On retrieving sequence from long-term memory', Psychological Review, 77, 317-331.

Ingram, T.T.S. (1960) 'Pediatric aspects of developmental dysphasia, dyslexia and dysgraphia', Cerebral Palsy Bulletin, 2, 254-277. S

Ingram, T.T.S. (1964) 'The dyslexic child', Word Blind Bulletin, 1 (4), 1. S

Ingram, T.T.S., Mason, A.W. and Blackburn, I. (1970) 'A reprospective study of 82 children with reading disability', Developmental Medicine and Child Neurology, 12, 271. S

Jansen, M. (1973) In J. Downing (Ed.) Comparative Reading. New York: Macmillan.

Jansky, J. and de Hirsch, K. (1972) Predicting Reading Failure. New York: Harper and Row.

Johnson, D.J. and Myklebust, H.R. (1967) Learning Disabilities. New York: Grune and Stratton.

Jorm, A.F. (1979) 'The cognitive and neurological basis of developmental dyslexia: a theoretical framework and review', Cognition, 7, 19-33.

Kahneman, D. (1968) 'Method, findings, and theory in studies of visual masking', Psychological Bulletin, 70, 404-425.

Kawi, A.A. and Pasamanick, B. (1959) 'Prenatal and paranatal factors in the development of childhood reading disorders', Monograph of the Society for Research in Child Development, 24, (4), 1. S

Keeney, T.J., Cannizzo, S.R. and Flavell, J.H. (1967) 'Spontaneous and induced verbal rehearsal in recall task', Child Development, 38, 953.

Kelly, R.T. and Martin, D.W. (1974) 'Memory for random shapes: a dual task analysis', Journal of Experimental Psychology, 103, 224-229.

Kinsbourne, M. and Warrington, E.K. (1962) 'A disorder of simultaneous form perception', Brain, 85, 461.

Kirk, S.A. (1972) Educating Exceptional Children. S Boston: Houghton-Mifflin.

Kirk, S.A., McCarthy, J.J. and Kirk, W.D. 'The Illinois Test of Psycholinguistic Abilities: Examiners Manual. Revised Edition. Urbana: University of Illinois Press.

Klasen, E. (1972) The Syndrome of Specific Dyslexia. Lancaster: M.T.P.

Kleiman, G.M. (1975) 'Speech recoding in reading', Journal of Verbal Learning and Verbal Behaviour, 24, 323-339.

Kolers, P.A. and Katzman, M.T. (1966) 'Naming sequentially presented letters and words', Language and Speech, 9, 84-95.

Konorski, J. (1967) Integrative Activity of the Brain. Chicago: University of Chicago Press.

Kroll, N.E.A., Parks, T., Parkinson, S.R., Bieber, S.L. and Johnson, A.L. (1970) 'Short-term memory while shadowing: recall of visually and aurally presented letters', Journal of Experimental Psychology, 85, 220-214.

La Berge, D. and Samuels, S.J. (1974) 'Toward a theory of automatic information processing in reading', Cognitive Psychology, 6, 293-323.

Landauer, T.K. (1962) 'Rate of implicit speech', Perceptual and Motor Skills, 15, 646.

Legein, Ch.P. and Bouma, H. (1980) 'Visual recognition experiments in dyslexia'. To appear in G.Th. Pavlidis and T.R. Miles (Eds.) Dyslexia Research and Its Educational Implications. Chichester: Wiley.

Lenneberg, E.H. (1967) Biological Foundations of Language. New York: John Wiley.

Lerner, J.W. (1971) Children with Learning Disabilities. S Boston: Houghton-Mifflin.

Lesevre, N. (1964) 'Les movements oculaires d'exploration'. These de Paris. Cited in M. Critchley (1970) Op. Cit.

Levy, B.A. (1971) 'The role of articulation in auditory and visual short-term memory', Journal of Verbal Learning and Verbal Behaviour, 10, 123-132.

Levy, B.A. (1977) 'Reading: speech and meaning processes', Journal of Verbal Learning and Verbal Behaviour, 16, 623-628.

Levy, B.A. (1978) 'Speech analysis during sentence processing: reading versus listening', Visible Language, 12, 81-101.

Levy, D. (1979) 'Computers and chess', Elektor, 45 (1), 34.

Levy-Schoen, A. and O'Regan, K. (1979) 'The control of eye movements in reading'. In P.A. Kolers, M. Wrolstad and H. Bouma (Eds.) Processing of Visible Language I. New York and London: Plenum Press.

Liberman, A.M. (1970) 'The grammars of speech and language', Cognitive Psychology, 1, 301-323.

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

Liberman, I.Y., Shankweiler, D., Liberman, A.M., Fowler, C. and Fischer, F.W. (1977) 'Phonemic segmentation and recoding in the beginning reader'. In A.S. Reber and D. Scarborough (Eds.) Toward a Psychology of Reading. Hillsdale, N.J.: Erlbaum.

Liss, P.H. and Haith, M.M. (1970) 'The speed of visual processing in children and adults: effects of backward and forward masking', Perception and Psychophysics, 8, 396-398.

Locke, J.L. and Fehr, F.S. (1970) 'Young children's use of the speech code in a recall task', Journal of Experimental Child Psychology, 10, 367.

Lowe, D.G. (1975) 'Temporal aspects of selective masking', Quarterly Journal of Experimental Psychology, 27, 375-385.

Luria, A.R. (1966) Higher Cortical Functions in Man. New York: Basic Books.

