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THE EFFECTS OF CONTEXT ON THE VISUAL DURATION THRESHOLD FOR WORDS

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Visual duration thresholds for words were measured under three conditions: (i) with a highly predictive context; (ii) with a lesser predictive context; (iii) a control condition with no context. The results show that the visual duration threshold for a word is reduced in the presence of a context by an amount depending on the probability of the word given the context. This result agrees with previous related findings.

The errors made by the subjects could be classified into three main groups. The first of these groups showed the effect of expectancy, or response bias. Further errors showed the influence of previous stimuli or responses and the third group indicated the role of the stimulus in determining the response. A model for the recognition of words is outlined which accounts for these results and attempts to define what is meant by 'the effects of response bias in the perception of words'.

I. Introduction

A hypothesis concerning the improvement of reading

It has been established (see Morton, 1959, 1961) that the reading efficiency of literate adults and students can be improved without recourse to the training of oculo-motor or 'perceptual' skills. Indeed, except in a few extreme cases, such training seems irrelevant to the problem. In addition, while it is apparent that 'intellectual skills' may be trained with profit, it is possible for a person to improve his reading proficiency merely by reading 'more actively' and concentrating more. This implies that there is some factor, or factors, relevant to the process of reading, which is not being fully utilized. The hypothesis is put forward that one of these factors is related to the statistical properties of language, or, more precisely, that the factor can be described in terms of such properties.

Thus we can consider that a reader, having language experience characteristic of the language as a whole, utilizes some of the available context in order to 'predict' the immediate stimulus. This would have the effect of making the immediate stimulus more probable, and the reader would require fewer visual cues to perceive it.

Assuming that such an effect takes place, then as a reader concentrates more in reading, he might be able to utilize the preceding context more effectively in predicting the immediate stimulus, facilitating its perception even more. It must be noted that the act of prediction is not envisaged as being in any sense deliberate. It is viewed merely as a function of the brain mechanisms involved in reading.

The effects of context in language behaviour

The hypothesis makes the assumption that context facilitates performance in verbal behaviour. Such an effect has been shown by several recent studies. 'Context' will be taken to include any factor which limits the number of possible stimuli, or increases the probability of occurrence of particular stimuli. In information theory terms, the stimulus contains less information, or is more redundant.

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In language studies there are two general methods of varying the information in a stimulus. The first is by utilizing the existing probability structure of the language, in terms of letters or words. To use the probability structure of the language in such a way, one does not assume that all individuals act at any instant as though they are aware of this structure but merely that there is a certain degree of communality among the subjects used to generate the material and those tested with it, with respect to their experience of language.

The second method involves the experimenter artificially imposing constraints upon the experimental situation, for example, by varying the number of words in a list from which the response has to be made.

Studies in the psychology of language have used both these methods of varying the information in a stimulus. The results show that increasing redundancy affects the recall of words (Miller & Selfridge, 1950), nonsense syllables (Rubenstein & Aborn, 1954) and letters (G. A. Miller, 1958) and the learning of words (Sharp, 1958), nonsense syllables (Baddeley, 1960 personal communication) and letters (Adelson, Muckler & Williams, 1955).

The effects of context in recognition tasks have been shown for both visual and auditory presentation with a variety of contexts.

Miller, Heise & Lichten (1951) and O'Neill (1957) both found that words presented auditorally were more readily recognized in noise when presented in a sentence than in isolation. Both experiments showed that the removal of the context raised the threshold for 50 % correct recognition by 6 db. Miller *et al.* (1951) also showed that with monosyllables the threshold was lowered by presenting the subject with a list of words from which the stimulus was drawn. The ease of recognition was inversely related to the number of items in the list. Under similar conditions, I. Miller (1957) found that nonsense bi-syllables were more readily recognized in redundant lists. Bruce (1958) compared the auditory recognition of sentences in isolation, in the context of a correct description of their topic, and with an incorrect description of their topic. He found that the correct context led to an increase in the number of words recognized, and the false context reduced the score.

