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BASIC EXPERIMENTS ON READING

[ΛΕΥΚΗ ΣΕΛΙΔΑ]

ABSTRACT

In three experiments the rate of acquisition of information from a visual display was measured, using the method of backward masking (Sperling, 1963). Experiment I, which included a control for letter redundancy, showed that the rate of acquisition from an array of letters or words is determined not by the number of visual characters to be processed but by the number of names into which they are to be encoded. In a second, control experiment, no effect was found on acquisition rate of the number of alternative characters to be encoded. The third experiment showed that the time needed to identify words of the same frequency of occurrence was unrelated either to word length or to the number of syllables in the name. The results are contrasted with those obtained in RT and comparison tasks. They are interpreted as evidence that (1) the backward masking paradigm provides a direct measure of identification or naming latency; (2) visually presented words are processed as wholes: that is, prior to word identification there is no intermediate stage of representation, not subject to backward masking, in units of size smaller than the complete word (e.g. letters, spelling patterns, syllables); (3) words are initially represented in an abstract or *lexical* code, which does not reflect either sensory or motor attributes of the word name.

[ΛΕΥΚΗ ΣΕΛΙΔΑ]

INTRODUCTION

«Whether a word is recognised directly as a visual pattern or whether the letters are first recognised and then the letter-pattern is recognised as a word, or whether both processes can occur together, we do not yet know» (Sperling, 1970). Several recent studies have compared the recognition of printed letters within a word or familiar spelling pattern with recognition of the same letter or letters occurring in an unrelated letter group, or in isolation (e.g. Adelman & Smith, 1971; Cohen, 1969; Eichelman, 1970; Hochberg, 1970; Krüger, 1970; Reicher, 1969; Wheeler, 1970). All of these experiments employed some form of matching or comparison task, and all showed greater speed or accuracy of matching for the letters embedded in words or familiar orthographic patterns. Unfortunately, however, it is not clear how these results, concerning the ability to find or match individual letters, are to be related to word recognition in normal reading. Matching tasks undoubtedly provide a useful means of defining the memory codes used in mental comparisons, and in this case confirm, what we knew before, that people can recode a string of letters forming a word into the name of that word. But about how the information in the visual display is initially converted into such a memory code, i.e. about the recognition or naming process itself, they provide at best rather indirect evidence. The superiority of letters within words over unrelated letter groups in matching tasks of this kind is often remarkably small: using forced-choice recognition of a probed letter, Reicher (1969) for example obtained an increase of only 8% in the proportion of correct choices for letters within 4-letter words over letters in unrelated quadrigrams; and similar results are reported by other Es. As Wheeler (1970) concluded from these experiments, «the perceptual units might be words, but the data do not require this. Any unit size of digram or spelling pattern or larger would account for the word superiority effect.» This is scarcely sufficient to justify the widely held belief that «familiar words are perceived as wholes rather than piecemeal by the skilled reader» (Kollers, 1970). If Kollers' hypothesis concerning recognition units in reading

is correct, then either the matching task for some reason prevents skilled readers from fully using their perceptual ability, or (what amounts possibly to the same thing) the results are determined largely by quite distinct, pre- or post-recognition *memory*, etc., limitations imposed by the additional task of comparison.

A different experimental paradigm offering a more direct approach to the identification process in letter or word recognition was introduced by Sperling (1963). In this paradigm a briefly presented array of visual characters is followed, after a short, variable interval, by a second complex pattern, designed to cut short the time for which information concerning the previous array remains available in iconic visual memory (Neisser, 1967). Under these conditions the number of unrelated items in the array which can be correctly reported increases approximately linearly with increasing delay of the second, masking stimulus at least over the first three or four items, typically at a rate of one letter per 10 to 15 msec delay of the masking stimulus (Sperling, 1963; Allport, 1968). There has been some unresolved controversy over the extent to which the visual information in the previous array is actively inhibited or «erased» by the arrival of the masking field, or only degraded through integration with it (e.g. Neisser, 1967; Liss, 1968; Spencer & Shuntich, 1970; Coltheart, 1972). Clearly, in either case the effectiveness of the mask will depend on relatively local relationships between the contours in the array and in its masking stimulus (Kahneman, 1968; Lefton, 1972). The fact that certain types of masking sequences are ineffective, in that both target and mask are still phenomenally present after the arrival of the latter (e.g. Eriksen & Eriksen, 1971), cannot then in itself be valid grounds for supposing that, with more suitable contour configurations, masking may not be instantaneous and complete. More specifically, where the relative configurations of target and mask are such that, if both are exposed simultaneously, the target array is illegible, then with delayed onset of the mask stimulus integration will have the same effect in abruptly terminating the availability of the previous array as active inhibition. In this case, any information about the previous array which appears in the subject's report must have been extracted from the visual icon and represented in some way not vulnerable to backward masking by the time the mask occurred.