Luria, A.R. (1973) The Working Brain. New York: Basic Books.

MacMeeken, M. (1939) Ocular Dominance in Relation to Developmental Aphasia. London: University of London Press. S

Mackworth, J.F. (1963) 'The relation between the visual image and post-perceptual immediate memory', Journal of Verbal Learning and Verbal Behaviour, 2, 75-85.

Mackworth, J.F. (1971) 'Some models of the reading process: learners and skilled readers'. In M. Kling, E.B. Davis and J.J. Geyer (Eds.) The Literature of of Research in Reading with Emphasis on Models. Project No. 2: The Literature Search. Cornell University and U.S. Office of Education. S

Mackworth, J.F. (1972) 'Some models of the reading process: learners and skilled readers', Reading Research Quarterly, 7, 701-753.

Mackworth, J.F. and Mackworth, N.H. (1974) 'How children read: matching by sight and sound', Journal of Reading Behaviour, 6 (3), 295-303.

Mackworth, N.H. (1965) 'Visual noise causes tunnel vision', Psychonomic Science, 3, 67-68.

Makita, K. (1968) 'The rarity of reading disability in Japanese children', American Journal of Orthopsychiatry, 38, 599-614.

Malmquist, E. (1958) Factors Related to Reading Disabilities in the First Grade of Elementary School. Stockholm: Almqvist and Wiksell.

Manzo, A.V. (1977) 'Dyslexia as specific psychoneurosis', Journal of Reading Behaviour, 9, 305.

Marcel, A. (1976) 'Unconscious reading - experiments on people who do not know that they are reading'. Paper given to the British Association for the Advancement of Science, September 1976.

Marcel, A. (1978) 'Prerequisites for a more applicable psychology of reading'. In M.M. Gruneberg, P.E. Morris and R.N. Sykes (Eds.) Practical Aspects of Memory. London: Academic Press.

Marcel, A.J. (1979) 'Surface dyslexia and beginning reading - a revised hypothesis of the pronunciation of print and its impairments'. To appear in M. Coltheart, K.E. Patterson and J.C. Marshall (Eds.) Deep Dyslexia. London: Routledge and Kegan Paul.

Marcel, A.J. (in preparation) Conscious and unconscious reading: the effects of visual masking on word perception

Marcel, A., Katz, L. and Smith, M. (1974) 'Laterality and reading deficiency', Neuropsychologia, 12, 131-139.

Marcel, A. and Patterson, K. (1978) 'Word recognition and production: reciprocity in clinical and normal studies'. In J. Requin (Ed.) Attention and Performance VII. New Jersey: Erlbaum.

Marie, P. (1926) Travaux et Memoires. Vol. 1 L'aphasie. S
Paris: Masson.

Marshall, J.C. and Newcombe, F. (1973) 'Patterns of paralexia: a psycholinguistic approach', Journal of Psycholinguistic Research, 2, 175-199.

Martin, P.R. and Fernberger, S.W. (1929) 'Improvement in memory span', American Journal of Psychology, 41, 91.

Massaro, D.M. (1979) 'Reading and listening'. In P.A. Kolers, M.E. Wrolstad and H. Bouma (Eds.) Processing of Visible Language, 1. New York and London: Plenum Press.

Matthews, M.L. and Henderson, L. (1970) 'Fast presentation rate and the recall of item and order information', Nature, 226, 374-376.

Mattingly, I.G. (1972) 'Reading, the linguistic process, and linguistic awareness'. In J.K. Kavanagh and I.G. Mattingly (Eds.) Language by Ear and by Eye. Cambridge, Mass.: MIT Press.

Mattis, S. (1978) 'Dyslexia syndromes: a working hypothesis that works'. In A.L. Benton and D. Pearl (Eds.) Dyslexia: An Appraisal of Current Knowledge. New York: Oxford University Press.

Mattis, S., French, J.H. and Rapin, I. (1975) 'Dyslexia in children and adults: three independent neurological syndromes', Developmental Medicine and Child Neurology, 17, 150.

McCarthy, J.J. and Kirk, S.A. (1961) Illinois Test of Psycholinguistic Abilities. Urbana, Illinois: Institute for Research in Exceptional Children.

McCarver, R.B. (1972) 'A developmental study of the effect of organization cues on short-term memory', Child Development, 43, 1317.

McClearn, G.E. (1978) 'Review of "Dyslexia - Genetic Aspects"'. In A.L. Benton and D. Pearl (Eds.) Dyslexia: An Appraisal of Current Knowledge. New York: Oxford University Press.

McFie, J. (1960) 'Psychological testing in clinical neurology, Journal of Nervous and Mental Disease, 131, 383.

McKeever, W.F. and Van Deventer, A.D. (1975) 'Dyslexic adolescents: evidence of impaired visual and auditory language processing associated with normal lateralization and visual responsivity', Cortex, 11, 361.

McLeod, J. (1967) 'Some perceptual factors related to childhood dyslexia'. In M.D. Jenkinson (Ed.) Reading Instruction: An International Forum. Newark, Del.: International Reading Association. S

McNicol, D. (1971) 'The confusion of order in short-term memory, Australian Journal of Psychology, 23, 77-84.

Merickle, P. (1976) 'On the disruption of visual memory: interference produced by visual report cues', Quarterly Journal of Experimental Psychology, 28, 193-202.

Merickle, P.M. and Coltheart, M. (1972) 'Selective forward masking', Canadian Journal of Psychology, 26, 296-302.