In a visual recognition task, Miller, Bruner & Postman (1954), exposing 8-letter sequences of zero-, 1st-, 2nd- and 4th-order approximations for times ranging from 10 to 500 msec., found that the number of letters recognized increased with the order of approximation over the whole range of exposure times. E. E. Miller (1956) presented two groups of 25 sentences either in random order or in an order where the sequence told a story, and found that significantly more words were perceived in the 'story' condition.

No work has been found on the effect of a sentence context on the visual perception of words, which is the paradigm for reading. It is necessary that context should operate in this situation if the original hypothesis is true. We would expect the presentation of a sentence context to facilitate the perception of a word. In addition, from concepts derived from information theory, we would expect there to be a linear relationship between the ease of perception of the word and the logarithm of the probability of it occurring given the context. The ease of perception of the stimulus words are measured in the present experiment by measuring their visual duration thresholds.

II. Materials

It was necessary to prepare a series of words with context which predicted them to a more or less specifiable extent. The contexts were incomplete sentences which could be completed by the addition of a single word; e.g.

It was a most exciting ——.
She looked into the ——.
He walked round the ——.

The incomplete sentences are referred to hereafter simply as 'sentences'.

It seemed possible that the properties of the sentence, apart from the stimulus, might exert an influence on the threshold. That is, different sentences might set up different preparatory states in the subject, depending on the number and nature of the responses possible.

To investigate this point it seemed advisable to have more than one word associated with each sentence. The method adopted for doing this was to have one word with a high transitional probability and one with a low transitional probability connected with each sentence, and to have each word connected in a like way with two sentences. In this way the sentence effect, if any, could be examined. 'High' was defined arbitrarily as $P \geqslant 0{\cdot}15$, 'low' as $P < 0{\cdot}15$. The two classes were termed Condition 1 and Condition 2 respectively.

Accordingly, 30 sentences were designed which seemed likely to produce responses from which a satisfactory selection of words and sentences could be made. The sentences were arranged in lists such that there was maximum possible separation between those sentences likely to produce a similar response, in order to reduce interference effects. They were then presented one at a time to subjects with the instruction to respond immediately by saying the first word which occurred to them which completed the sentence grammatically and logically. If any response was outside these conditions the sentence was presented again. In this way a hundred responses to each sentence were collected from a hundred female students.

Table 1. *Examples of response configurations*

1. Sentence: The cup was placed on the —.

Responses:			
table	67	drainer	1
saucer	16	chair	1
sideboard	6	chest	1
shelf	4	cupboard	1
mantlepiece	3		

2. Sentence: They went to see the new ——.

film	22	baby	2
house	20	bedroom	1
show	14	hospital	1
play	12	exhibition	1
car	6	bungalow	1
building	6	curtains	1
picture	3	calf	1
moon	3	child	1
flat	2	toys	1
shop	2		

The responses for each sentence were summed for each word, the frequencies of occurrence of the words being used as an estimate of their transitional probabilities. Examples of the configurations obtained are given in Table 1. The lists of words and sentences were examined for combinations fulfilling the conditions stated above. Since the sequences were incomplete, a further 25 sentences were prepared, and the same procedure was followed with another 100 female students. Among the 55 sentences there were 24 sentences and words which could be suitably combined, of which 18 were used in the experiment. These 18 sentences and words are given in Table 2. It will be seen that the word 'coat', for example, occurs as a high probability word in the context of sentence 1, and as a low probability word in the context of sentence 3.

To control for possible differences in threshold due to the configuration of the word in isolation, a third condition was used, employing a row of 'x's' instead of a context sentence, to give the same stimulus conditions.

The three conditions of presentation were then:

Condition 1—high probability context.
Condition 2—low probability context.
Condition 3—control condition, no context.

The sentences and words were printed in indian ink on white card in lower case, using U.N.O. stencils, and photographic slides were prepared.