Sperling (1967, 1970) has argued that the initial, very rapid increase in the accuracy of the subject's report reflects the rate at which information in the icon can be translated into an abstract or symbolic code

representing the names of the characters. The results of this translation are coded initially as purely abstract or *lexical* items, and not as bundles of either visual, acoustic, or articulatory features. Specifically, he has suggested, the resulting initial name code, held briefly in a recognition buffer-memory, is functionally analogous to the machine-coded address in memory of programs for speaking the name concerned. Regardless of the appropriateness, or otherwise, of the analogy with a location-addressed memory system, and regardless too of the specific relationship with an articulatory code which he postulates, the essential feature of Sperling's suggestion is that the backward masking/identification paradigm reflects the rate of transfer of information from a visual to an abstract, linguistic representation, coded neither in terms of sensory nor motor attributes, which we shall call a *lexical code*. Clearly, objections to this interpretation of backward masking/identification data on the grounds that articulation or subvocal «rehearsal» of letter names cannot occur at such rapid rates (e.g. Neisser, 1967) are simply irrelevant.

It is of course not necessary that the rate of transfer of information thus defined represents a spatially serial «scan». Indeed, there is some evidence that information from several spatially separate, unrelated letters can be processed simultaneously (Sperling, 1967, 1970), a conclusion supported also from other experimental paradigms (e.g. Beller, 1970; Donderi & Case, 1970; Egeth, Jonides, & Wall, 1972; Sperling, Budiansky, Spivak, & Johnson, 1971).

Nevertheless, the information appearing in the subject's report increases, with delay of the masking stimulus, at a finite rate. The question which naturally arises, and to which this paper is addressed, is what limits this rate of gain of information?

EXPERIMENT I

The aim of this experiment was to compare the rate of gain of information in the backward masking/identification paradigm for words vs. unrelated letter groups (consonants). To make the comparison as unambiguous as possible, identification of any subset of the letters within a word should not, by itself, be a sufficient basis for identifying any of the remaining letters, i.e. simply from a knowledge of English orthography. The words selected were all of three letters, such that no letter could be predicted solely from knowledge of the

other two, nor of any one letter alone. For every word in the experimental set, others differing from it at each letter position by only one letter also occurred in the set.

Predictions

Two general classes of hypotheses are considered here: (I) those which assume that the rate of gain of information observed in the backward masking/identification paradigm with alphanumeric stimuli reflects capacity limits in the processing of *visual* features (e.g. Runelhart, 1970). Class I also includes the hypothesis that information is transferred initially merely to a second stage of short-term visual memory (STVM), of greater persistence than the icon and not subject to backward masking, but still essentially *visually* coded (Coltheart, 1972; Henderson, 1972; Mitchell, 1972). In the comparison of words vs. unrelated letters, all hypotheses in this class predict that the limiting factor will be simply the number of letters in the display (given the control in the selection of letter redundancy). A similar prediction is presumably implied by the hypothesis that a masking stimulus produces only a partial degradation of the icon (Neisser, 1967; Eriksen & Eriksen, 1971, etc.).

(II) Hypotheses which ascribe the limited rate of gain of information to some rate-limiting aspect of the *naming* process, i.e. in accessing appropriate linguistic or long-term memory categories. A strong form of this hypothesis (IIa) predicts that the acquisition rate is limited simply by the number (and type) of names to be found (Sperling, 1967; Beller, 1970). In its simplest interpretation, the rate of gain of 3-letters words should be just three times as fast, letter for letter, as that of unrelated letters. Other hypotheses of a weaker variety (IIb) predict an advantage due to the greater redundancy or familiarity of words over unrelated letters but of lesser extent. These hypotheses posit an intermediate stage of mapping onto phonemic or orthographic units, prior to word identification (e.g. Gibson, Pick, Osler, and Hammond, 1962; Gibson, Shurcliff, & Yonas, 1970). Assuming that the subject need only encode information from the display into the earliest level of representation available to him beyond that of the icon in order for it to escape the effects of backward masking, the increase in accuracy of a subject's report with increasing delay of the mask should then be limited by the rate of transfer to this intermediate stage, if it exists.

Method

Apparatus. The stimulus sequence was presented binocularly by means of a Scientific Prototype model GB 3-channel tachistoscope.

The sequence of events during each trial was as follows. An adapting field was presented containing a small black fixation cross. When ready, the subject initiated a trial by pressing a handheld microswitch, and (1) the adapting field was replaced by the test field (different on each trial) for 20 msec: then (2) the adapting field returned for a variable, brief interval (20 or 40 msec) and (3) the masking field was exposed for a constant 2.0 sec. Onset-onset delays between test stimulus and mask were thus 20, 40 and 60 msec respectively.

The masking field consisted of a random pattern of fragments of the letters, the fragments distributed in all orientations and in such a way as to blacken on average 65% of the total masking field. The particular masking pattern was changed at irregular intervals during each experimental session.

Materials. Three-letter words monosyllables with estimated frequencies of 10 or more per million were selected (Thorndike & Lorge, 1944). The other principal criterion for selection was that every letter of each word should be replaceable by at least one alternative letter to still form a common 3-letter word. (For example, BEG can be altered by the first letter to form LEG, PEG, etc., by the second to form BAG, by the third to form BED, BEE and so on).

Either 3 or 9 letters (depending on the condition) were arranged in a horizontal row on each stimulus card, to form three different types of display: (1) A row of *three randomly selected letters* (consonants) (Condition L3). (2) A row of *three 3-letter words* (Condition W3). (3) A row of *nine consonants*, randomly selected as in condition L3, positioned in a horizontal row in three groups-of-three and corresponding exactly to the letter positions in condition W3 (Condition 3L3).