Merickle, P.M., Coltheart, M. and Lowe, D.G. (1971) 'On the selective efforts of a patterned masking stimulus', Canadian Journal of Psychology, 25, 264-279.

Meudell, P.R. (1972) 'Short-term visual memory: comparative effects of two types of distraction on the recall of visually presented verbal and nonverbal material', Journal of Experimental Psychology, 94,

Meudell, P. (1980) 'Alexia, dyslexia and normal reading'. To appear in G.Th. Pavlidis and T.R. Miles (Eds.) Dyslexia Research and its Educational Implications. Chichester: Wiley.

Meyer, D.E., Schvaneveldt, R.W., and Ruddy, M.G. (1975) 'Loci of contextual effects on visual word-recognition'. In Rabbitt, P.M.A. and Dornic, S. (Eds.) Attention and Performance V. London: Academic Press.

Miles, E. (1980) 'A study of dyslexic weaknesses and the consequences for teaching'. In G.Th. Pavlidis and T.R. Miles (Eds.) Dyslexia Research and its Educational Implications. Chichester: Wiley.

Miles, T.R. (1961) 'Two cases of developmental aphasia', J. Child. Psychol. Psychiat., 48-70.

Miles, T.R. (1970) On Helping the Dyslexic Child. London: Methuen Educational Ltd.,

Miles, T.R. (1975) The Dyslexic Child. Priory Press.

Miles, T.R. (1975) 'Dysnechia: or "more on the dyslexia dilemma"', Dyslexia Review, 14, 4.

Miles, T.R. (1978) Understanding Dyslexia, London: Hodder and Stoughton.

Miles, T.R. (1979) 'Dyslexia as a limitation in short-term memory'. Talk delivered to St. Bartholomew's Hospital, London.

Miles, T.R. (in preparation) Dyslexia Face to Face. Granada.

Miles, T.R. and Ellis, N.C. (1980) 'Dyslexia as a lexical encoding deficiency II: clinical observation'. To appear in G.Th. Pavlidis and T.R. Miles (Eds.) Dyslexia Research and its Educational Implications. Chichester: Wiley.

Miles, T.R. and Miles, E. (1975) More Help for Dyslexic Children. London: Methuen Educational Ltd.

Miles, T.R. and Wheeler, T.J. (1974) 'Towards a new theory of dyslexia', Dyslexia Review.

Miles, T.R. and Wheeler, T.J. (1977) 'Responses of dyslexic and non-dyslexic subjects to tachistoscopically presented digits', I.R.C.S. Medical Science, 5, 149.

Miller, G.A., Bruner, J.S. and Postman, L. (1954) 'Familiarity of letter sequences and tachistoscopic identification', Journal of General Psychology, 50, 129.

Miller, G.A., Heise, G.A. and Lichten, W. (1941) 'The intelligibility of speech as a function of the context of the test materials', Journal of Experimental Psychology, 41, 329.

Minsky, M.L. and Papert, S. (1973) Artificial Intelligence. Eugene, Oregon: Condon Lecture Publications.

Mitchell, D.C. (1972) 'Short-term visual memory and pattern masking', Quarterly Journal of Experimental Psychology, 24, 294-305.

Mitchell, D.C. (1976) 'Buffer storage modality and identification time in tachistoscopic recognition', Quarterly Journal of Experimental Psychology, 28, 325-337.

Mittler, P. and Ward, J. (1970) 'The use of the Illinois Test of Psycholinguistic Abilities on British four-year-old children', British Journal of Educational Psychology, 40, 43.

Morley, M.E. (1972) The Development and Disorders of Speech in Childhood, 3rd edition. Edinburgh: Churchill Livingstone.

Morton, J. (1964) 'The effects of context upon speed of reading, eye-movements and eye-voice span', Quarterly Journal of Experimental Psychology, 16, 340-354.

Morton, J. (1968) 'Repeated items and decay in memory', Psychonomic Science, 10, 219.

Morton, J. (1969) 'The interaction of information in word recognition', Psychological Review, 76, 165-178.

Morton, J. (1970) 'A functional model of memory'. In D.A. Norman (Ed.) Models of Human Memory. New York: Academic Press.

Morton, J. (1977) Perception into Memory, Open University Cognitive Psychology Course D303, Unit 14. Milton Keynes: Open University Press.

Morton, J. (1978) 'Facilitation in word recognition: experiments causing change in the logogen model'. In H. Bouma, P.A. Kolers and M. Wrolstad (Eds.) Processing of Visible Language.

Morton, J. (1979) 'Word recognition'. In J. Morton and J.C. Marshall (Eds.) Psycholinguistic Series 2: Structures and Processes. London: Elek.

Moyle, D. (1968) The Teaching of Reading. London: Ward Lock.

Muehl, S. and Forell, E.R. (1973) 'A follow-up study of disabled readers: variables related to high school reading performance', Reading Research Quarterly, 9, 110.

Murray, D.J. (1967) 'The role of speech responses in short-term memory', Canadian Journal of Psychology, 21(3), 263-276.

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

Murray, D.J. and Roberts, B. (1968) 'Visual and auditory presentation, presentation rate, and short-term memory in children', British Journal of Psychology, 59, 119.

Murrell, G.A. and Morton, J. (1974) 'Word recognition and morphemic structure', Journal of Experimental Psychology, 102, 963-968.