Table 2. *The stimulus words and context sentences*

	Words	
Sentences	Condition 1	Condition 2
(1) Coming in he took off his	coat: 32	shoes: 14
(2) She cleaned the dirt from her	shoes: 44	dress: 6
(3) She bought a new	dress: 32	coat: 10
(4) Together they had the first	dance: 17	prize: 2
(5) He hoped to win the	prize: 24	cup: 4
(6) At the sink she washed a	cup: 27	saucer 2
(7) The cup was placed on the	saucer: 16	shelf: 4
(8) She reached up to dust the	shelf: 22	window: 3
(9) She gazed thoughtfully through the	window: 89	door: 4
(10) Quickly she walked towards the	door: 44	shop: 3
(11) He bought a book at the	shop: 70	station: 4
(12) He asked the way to the	station: 36	cinema: 6
(13) They went to the	cinema: 21	dance: 4
(14) They went to see the new	film: 22	picture: 3
(15) They looked intently at the	picture: 29	film: 4
(16) He was wakened by the	birds: 16	noise: 13
(17) She was startled by the	noise: 45	train: 2
(18) In the distance she heard the	train: 16	birds: 4

The figure following each word is the number of times the word was given as a response to the sentence in 100 subjects.

III. APPARATUS

The apparatus consisted of a rigid white cardboard screen, two projectors and a falling plate tachistoscope. The screen contained a slit of transparent paper on which the context sentence, or the row of 'x's', was projected. The beam of the other lantern passed through the tachistoscope opening to permit the word to be exposed for a limited amount of time, at the end of the sentence and precisely aligned with it. The lens of the second lantern was stopped to give a sharp on-set and cut-off of illumination as the tachistoscope plates fell, and the intensities of the beams were adjusted to give equal brightness on the screen. The subject sat facing the screen at a distance of 4 ft. in a slightly darkened room. The letters on the screen were a quarter of an inch high and could be read clearly by all the subjects. The tachistoscope was checked with a photoelectric cell and a Chronotron timer and was found to have a consistency of $\pm 3\%$ over the whole range.

IV. PROCEDURE

The words were arranged in an order which gave maximum separation between those connected with the same sentence, and three lists were drawn up, as far as possible at random, assigning contexts to the words. Constraints were applied so that each list contained six of each of the three conditions. The three lists of words and conditions may be seen in Table 3.

It was not possible to present any word more than once to any subject, since previous work indicates that the threshold for a word would be affected by a recent presentation. Hence each subject was presented with only one list and saw each word only once in one of the three conditions.

Since previous work indicated that there was a marked practice effect in the tachistoscopic recognition of words (e.g. Howes & Solomon, 1951), two further precautions were taken. First, at least three practice words were given, one paired with each of the three conditions. The second precaution was to present the words in four alternative orders: 1–18; 18–1; 9–1; 18–10; 10–18; 1–9. Thus there were three lists with four possible orders of presentation each.

The subjects were 24 female students who were assigned at random to one of three groups of eight, each group being given one of the three lists. Two subjects in each group had the list in each of the four orders. Any subjects with defective vision wore their normal correcting lenses.

The subjects were tested singly. The following instructions were given: 'This is an experiment to find out how we perceive words. I'm going to flash words on to the screen here, and I want you to tell me what word or part of a word you see or think you see. I don't want you to guess though. The words will be presented in two ways, either with an incomplete sentence in front of it, which the word completes grammatically and logically, or with a row of 'x's' in front. In both cases your procedure will be the same. I will not necessarily tell you whether your response is correct or not.'

The practice words were then presented and the subjects became familiar with the procedure.

For each run the sentence was projected on to the screen until the run was completed. After the subject had read the sentence the signal 'ready' was given, and the word exposed. The method of ascending limits was used, the exposure time being raised by increments of 11·54 msec (equivalent to two units of the arbitrary scale on the tachistoscope) to a criterion of two successive correct responses. Following one correct response, the exposure time was kept the same for the next exposure. The starting-point for each run varied with the subject, word and condition, and was based on an estimate such that three incorrect, partial or 'nil' responses might be given before the correct one. All partial or incorrect responses were noted.

After the experiment, without previous warning, each subject was asked to recall all the words she had seen. When no more words could be recalled, those sentences were read out comprising the contexts for the words not remembered and additional responses were noted.