Design and Procedure. Each subject completed two sessions of about 1 hour each on two successive days. The first session was treated as practice. A session consisted of three blocks of trials under each of the three display conditions, 96 trials in all. The conditions were presented in a counterbalanced order between subjects. The subject always knew in advance which condition he was in, and whether the display was composed of random letters or words. In the experimental session each stimulus card was presented once only, in a different randomized sequence for each subject.

After each trial the subject said aloud and then wrote down his report of what he had seen. He was encouraged to guess, but was permitted to leave blanks if necessary.

Subjects. The subjects were six undergraduates and one graduate student at the University of Aberdeen. Three were female from 18 to 26 years. They were not informed of the aims of the experiment.

Results. Figure 1 shows the mean number of letters correctly reported per trial, as a function of effective exposure duration (delay of the masking stimulus). It is clear that accuracy of report from both the letter arrays (Conditions L3 and 3L3) increases rapidly with increasing delay of a subsequent masking field, as found in earlier experiments (e.g. Sperling, 1963). The really striking feature of Figure 1, however, is the very much faster rate of gain of information when the letter-arrays form 3-letter words (Condition W3).

The initial increase in accuracy of report for the letter displays (L3) corresponds to a rate of one letter correct for each additional 13 msec delay of the masking stimulus, which is in rather good agreement with previous results (Sperling, 1963; Allport, 1968). When the letter arrays constitute 3-letter words, on the other hand, i.e. in Condition W3 the corresponding rate is 4.6 msec per letter, or approximately three times as fast. Even with the 20 msec delay of the masking stimulus, the difference between conditions L3 and W3 is still highly significant.

The second control condition (3L3) gave consistently higher scores than L3. It seems likely that these differences were due to the greater opportunity for guessing in 3L3 letter arrays, where the subject attempts to report 9 letter positions, against only 3 positions in L3. That the absolute difference in scores between the two conditions remains the same between 40 and 60 msec, i.e. that the *rate* of increase in accuracy is the same, supports this interpretation. On the other hand the differences between condition 3L3 and W3 are highly significant, with no overlap of scores between the two conditions at either duration.

At each exposure interval, the number of letters correctly reported in Condition W3 is almost exactly three times as great as in Condition L3. When scored for the total number of *words* correctly reported (Figure 1, dotted line) where an «item» in L3 is a single letter and in W3 is a complete 3-letter word, the difference in scores between the two conditions was not statistically significant at any exposure duration (as predicted by hypothesis IIa).

Discussion. The results clearly support the predictions of hypothesis IIa, that the rate of gain of information in the backward mask-