Myklebust, H.R. (1952) Exceptional Children, 19, 9

Naidoo, S. (1970) 'The assessment of dyslexic children'. In A.W. Franklin and S. Naidoo (Eds.) Assessment and Teaching of Dyslexic Children. London: Invalid Children's Aid Association.

Naidoo, S. (1972) Specific Dyslexia. Bath: Pitman Press.

Naidoo, S. (1980) 'The teaching of dyslexic children'. In G.Th. Pavlidis and T.R. Miles (Eds.) Dyslexia Research and its Educational Implications. Chichester: Wiley.

Neale, M.D. (1958) Neale Analysis of Reading Ability (test booklet). Macmillan 1966.

Neisser, U. (1954) 'An experimental distinction between perceptual process and verbal response', Journal of Experimental Psychology, 47, 399-402.

Neisser, U. (1963) 'Decision time without reaction time: experiments in visual scanning', American Journal of Psychology, 76, 376-385.

Neisser, U. (1967) Cognitive Psychology. New York: Appleton-Century-Crofts.

Neisser, U. (1976) Cognition and Reality. San Francisco: W.H. Freeman & Co.

Neisser, U. and Beller, H.K. (1965) 'Searching through word lists', British Journal of Psychology, 66, 349-358.

Newcombe, F. (1969) Missile Wounds of the Brain: A Study of Psychological Defects. London: Oxford University Press.

Newell, A. (1974) 'You can't play twenty questions with nature and win'. In W.G. Chase (Ed.) Visual Information Processing. New York: Academic Press.

Newton, M. and Thomson, M. (1976) The Aston Index: a Classroom Test for Screening and Diagnosis of Language Difficulties. Cambridge: Learning Development Aids.

Nickerson, R.S. (1972) 'Binary-classification reaction time: a review of some studies of human information-processing capabilities', Psychonomic Science Monograph Supplements, 4, 275-318.

Norman, D.A. (1978) Overview, Open University Cognitive Psychology Course, Units 31-32. Milton Keynes: Open University Press.

Oldfield, R.C. (1966) 'Things, words and the brain', Quarterly Journal of Experimental Psychology, 18, 340-353.

Oldfield, R.C. and Wingfield, A. (1965) 'Response latencies in naming objects', Quarterly Journal of Experimental Psychology, 17, 273-281.

Olsson, J.E. and Furth, H.G. (1966) 'Visual memory span in the deaf', American Journal of Psychology, 79, 480-484.

Ornstein, P.A., Naus, M.J. and Liberty, C. (1975) 'Rehearsal and organizational processes in children's memory', Child Development, 46, 818.

Orton, S.T. (1937) Reading, Writing and Speech Problems in Children. New York: W.W. Norton & Co.

Owen, F.W. (1978) 'Dyslexia - genetic aspects'. In A.L. Benton and D. Pearl (Eds.) Dyslexia: An Appraisal of Current Knowledge. New York: Oxford University Press.

Panchella, R.G. (1974) 'The interpretation of reaction time in information-processing research'. In Kantowitz (Ed.) Human Information Processing. London: Wiley.

Parks, T., Parkinson, S.R. and Kroll, N.E. (1971) 'Visual and auditory short-term memory: effects of phonemically similar auditory shadow material during the retention interval', Journal of Experimental Psychology, 87, 274-280.

Patterson, K.E. (1978) 'Phonemic dyslexia: errors of meaning and the meaning of errors', Quarterly Journal of Experimental Psychology, 30, 587-601.

Patterson, K.E. and Marcel, A.J. (1977) 'Aphasia, dyslexia and the phonological coding of written words', Quarterly Journal of Experimental Psychology, 29, 307-318.

Pavlidis, G.Th. (1978) 'The dyslexics' erratic eye movements: case studies', Dyslexia Review, 2(1), 22-28.

Perfetti, C.A. and Hogaboam, T. (1975) 'The realtionship between simple word decoding and reading comprehension skill', Journal of Educational Psychology, 67, 461-469.

Phillips, W.A. (1974) 'On the distinction between sensory storage and short-term visual memory', Perception and Psychophysics, 16, 283-290.

Phillips, W.A. and Baddeley, A.D. (1971) 'Reaction time and short-term visual memory', Psychonomic Science, 22, 73-74.

Phillips, W.A. and Christie, D.F.M. (1977a) 'Components of Visual Memory', Quarterly Journal of Experimental Psychology, 29, 117-133.

Phillips, W.A. and Christie, D.F.M. (1977b) 'Interference with visualization', Quarterly Journal of Experimental Psychology, 29, 637-650.

Pollock, J. (1978) Signposts to Spelling. London: Helen Arkell Dyslexia Centre.

Posner, M.I. (1969) 'Abstraction and the process of recognition'. In J.T. Spence and G. Bower (Eds.) The Psychology of Learning and Motivation, Vol. 3. Academic Press.

Posner, M.I., Boies, S.J., Eichelman, W.H. and Taylor, R.L. (1969) 'Retention of name and visual codes of single letters', Journal of Experimental Psychology, 79, 1-16.

Posner, M.I. and Keele, S.W. (1967) 'Decay of visual information from a single letter', Science, 158, 137-139.

Posner, M.I. and Konick, A.F. (1966) 'Short-term retention of visual and kinaesthetic information', Organizational Behaviour and Human Performance, 1, 71-86.

Posner, M.I., Lewis, J.L. and Conrad, C. (1972) 'Component processes in reading: a performance analysis'. In J.F. Kavanagh and I.G. Mattingly (Eds.) Language by Ear and by Eye. Cambridge, Mass.: M.I.T. Press.

Pratt, F. (1939) Secret and Urgent: The Story of Codes and Ciphers. London: Robert Hale. S

Prechtl, H.F.R. and Stemmer, J.C. (1962) 'The choreiform syndrome in children', Developmental Medicine and Child Neurology, 4, 119. S

Quinault, F. (1972) 'Cross associations, opposites and reversibility'. Unpublished paper: University of St. Andrews.

Rabinovitch, R.D., Drew, A.L., De Jong, R.N., Ingram, W. and Withey, L.I. (1954) 'A research approach to reading retardation', Research Publication of the Association for Research in Nervous and Mental Disorders, 34, 363.

Rabinovitch, M.S. and Strassberg, R. (1968) 'Syntax and retention in good and poor readers', The Canadian Psychologist, 9, 142.

Raphael, B. (1976) The Thinking Computer. San Francisco: W.H. Freeman & Co.

Reed, J.C. (1970) 'The deficits of retarded readers - fact or artifact?', Reading Teacher, 23, 347.

Reid, J. (Ed.) (1972) Reading: Problems and Practices. London: Ward Lock.

Reynolds, A.G. and Flagg, P.W. (1977) Cognitive Psychology. Cambridge, Mass.: Winthrop Publishers Inc.

Richardson, J.T.E. (1976) 'The effects of stimulus attributes upon latency of word recognition', British Journal of Psychology, 67, 315.

Richardson, J.T.E. and Baddeley, A.D. (1975) 'The effect of articulatory suppression in free recall', Journal of Verbal Learning and Verbal Behaviour, 14, 623-629.

Riegel, K.F. and Riegel, R.M. (1961) 'Prediction of word recognition thresholds on the basis of stimulus parameters', Language and Speech, 4, 157.

Roberts, L.G. (1965) 'Machine perception of three-dimensional solids'. In J.T. Tippett, D.A. Kerkowitz, L.C. Clapp, C.J. Koester and A. Vanderburgh (Eds.) Optical and Electro-Optical Information Processing. Cambridge, Mass.: M.I.T. Press.

Robinson, M.E. and Schwartz, L.B. (1973) 'Visuo-motor skills and reading ability: a longitudinal study', Developmental Medicine and Child Neurology, 15, 281-286.

Rourke, B.P. (1976) 'Reading retardation in children: developmental lag or deficit?' In R.M. Knights and D.J. Bakker (Eds.) The Neuropsychology of Learning Disorders. Baltimore: University Park Press.

Routh, D.A., Frosdick, R.M., Eddowes, G. and Livesey, R.L. (1979) 'Aspects of articulatory suppression'. Paper given to the Oxford meeting of the Experimental Psychology Society, July 1979.

Rozin, P. and Gleitman, L.R. (1977) 'The structure and acquisition of reading II: the reading process and the acquisition of the alphabetic principle'. In A.S. Reber and D.L. Scarborough (Eds.) Towards a Psychology of Reading. Hillsdale, N.J.: Erlbaum.

Rudel, R.G. and Denckla, M. (1974) 'Relation of forward and backward digit repetition to neurological impairment in children with learning disabilities', Neuropsychologia, 12, 109-118.

Rugel, R.P. (1974) 'WISC subtest scores of disabled readers', Journal of Learning Disabilities, 7, 48-55.

Rumelhart, D.E., Lindsay, P.H. and Norman, D.A. (1972) 'A process model for long-term memory'. In E. Tulving and W. Donaldson (Eds.) Organization and Memory. New York: Academic Press.

Rundus, D. and Atkinson, R.C. (1970) 'Rehearsal processes in free recall: a procedure for direct observation', Journal of Verbal Learning and Verbal Behaviour, 9, 99.

Rutter, M. (1978) 'Prevalence and types of dyslexia'. In A.L. Benton and D. Pearl (Eds.) Dyslexia: An Appraisal of Current Knowledge. New York: Oxford University Press.

Rutter, M. and Yule, W. (1973) 'Specific reading retardation'. In L. Mann and D. Sabatino (Eds.) The First Review of Special Education. Philadelphia: Buttonwood Farms. S

Rutter, M. and Yule, W. (1975) 'The concept of specific reading retardation', Journal of Child Psychiatry, 16, 181.

Ryan, J. (1969) 'Temporal grouping, rehearsal and short-term memory', Quarterly Journal of Experimental Psychology, 21, 148-155.

Sasanuma, S. and Fujimura, O. (1971) 'Selective impairment of phonetic and non-phonetic transcription of words in Japanese aphasic patients: Kana versus Kanji in visual recognition and writing', Cortex, 7, 1.

Satz, P. (1976) 'Cerebral dominance and reading disability: an old problem revisited'. In R.M. Knights and D.J. Bakker (Eds.) The Neuropsychology of Learning Disorders. Baltimore: University Park Press.

Savin, H.B. (1972) 'What the child knows about speech when he starts to learn to read'. In J.F. Kavanagh and I.G. Mattingly (Eds.) Language by Ear and by Eye. Cambridge, Mass.: M.I.T. Press.

Scarborough, D.L. (1972) 'Memory for brief visual displays of symbols', Cognitive Psychology, 3, 408-429.

Scarborough, D.L. and Scarborough, H. (1975) 'Encoding and memory processes for visual displays'. In P.M.A. Rabbitt and S. Dornic (Eds.) Attention and Performance V. London: Academic Press.