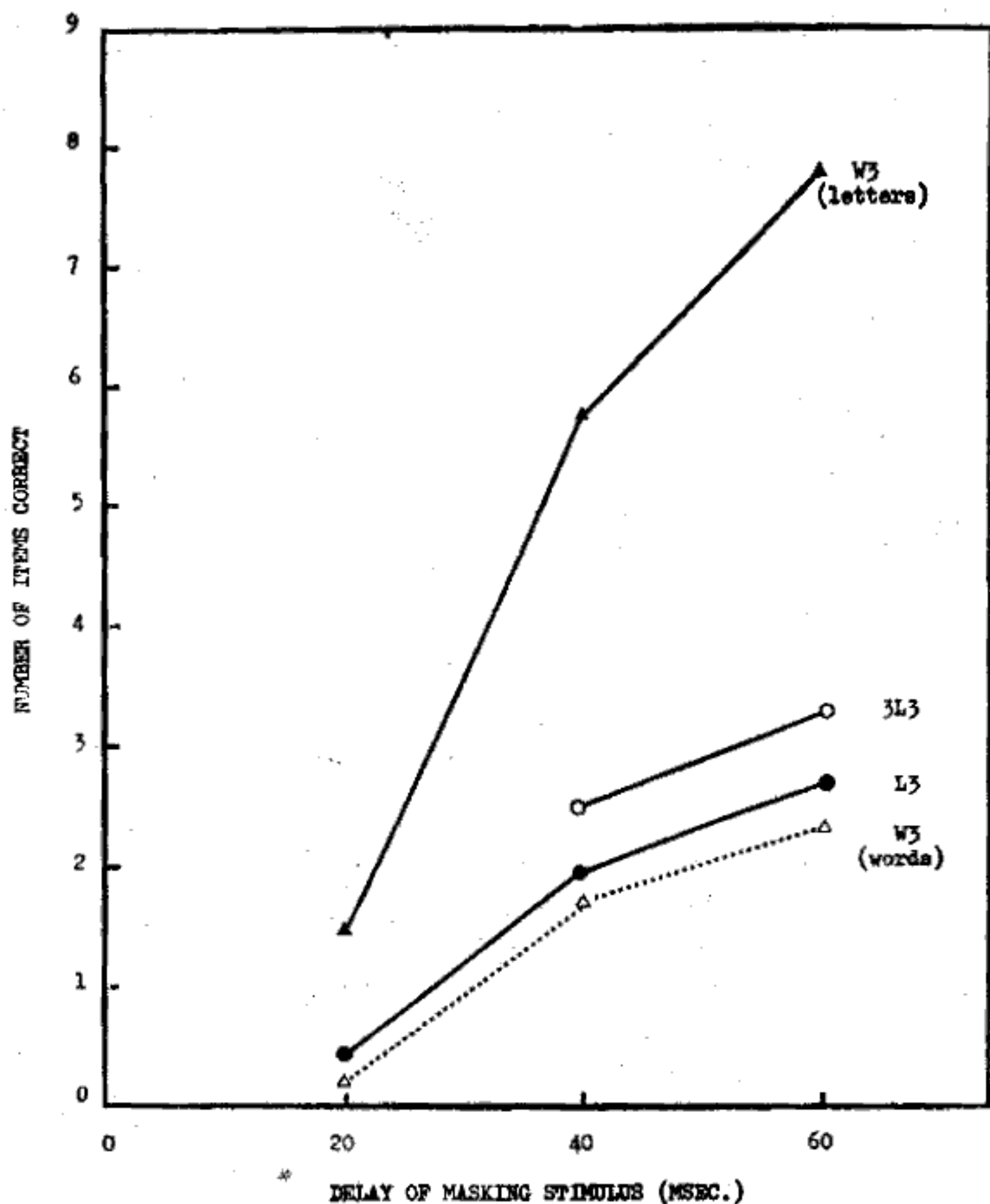


Figure 1. The number of items correctly reported, as a function of onset-onset delay between the letter array and masking stimulus. (The letter array appeared for a constant 20 msec.) Triangles represent data points for arrays of three-letter words, circles for unrelated consonants. The dotted line shows results scored in terms of the number of complete words correct.

ing/identification paradigm is here limited by the number of names to be encoded, rather than by the number of visual characters. Hypotheses of type I or IIb are rejected. On the other hand the results do not rule out the hypothesis that the initial encoding of word stimuli is in units of syllable size, since all words in Experiment I were monosyllabic. We return to this question in Experiment III.

The data also suggest that generalizations about a regular «noticing order» within letter groups in normal reading (e.g. Brown, 1970) based on data of this kind should be treated with caution.

EXPERIMENT II

Since even partial letter identification in Experiment I would presumably reduce the range of possible alternatives in the remaining positions, which could still form an English word, and this might possibly have contributed to the word superiority found in Experiment I, a new experiment was carried out to test whether restricting the range of alternatives, in the unrelated letter condition, could produce a similar advantage.

Method

Materials. Three different sizes of vocabulary were used — 4, 8, and 16 consonants. The particular ensembles were carefully selected to form, as far as possible, familiar groups (Fitts & Switzer, 1962), and to minimize acoustic confusion (Conrad, 1964). The groups finally adopted were: JKLM (4-ensemble), JKLMQRST (8-ensemble), and BCFGHJKLMQRSTWYZ (16-ensemble). The letters were printed in a horizontal row.

Apparatus. The apparatus and the general sequence of events on each trial, was as for Experiment I.

Design and Procedure. Each subject was tested on successive days on each of the three letter-ensembles, in a randomized order. He began each session by memorizing the ensemble to be tested, which he then rehearsed aloud continuously for two minutes. For each ensemble size the subject encountered each of the six effective exposure durations in blocks of 12 trials each, and in a randomized order different for each subject.

Subjects. The subjects were five paid volunteer students from the

University of Aberdeen. None of them had participated in the previous experiment. Their ages ranged from 18 to 22 years.

Results.

The results are summarized in Figure 2. A within-subjects analysis of variance showed a very large main effect due to delay of the masking stimulus, that is, different subjects showed different rates of gain of information. There was no significant effect of ensemble size.

Discussion

The results of Experiment II give no support whatever to the idea that restricting *a priori* the number of alternative letters affects the rate of gain of information. This inevitably weakens the suggestion regarding word-recognition, that information from different letter positions in a word mutually interacts to restrict the range of alternatives at other positions, or at least that an interaction of this sort, prior to word identification, contributes to the superiority of words over letter arrays, although clearly the experiment does not directly refute it. A more direct test has not yet been made.

EXPERIMENT III

In Experiment I, monosyllabic 3-letter words were encoded apparently at the same rate as single, unrelated letters. This result is compatible with the hypothesis that the visual information is mapped either onto orthographic, phonemic, or other units of syllable length, or directly into whole word units, regardless of the number of syllables. It also leaves open the possibility that, with words of more than three letters, the number of visual characters to be encoded may also have some limiting effect on the rate of transfer of information from the display. These problems are addressed in Experiment III.

Method

Apparatus. The details of apparatus and the sequence of events on each trial were the same as for Experiments I and II, except that, following the 20 msec exposure of the stimulus array, the adapting field returned for 80 msec, to give a constant onset-onset interval of 100 msec between test and masking stimuli.