Scarborough, D.L. and Sternberg, S. (1967) 'Processing items and their order in sequential visual displays'. Paper presented to a Meeting of the Eastern Psychological Association, Boston, April 1967.

Schlesinger, I.M. (1968) Sentence Structure and the Reading Process. The Hague: Mouton.

Schlosberg, H. (1965) 'Time relations in serial visual perception', Canadian Psychologist, 6, 161.

Schulman, H.G. (1970) 'Encoding and retention of semantic and phonemic information in short-term memory', Journal of Verbal Learning and Verbal Behaviour, 9, 499.

Schulman, H.G. (1971) 'Similarity effects in short-term memory', Psychological Bulletin, 75, 399.

Schulman, H.G. (1972) 'Semantic confusion errors in short-term memory', Journal of Verbal Learning and Verbal Behaviour, 11, 221.

Segal, S.J. and Fusella, V. 'Influence of imaged pictures and sounds on detection of auditory and visual signals', Journal of Experimental Psychology, 83, 458-464.

Selfridge, O.G. (1959) 'Pandemonium: a paradigm for learning'. In Proceedings of a Symposium on the Mechanization of Thought Processes. London: HMSO.

Senf, G.M. (1969) 'Development of immediate memory for bisensory stimuli in normal children and children with learning disorders', Developmental Psychology, 6, 28.

Seymour, P.H.K. (1973) 'A model for reading, naming and comparison', British Journal of Psychology, 64, 35-49.

Seymour, P.H.K. and Porpodas, C.D. (1979) 'Lexical and non-lexical processing of spelling in developmental dyslexia'. To appear in U. Frith (Ed.) Cognitive Processes in Spelling. London: Academic Press.

Shallice, T. (1975) 'On the contents of primary memory'. In P.M.A. Rabbitt and S. Dornic (Eds.) Attention and Performance V. London: Academic Press.

Shallice, T. and Warrington, E.K. (1975) 'Word recognition in a phonemic dyslexic patient', Quarterly Journal of Experimental Psychology, 27, 187-200.

Shannon, C. and Weaver, S. (1962) The Mathematical Theory of Communication. Urbana.

Silberberg, N.E., Iverson, I.A. and Goins, J.T. (1973) 'Which remedial reading method works best?', Journal of Learning Disabilities, 6, 547.

Silver, A.A. (1968) 'Diagnostic considerations in children with reading disability'. In G. Natchez (Ed.) Children with Reading Problems. New York: Basic Books.

Silver, A.A. and Hagin, R.A. (1967) 'Strategies of intervention in the spectrums of defects in specific reading disability', Bulletin of the Orton Society, 17, 39.

Silver, A.A. and Hagin, R. A. (1975) Search: a Scanning Instrument for the Identification of Potential Learning Disability: Experimental Edition. New York: New York University Medical Centre. S

Smelt, E.D. (1972) How to Speak, Read and Spell. Melbourne: Melbourne Y.M.C.A.

Smith, E.E. and Spoehr, K.T. (1974) 'The perception of printed English: a theoretical perspective'. In B.H. Kantowitz (Ed.) Human information Processing: Tutorials in Performance and Cognition. Hillsdale, N.J.: Erlbaum.

Smith, F. (1978) Understanding Reading, 2nd edition. New York: Holt, Rinehart and Winston.

Snowling, M.J. (1980) 'The development of grapheme-phoneme correspondence in normal and dyslexic readers', Journal of Experimental Child Psychology, in press.

Sokolov, A.N. (1972) Inner Speech and Thought. New York: Plenum Press.

Spache, G.D. (1976) Investigating the Issues of Reading Disabilities. Boston, Mass.: Allyn and Bacon.

Sperling, G. 'A model for visual memory tasks', Human Factors, 5, 19-31.

Sperling, G. (1967) 'Successive approximations to a model for short term memory', Acta Psychologica, 27, 285-292.

Spoehr, K.T. and Smith, E.E. (1973) 'The role of syllables in perceptual processing', Cognitive Psychology, 5, 71-89.

Spoehr, K.T. and Smith, E.E. (1975) 'The role of orthographic and phonotactic rules in perceiving letter patterns', Journal of Experimental Psychology: Human Perception and Performance, 104, 35-47.

Spreen, O. (1970) 'Postscript: review and outlook'. In D.J. Bakker, and P. Satz (Eds.) Specific Reading Disability. Rotterdam University Press.

Spreen, O. (1978) 'The dyslexias: a discussion of neurobehavioural research'. In A.L. Benton and D. Pearl (Eds.) Dyslexia: An Appraisal of Current Knowledge. New York: Oxford University Press.

Spring, C. (1976) 'Encoding speed and memory span in dyslexic children', Journal of Special Education, 10, 35-46.

Spring, C. and Capps, C. (1974) 'Encoding speed, rehearsal, and probed recall of dyslexic boys', Journal of Educational Psychology, 66, 780-786.

Stainton Rogers, W. (1978) 'The relationship between item and position report proficiency: what does it tell us about visual information processing?' First draft.

Stanley, G. (1976) 'The processing of digits by children with specific reading disability (dyslexia)', British Journal of Educational Psychology, 46, 81.

Stanley, G. and Hall, R. (1973a) 'A comparison of dyslexics and normals in recalling letter arrays after brief presentation', British Journal of Educational Psychology, 43, 301-304.

Stanley, G. and Hall, R. (1973b) 'Short term visual information processing in dyslexics. Child Development, 44, 841-844.

Steinheiser, F.H. and Burrows, D.J. (1973) 'Chronometric analysis of speech perception', Perception and Psychophysics, 13, 426-30.

Sternberg, S. (1970) 'Memory scanning: mental processes revealed by reaction-time experiments'. In J.S. Antrobus (Ed.) Cognition and Affect. Boston: Little, Brown and Co.

Stevens, K.N. (1972) 'Segments, features and analysis by synthesis'. In J.K. Kavanagh and I.G. Mattingly (Eds.) Language by Ear and by Eye. Cambridge, Mass.: M.I.T. Press.

Stinchfield, S.N. and Young, E.H. (1938) Children with Delayed and Defective Speech. London: Oxford University Press.

Strag, G.A. (1972) 'Comparative behavioural ratings of parents with severe mentally retarded, special learning disability and normal children', Journal of Learning Disabilities, 5, 52.

Supramanian, S. and Audley, R.J. (1976) 'The role of naming difficulties in reading backwardness'. Paper presented to the British Association for the Advancement of Science Annual Conference.

Tarnopol, L. and Tarnopol, M. (1977) 'Introduction to neuropsychology'. In L. Tarnopol and M. Tarnopol (Eds.) Brain Function and Reading Disabilities. Baltimore: University Park Press.

Taylor, E.A. (1957) 'The spans: perception, apprehension and recognition', American Journal of Opthalmology, 44, 501-507.

Teuber, H.L. (1960) Visual Field Defects after Penetrating Missile Wounds of the Brain. Cambridge, Mass.: Harvard University Press.

Thomas, C.J. (1905) 'Congenital "word-blindness" and its treatment', Opthalmoscope, 3, 380.

Tinker, M.A. (1946) 'The study of eye movements in reading', Psychological Bulletin, 43, 2, 93-120.

Tinker, M.A. (1951) 'Fixation pause duration in reading', Journal of Educational Research, 44, 471-479.

Tinker, M.A. (1958) 'Recent studies of eye-movements in reading', Psychological Bulletin, 55, 215-231.

Tinker, M.A. (1963) Legibility of Print. Iowa State University Press.

Tinker, M.A. (1965) Bases for Effective Reading. Minneapolis: University of Minnesota Press.

Torgesen, J. and Goldman, T. (1977) 'Verbal rehearsal and short-term memory in reading-disabled children', Child Development, 48, 56-60.

Toulmin, S. (1953) The Philosophy of Science. An Introduction. London: Hutchinson's University Library.

Townsend, J.T. (1971) 'Theoretical analysis of an alphabetic confusion matrix', Perception and Psychophysics, 9, 40-50.

Treisman, A. (1960) 'Contextual cues in selective listening', Quarterly Journal of Experimental Psychology, 12, 242-248.

Turvey, M.T. (1966) 'The effects of rehearsing analyzed information upon the retrieval of unanalyzed information', Psychonomic Science, 6, 365-366.

Turvey, M.T. (1973) 'On peripheral and central processed in vision: inferences from an information-processing analysis of masking with patterned stimuli', Psychological Review, 80, 1-52.

Turvey, M.T. and Kravetz, S. (1970) 'Retrieval from iconic memory with shape as the selection criterion', Perception and Psychophysics, 8, 171-172.

Tversky, B. (1969) 'Pictorial and verbal encoding in a memory search task', Perception and Psychophysics, 4, 225-233.

Tversky, B. and Sherman, T. (1975) 'Picture memory improves with longer on time and off time', Journal of Experimental Psychology: Human Learning and Memory, 1, 114-118.

Underwood, G. (1978) 'Concepts in information processing theory'. In G. Underwood (Ed.) Strategies of Information Processing. London: Academic Press.

Underwood, G. and Holt, P.O'B. (1979) 'Cognitive skills in the reading process: a review', Journal of Research in Reading, 2, 82-94.

Vellutino, F.R. (1978) 'Towareds an understanding of dyslexia: psychological factors in specific reading disability'. In A.L. Benton and D. Pearl (Eds.) Dyslexia: An Appraisal of Current Knowledge. New York: Oxford University Press.

Vellutino, F.R. (1979) 'Alternative conceptualizations of dyslexia: evidence in support of a verbal-deficit hypothesis', Harvard Educational Review, 47, 334-354.

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

Vellutino, F.R., Steger, J.A. and Kandel, G. (1972) 'Reading disability: an investigation of the perceptual deficit hypothesis', Cortex, 8, 106-118.

Venezky, R. (1970) The Structure of English Orthography. The Hague: Mouton.

Vernon, M.D. (1971) Reading and Its Difficulties. Cambridge University Press.

Vernon, M.D. (1977) 'Varieties of deficiency in the reading process', Harvard Educational Review, 47(3), 396-410.

Vernon, M.D. (1979) 'Variability in reading retardation', British Journal of Psychology, 70, 7-16.

Vogel, S.A. (1974) 'Syntactic abilities in normal and dyslexic children', Journal of Learning Disabilities, 7, 103.

Volkman, F.C., Schick, A.M.L. and Riggs, L.A. 'Time course of visual inhibition during voluntary saccades', Journal of the Optical Society of America, 58, 562-569.

Von Wright, J.M. (1968) 'Selection in visual immediate memory', Quarterly Journal of Experimental Psychology, 20, 62-68.

Von Wright, J.M. (1970) 'On selection in immediate visual memory', Acta Psychologica, 33, 280-297.