NUMBER OF LETTERS CORRECT

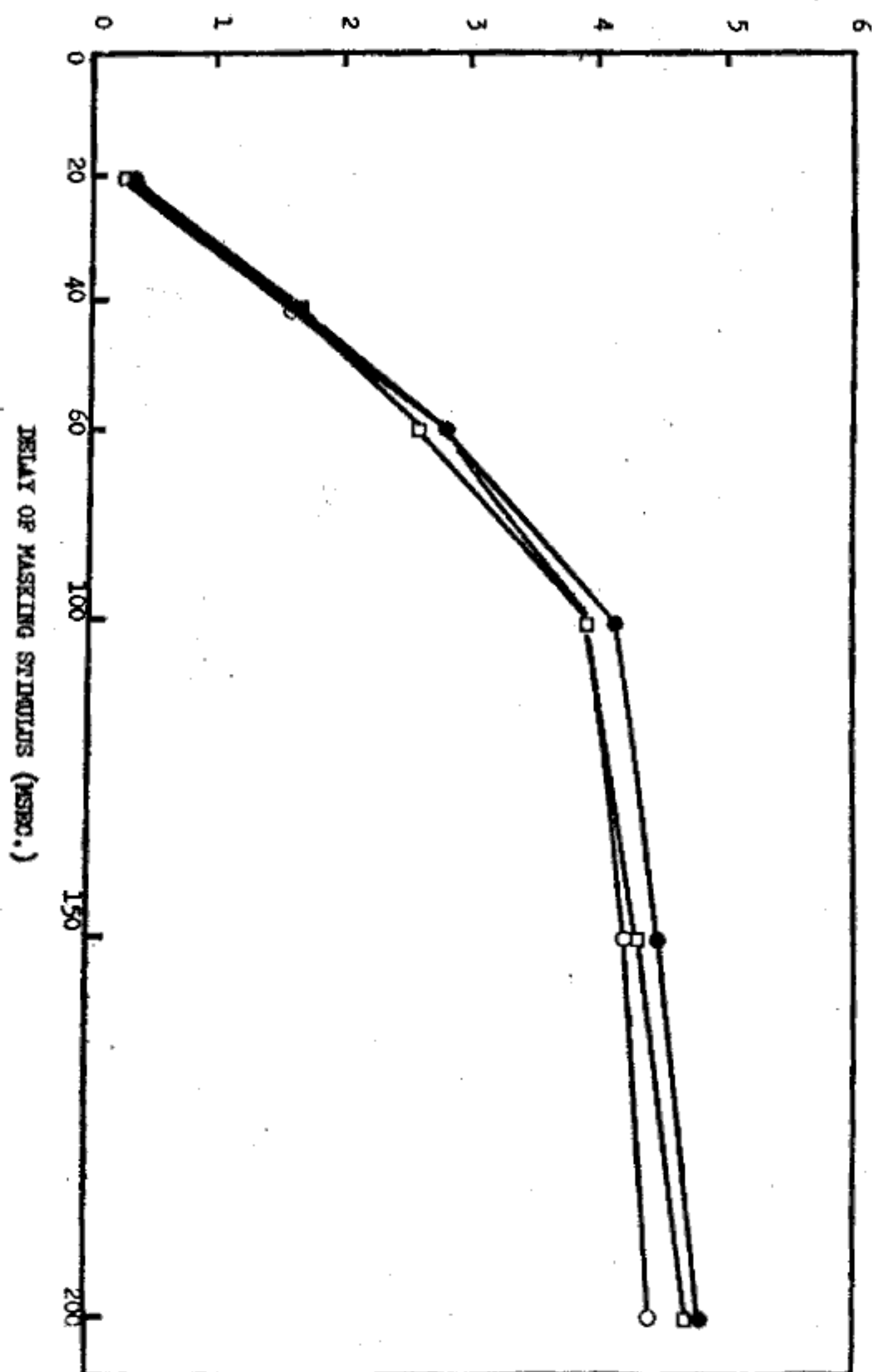


Figure 2. The number of letters correctly reported, as a function of onset-onset delay between the letter array and masking stimulus, for three different sizes of letter ensemble:

○, 4 alternatives; ●, 8 alternatives; □ 16 alternatives (Experiment II).

Materials. On each trial three different English words were presented in a horizontal row, the middle word of the three in the center of the card, immediately above the position occupied by the fixation cross in the adapting field. There were six different source populations of words, each defining one of six different conditions. The words were either high frequency (HF), i.e. occurring 100 or more times per million, or low frequency (LF), i.e. occurring less than 10 times per million, in the Thorndike-Lorge word count (Thorndike & Lorge, 1944). In each frequency range the words were drawn from three different subgroups: (1) three-letter, monosyllabic words as in Experiment I; (2) monosyllabic words of 5 or 6 letters; and (3) bisyllabic words of 5 or 6 letters. The mean rated frequencies of the LF words was, for 3-letter words 4.3, for 5/6 letter monosyllables 4.4, and for 5/6 letter bisyllabic words 4.2 per million. There was an equal proportion of 5- and 6-letter words. (5-letter as well as 6-letter words were included in order to increase the variability of spelling patterns.) In each stimulus array there was at least one 5-letter and one 6-letter word. Of the bisyllabic words approximately two-thirds had the principal stress on the first syllable. No word appeared in more than one stimulus array, and combinations of words which were judged to form syntactically or semantically acceptable groupings were excluded. No two words in any array had the same initial sound.

The letters were printed in uppercase black Letraset, and spaced 0.5 cm center to center within words, as in Experiment I. In arrays of 5- and 6-letter words, there was a space of 0.8 cm between words. The 3-letter words were centered, respectively, on the positions occupied by each of the three 5- or 6-letter words in a corresponding array, i.e. with a space of approximately 1.5 cm between words.