Walton, N.H. (1957) 'Vision and rapid reading', American Journal of Optometry, 34, 73-82.

Warren, R.E. (1970) 'Stimulus encoding and memory'. Doctoral dissertation, University of Oregon. S

Warren, R.M. (1971) 'Identification times for phonemic components of graded complexity and for spelling of speech', Perception and Psychophysics, 9, 345-349.

Warrington, E.K. (1967) 'The incidence of verbal disability associated with reading retardation', Neuropsychologia, 5, 175-179.

Warrington, E.K., Logue, V. and Pratt, R.T.C. (1971) 'The anatomical localization of selective impairment of auditory verbal short-term memory', Neuropsycholgia, 9, 377-387.

Wason, P. (1978) Hypothesis Testing and Reasoning. Open University Cognitive Course, Block 4, Unit 25.

Wason, P.C. and Evans, J.St.B.T. (1974) 'Dual processes in reasoning?', Cognition, 3, 141-154.

Watkins, E.J. and Wheeler, T.J. (1976) 'Laterality and short-term information processing implications for reading failure', I.R.C.S. (Res. Psychol.), 4, 139.

Wechsler, D. (1949) Wechsler Intelligence Scales for Children. New York: Psychological Corporation.

Weiner, N. (1947) Cybernetics. New York. S

Wepman, J.M. (1971) 'Modalities and learning'. In H.M. Robinson (Ed.) Coordinating Reading Instruction. Glenview, Ill.: Scott, Foresman. S

Wheeler, T.J. (1977) 'A study of information processing in dyslexic subjects'. Unpublished Ph.D. thesis, University of Wales.

Wheeler, T.J. and Watkins, E.J. (1978) 'Dyslexia: the problems of definition', Dyslexia Review, 1 (1), 13.

Wheeler, T.J. and Watkins, E.J. (1979) 'Dyslexia: a review of symptomology', Dyslexia Review, 2(1), 12.

Whetnall, E. and Fry, D.B. (1964) The Deaf Child. London: Heinemann Medical Books.

Wickelgren, W.A. (1965a) 'Acoustic similarity and intrusion errors in short-term memory', Journal of Experimental Psychology, 73, 165-171.

Wickelgren, W.A. (1965b) 'Short-term memory for phonemically similar lists', American Journal of Psychology, 78, 567-574.

Wickelgren, W.A. (1967) 'Rehearsal grouping and hierarchical organization of serial position cues in immediate memory', Quarterly Journal of Experimental Psychology, 19, 97-102.

Wilkinson, A.M. (1971) The Foundations of Language. London: Oxford University Press.

Wilks, Y. (1972) Grammar, Meaning and the Machine Analysis of Natural Language. London: Routledge and Kegan Paul. S

Winnick, W.A. and Daniel, S.A. (1970) 'Two kinds of response priming in tachistoscopic recognition', Journal of Experimental Psychology, 84, 74-81.

Winnick, W.A. and Kressel, K. (1965) 'Tachistoscopic recognition thresholds, paired-associate learning, and free recall as a function of abstractners-concreteners and word frequency'. Journal of Experimental Psychology, 70, 163.

Winograd, T. (1972) Understanding Natural Language. New York: Academic Press. S

Witelson, S.F. 'Abnormal right hemisphere specialization in developmental dyslexia'. In R.M. Knights and D.J. Bakker (Eds.) The Neuropsychology of Learning Disorders: Theoretical Approaches. University Park Press.

Wolford, G. and Hollingsworth, S. (1974) 'Evidence that short-term memory is not the limiting factor in the tachistoscopic full-report procedure'. Memory and Cognition, 2, 796.

Ysseldyke, J.E. (1973) 'Diagnostic-prescriptive teaching: the search for aptitude-treatment interaction'. In L. Mann and D. Sabatino (Eds.) The First Review of Special Education (Vol. 1). Philadelphia: Buttonwood Farms. S

Yuille, J.C. and Ternes, W. (1975) 'Attention and modality specific interference as determinants of short-term verbal and visual retention', Canadian Journal of Psychology, 29, 360-374.

Yule, W., Rutter, M., Berger, M. and Thompson, J. (1974) 'Over- and under-achievement in reading: distribution in the general population', British Journal of Educational Psychology, 44, 1-12.

Zangwill, O.L. (1960) Cerebral Dominance and Its Relation to Psychological Function. Springfield: Charles C. Thomas.

Zangwill, O.L. (1962) 'Dyslexia in relation to cerebral dominance'. In J. Money (Ed.) Reading Disability. Baltimore: John Hopkins Press.

Zeki, S. (1974) 'The mosaic organization of the visual cortex in the monkey'. In R. Bellairs and E.G. Gray (Eds.) Essays on the Nervous System: a Festschrift for Professor J.Z. Young. Oxford University Press. S

Zigmond, N. 'Remediation of dyslexia: a discussion'. In A.L. Benton and D. Pearl (Eds.) Dyslexia: An Appraisal of Current Knowledge. New York: Oxford University Press.

Zuber, B.L. and Stark, L. (1966) 'Saccadic suppression: evaluation of visual threshold associated with saccadic eye movements', Experimental Neurology, 16, 65-79.

S : Secondary sources

'I can't read and I can't write
And I don't know my left from right
I can't tell if the sun's gonna shine
And I don't know if you'll ever be mine
But I'll make love to you any old time'.

J.J. Cale, 1979.