Design and Procedure. Each subject completed two sessions. In a practice session the delay of the masking stimulus was progressively reduced from 400 down to 100 msec, including five trials under each of the six word conditions. In the test session subjects received 10 trials with the 100 msec delay under each word condition, in a counterbalanced order over subjects. The subjects were told that this was an experiment on reading, and were instructed to write down as many letters as they could from each array in a prepared booklet. They were encouraged to guess, but could leave blanks where necessary. It was emphasised that single letters, or groups of letters which did not form a word, should still be put down. They were informed that each array contained three

English words, and were warned before each condition whether the arrays would be of 3-letter or 5/6-letter words, but were given no other information about the experiment.

Subjects. The subjects were 12 paid housewives from the Reading University subject panel. All had received at least 12 years of full-time education. Their ages ranged from 22 to 35 years.

Results.

The results were scored both for the number of individual letters and for the number of complete words correctly reported. They are summarized in Table I. A within-subjects analysis of variance showed a highly significant effect of word frequency, $F(1,22) = 41.9$, $p < .001$. With two exceptions for 5/6-letter monosyllables, all subjects obtained a higher letter score for HF words than in the corresponding LF conditions. As is apparent in Table I, subjects reported *more* letters correctly from the 5/6-letter words than from 3-letter words, $F(2,22) = 77.7$, $p < .001$. There was no interaction with word frequency. However, since nearly twice as many letters were available in 5/6-letter as in 3-letter-word displays, a more appropriate comparison is perhaps in terms of the *percentage* of letters correct, i.e. of the probability per letter of appearing correctly in the subject's report. Using this measure there was no significant effect of word length for HF words, $F(2,22) = 2.41$, $p > .1$, and a small effect, amounting to a difference of about 5% between 3-letter and 5/6-letter monosyllables, for LF words, $F(2,22) = 5.12$, $p < .025$. (A small effect of this kind might well be attributable to the differences in word spacing, lesser spatial masking of middle letters, etc., for the 3-letter words.)

The most revealing comparisons, however, are those based on the number of complete words correctly reported. With word-frequency held constant, neither the number of letters per word, nor the number of syllables per word, had any significant effect on the number of complete words identified, $F(2,22) = 1.35$, $p > .25$ for HF words, and $F(2,22) = 1.03$, $p > .25$ for LF words. The mean scores were virtually identical, in each case, as between one- and two-syllable words. Moreover, Newman-Keuls multiple-comparison tests on the number of individual letters identified also failed to show significant differences between the 5/6-letter words of one and two syllables.

To summarize, word frequency had a large effect, both on the number of individual letters and on the number of complete words

TABLE I
Mean Number of I items Correctly Reported (Experiment III)

	Number of complete words		Total number of letters		
	3 letter 1-syll.	5-6 letter words 1-syll. 2-syll.	3 letter 1-syll.	5-6 letter 1-syll.	words 2-syll.
High Frequency Words					
Mean	1.61	1.47	5.71	9.98	9.41
s.d.	0.45	0.52	1.22	2.81	2.61
Low Frequency Words					
Mean	1.01	0.93	4.70	7.81	7.48
s.d.	0.31	0.35	1.13	2.07	1.81

which could be identified. Word length, i.e. the number of letters per word, on the other hand, affected only the total number of letters reported, and had no effect either on the number of complete words, or on the probability *per letter* of appearing in the subject's report. Finally, the number of syllables per word had no significant effect, either in terms of the number of individual letters or of the number of complete words correctly identified.

Discussion

It is not easy to see how hypotheses of class I, which assert that the amount of information gained under backward masking conditions is a function simply of the quantity, or type, of *visual* features to be encoded, could account for the effect of word-frequency in Experiment III. Neither can they account readily for the greater number of letters gained from arrays containing 16 to 17 letters ($3 \times 5/6$ -letter words) than from arrays of only 9 letters (3×3 -letter words, given that performance levels were so far below a possible ceiling. The result of increasing the number of letters in the array while holding the number of *words* constant was to maintain a constant percentage of letters correct. By contrast, simply increasing the number of unrelated letters in the array, as in Experiment I, although it led to a small increase in the total number of letters reported, actually reduced the percentage of correctly reported letters per array by nearly threefold. Similar difficulties arise for the hypothesis (a special case of class I) that the initial rapid increase in accuracy with delay of masking represents the rate of transfer of alphanumeric characters to post-iconic STVM, whence the information is subsequently encoded into linguistic or other non-visual representations at a much slower rate (e.g. Coltheart, 1972). These results therefore support the conclusion reached in Experiment I, in which hypotheses of class I were rejected. This conclusion, of course, applies only to the identification of alphanumeric stimuli, and in no way implies that sensory information may not also be represented in post-iconic visual memory. The evidence is simply that, where stimuli under backward masking conditions are to be named, the rate of gain of information is not determined by the rate at which visual memory representations can be set up.

A more important finding of Experiment III was that whether a word is of one or two syllables has no effect on the rate of gain of information. This is difficult to explain for hypothesis IIb, which asserts

that, in identifying a familiar word, the rate of gain of information is limited by the rate of encoding into units of syllable size, or indeed into units of any size smaller than the complete word. More generally, the result appears to be incompatible with the notion that the initial name code for visually presented word (or letter) stimuli is in the form either of a phonemic (Conrad, 1964) or an articulatory representation (e.g. Colegate & Eriksen, 1970). This conclusion follows, at least, on the assumption that more complex representations take longer to set up than representations requiring fewer features, as e.g. Posner, Lewis, & Conrad (1971) have argued. Given this assumption, if the time needed to form a memory representation does not in fact depend on the number of articulatory or phonemic features in its name, this is evidence that the code which has been formed is isolable from either of these modes of representation. The only variable in these experiments found to influence the rate of gain of information (in terms of the foregoing argument, the rate at which a name code can be set up) was the purely lexical variable of word-frequency. This and all the other results reported here is in accord with hypothesis IIa, that visually presented words are mapped directly into an abstract, lexical code, at a rate defined by the accessibility of the latter. This does not imply that subjects necessarily read words serially, one at a time, but only that the rate at which the lexical code can be set up is the limiting factor. (Clearly, where non-word stimuli are used, other factors apparently irrelevant to *word* recognition, such as the pronounceability or familiarity of letter sequences, may once again become critical.)

GENERAL DISCUSSION

The results of these experiments contrast in several ways with those obtained in other experimental paradigms. In Same-Different comparison tasks the relative superiority of words over unrelated letters, briefly reviewed in the Introduction, is very slight in comparison with that found in Experiment I. Indeed where the effective exposure times with suitable backward masking are at all comparable, the accuracy level in name comparison tasks generally appears to be poorer than in whole-report identification tasks. (For example, in Experiment II with 100 msec between onsets of test stimulus and mask, subjects reported correctly on average 4.0 unrelated consonants from a 6-letter array. By way of comparison, with 110 msec between onsets of test stimulus and mask, and 5 letters in the array, Adelman & Smith's (1971) subjects could match correctly to a probe only between 56% and 60%, i.e. 2.8 to 3.0 unrelated letters. Other, similar comparisons are even less favourable to the matching performance). Too great emphasis should not be laid on comparisons across different experiments. However, it seems likely that the reception of the probe or comparison stimulus, and the additional subsequent task of comparison, impose quite different performance limitations from those which are effective in identification tasks. Comparison tasks also show an effect of the number of syllables on response time (Klapp, 1971), but so do identification, i.e. naming, tasks (Colegate & Eriksen, 1970; Eriksen, Pollack & Montague, 1970). Since there is no indication (Experiment III) of a syllable effect on identification accuracy under backward masking conditions — i.e. on the initial rate of gain of information — this is evidence that the effect occurs only after the word has been identified, in the course of organising an articulatory response. The finding of a syllable effect in Same-Different tasks therefore suggests that name comparisons are made on the basis of a (post-identification) articulatory code.

The suggestion that the syllable effect arises only after stimulus identification has also been challenged in an ingenious experiment by Pollack & Coltheart, cited in Coltheart (1972). In their experiment subjects had to respond to a visually presented two-digit number by

saying the number one greater than the one they saw. The results suggested that the number of syllables in the stimulus number affected the response time independently of the number of syllables in the response. This result would not conflict with the conclusions of the previous paragraph, however, if — as may be plausibly suggested — the number series is stored in its most rapidly accessible form as a sequence of articulatory rules. In this case, to find the appropriate response the subject must first translate the stimulus number into an articulatory code.

In sum, the present series of experiments provides strong support for the hypothesis that the observed rate of gain of information from word or letter arrays, as a function of onset-onset interval between stimulus and masking patterns, represents the rate at which information in the icon can access what we have referred to as a *lexical code*. In terms of Morton's (1969) model, accessing a lexical code would appear to be functionally equivalent to firing the appropriate logogen unit. Subsequent translation from lexical to articulatory code may then occur as a further, presumably optional stage — (Scarborough, 1972), and at a slower rate. The lexical code is held — in the terminology of Sperling's (1967) model — in a recognition buffer memory, having a capacity (defined by the changeover to a much slower rate of gain of information) of around 4 discrete items, at least as regards letter names (cf. Experiment II). If we are correct in equating the lexical code and hence the recognition buffer, as defined in these experiments, with Morton's logogen system, there is the obvious and rather interesting implication that the same limit of around 4 items applies to the number of outputs from unrelated logogen units (morphemes?) which can become available concurrently. Capacity limits of the recognition buffer for words, and in particular for syntactically or semantically related word sequences, have not yet been measured, and a number of interesting experiments suggest themselves along these lines. It would be particularly interesting to know whether, and if so in what ways, the lexical code, either in terms of rate of gain or of capacity limits, is affected by relations of deep structure. The running memory or eye-voice span (EVS) for reading aloud is known to be affected by structural linguistic factors (Levin & Kaplan, 1970). As the EVS is typically not much above 4-5 words (Idem), it would appear that most of this information could be contained in the recognition buffer, that is, contrary to the proposals of Morton (1969), in lexical rather than in articulatory code.

The experiments described here provide a strong disproof of the hypothesis that the amount of information extracted from brief displays of alphanumeric characters depends primarily on the number of visual features which require to be processed (e.g. Rumelhart, 1970). Clearly they do not in themselves rule out the possibility that there is some overall limiting rate at which visual features can be processed; they merely demonstrate that, if there is, it is too high to become a limiting factor in the sort of experiments with discrete alphanumeric stimuli, to which Rumelhart's model was directed. Allport (1968, Experiment II) showed that, under limiting conditions, the rate of gain of information in the backward masking paradigm could become a function of the discriminability of the critical visual features, but this result was found only with non-redundant features, and at levels of feature-discriminability well below that of the alphanumeric stimuli in typical «information-processing» experiments. Above a certain level of feature-discriminability further increases did not result in any corresponding increase in the rate of gain of information; i.e. some other factor had become limiting. With stimuli other than simple arrays of letters or digits, on the other hand, the information rate of visual feature extraction may again become critical. Here too, however, the rate — or capacity — limitations become manifest only within a given type of visual feature or «dimension» to be encoded, rather than over the process of feature extraction as a whole (Allport, 1971; Wing & Allport, 1972). Analogous considerations hold apparently at more complex levels of processing (Allport, Antonis, & Reynolds, 1972).

It is sometimes argued (e.g. Neisser, 1967) that the word-rates achieved by subjects in «reading for meaning» are so high as to preclude the possibility that every word is in fact identified. Yet the rate obtained in Experiment I for discrete, three-letter words, *if maintained*, would correspond to at least 2,0 words per minute. Until more is known at least about the capacity limits of the recognition buffer, i.e. of the lexical code, for connected text, we still have no means of estimating the limiting rate of word-identification in normal reading, and Neisser's conclusion would seem premature. In the meantime, as so often in experimental psychology, we have only succeeded in demonstrating what apparently was well known already, that familiar words are perceived as wholes by the skilled reader.

ΠΕΡΙΛΗΨΗ

Στήν έρευνα αὐτὴ ἀναλύονται τρία πειράματα, τὰ ὁποῖα ἔγιναν γιὰ νὰ μετρηθῇ ὁ ρυθμὸς πρόσληψης τῆς πληροφορίας ἀπὸ μιὰ ὀπτική ἐπίδειξη μὲ τὴ μέθοδο τῆς ἐπακόλουθης ἐπισκίασης (SPERLING, 1963). Τὸ πρῶτο πείραμα, μὲ τὸ ὁποῖο ἐλέγχεται ὁ πλεονασμὸς τῶν γραμμάτων, ἔδειξε ὅτι ὁ ρυθμὸς πρόσληψης τῆς πληροφορίας ἀπὸ μιὰ σειρά γραμμάτων ἢ λέξεων δὲν καθορίζεται ἀπὸ τὸν ἀριθμὸ τῶν ὀπτικῶν χαρακτήρων ποὺ πρέπει νὰ ἐπεξεργασθῇ τὸ ὑποκείμενο, ἀλλὰ ἀπὸ τὸν ἀριθμὸ τῶν ὀνομάτων στὰ ὁποῖα πρόκειται νὰ κωδικοποιηθοῦν οἱ χαρακτῆρες ποὺ παρουσιάζονται ὀπτικά. Τὸ δεῦτερο πείραμα ποὺ ἀποσκοποῦσε νὰ ἐλέγξῃ ἂν ὁ περιορισμὸς τοῦ ἀριθμοῦ τῶν γραμμάτων στὶς ἄλλες θέσεις τῆς σειρᾶς ἔχῃ κάποια ἐπίδραση στὸ ρυθμὸ πρόσληψης, δὲν ἔδωσε καμιά στατιστικῶς σημαντικὴ διαφορὰ. Τὸ τρίτο πείραμα ἔδειξε ὅτι ὁ χρόνος ποὺ χρειάζεται τὸ ὑποκείμενο γιὰ νὰ ἀναγνωρίσῃ λέξεις τῆς ἴδιας συχνότητάς δὲν ἐξαρτᾶται οὔτε ἀπὸ τὸ μῆκος τῶν λέξεων οὔτε ἀπὸ τὸν ἀριθμὸ τῶν συλλαβῶν τοῦ ὀνόματος. Τὰ ἀποτελέσματα αὐτὰ ἔρχονται σὲ ἀντίθεση μὲ ἐκεῖνα ποὺ ἔχουν συγκεντρωθῇ ἀπὸ ἔργα χρόνου ἀντιδράσεως καὶ συγκρίσεως. Ἑρμηνεύονται ὡς μαρτυρίες ὅτι: (1) ἡ ἐπακόλουθη ἐπισκίαση παρέχει μιὰ ἄμεση μέτρηση τοῦ χρόνου ἀναγνώρισης ἢ ὀνομασίας· (2) τὸ ὑποκείμενο ἐπεξεργάζεται τίς λέξεις ποὺ παρουσιάζονται ὀπτικά ὡς ὁλότητες. Δὲν ὑπάρχει δηλαδὴ πρὶν ἀπὸ τὴν ἀναγνώριση τῆς λέξεως ἐνδιάμεσο στάδιο, τὸ ὁποῖο νὰ μὴν ὑπόκειται σὲ ἐπακόλουθη ἐπισκίαση καὶ νὰ ἀπαρτίζεται ἀπὸ μονάδες μικρότερου μεγέθους ἀπὸ τὴν πλήρη λέξη (π.χ. γράμματα, ὀρθογραφικὲς μορφές, συλλαβές). (3) Οἱ λέξεις ἀρχικὰ ἀναπαριστῶνται μὲ ἓνα ἀφηρημένο ἢ «λεξιλογικὸ» κώδικα, ὁ ὁποῖος δὲν ἀντικατοπτρίζει οὔτε αἰσθητήρια οὔτε κινητικὰ χαρακτηριστικὰ τοῦ ὀνόματος τῆς λέξης.

[ΛΕΥΚΗ ΣΕΛΙΔΑ]

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