Table 3. *Mean threshold for words* (*in milliseconds*)

	Group I ($N = 8$)		Group II ($N = 8$)		Group III ($N = 8$)	
Word	Condition	Threshold	Condition	Threshold	Condition	Threshold
(1) coat	3	107	1	75	2	81
(2) dance	3	117	2	96	1	97
(3) saucer	1	76	2	74	3	104
(4) door	2	86	3	124	1	86
(5) cinema	1	90	3	102	2	89
(6) birds	1	70	2	92	3	104
(7) shoes	2	74	3	119	1	97
(8) prize	2	89	1	96	3	86
(9) shelf	3	99	1	70	2	79
(10) shop	3	86	2	76	1	56
(11) film	2	104	1	96	3	128
(12) noise	3	119	1	93	2	94
(13) dress	1	75	2	109	3	139
(14) cup	2	99	3	119	1	81
(15) window	2	70	3	100	1	56
(16) station	1	54	2	73	3	115
(17) picture	3	80	1	84	2	86
(18) train	1	59	3	99	2	81
Mean for the group		85·9		94·3		92·1

V. Results

(*a*) *Threshold*

The raw results are summarized in Table 3.

Since the order effects were negligible compared with the individual variation, the results were pooled and submitted to an analysis of variance. The analysis is complicated owing to the fact that only a third of the subject-word-condition combinations occur, and is described elsewhere (Morton, 1961). The results are summarized in Table 4.

Table 4. *Analysis of variance*

Source	D.F.	S.S.	M.S.*†	*F*	*P*
(1) Groups	2	164·70	82·35[1]	0·581	N.S.
(2) Subjects within groups	21	2978·26	141·82[2]	9·0	< 0·001
(3) Conditions: 1 *v.* 2	1	121·42	121·42[4]	4·56	< 0·05
(4) Conditions: 1 and 2 *v.* 3	1	1965·06	1965·06[4]	73·81	< 0·001
(5) Conditions × groups	4	107·76	26·94[3]	1·086	N.S.
(6) Conditions × subjects/groups	42	734·65	17·49[2]	1·116	N.S.
(7) Words	17	1459·18	85·83[3]	3·461	< 0·01
(8) Residual (words)	28	694·39	24·80[2]	1·583	< 0·05
(9) Residual (groups)	315	4937·44	15·67	—	—
	413	13162·86			

* Mean squares tested against: [1] Subjects within groups; [2] Residual (groups); [3] Residual (words); [4] Special error term equal to ($\text{M.S.}_8 + \text{M.S.}_6 - \text{M.S.}_9$) (see Morton, 1961) = 24·80 + 17·49 − 15·67 = 26·62.

† The error term for the conditions × groups source should also contain a component from the main words variance, and from the conditions × subject within group variance, but, since this source is not significant in any case, it is unnecessary to include these terms.

The following conclusions may be drawn from the analysis (the numbering of the conclusions corresponds to the numbering of the sources in the table):

(1) The difference between the groups is no more than would be expected from the differences between subjects.

(2) Subjects vary significantly in what might be called their basic threshold. This may be related to the degree of certainty required before a decision is made as to the nature of a stimulus (this as an attribute of the discrimination processes in the brain; cf. Tanner & Swets, 1954).

(3) and (4) As predicted, the threshold under Condition 1 is significantly lower than under Condition 2, and both context conditions have a very significant effect compared with the control condition.

(5) There is no difference between the groups in their effective use of context. This result, together with conclusion (1), means that we can pool the data from all three groups for further examination.

(6) Within each group of eight subjects there were significant (though only just significant) differences between the individuals in their effective use of context.

(7) The stimulus words which were used differed basically in their ease of perception. This is discussed below.

(8) The residual (word) term contains some variance due to the word × condition interaction which we would expect to be significant, since within the context conditions there is a considerable variation as to the actual transitional probability.

The results were further analysed in various ways. In these analyses the assumption was made that the uncontrolled variables affecting the threshold, i.e. group differences and word differences, did so in an additive way. Accordingly, the mean thresholds of each word in each condition were adjusted in the following way.

The group mean thresholds across all words and conditions in the arbitrary units were: group I, 9·14; group II, 10·31; group III, 10·00. To allow for individual differences in basic threshold, figures of 1·17 and 0·86 were then subtracted from the mean scores per word of group II and group III respectively, to make the three group means equal. To correct for the basic differences in the thresholds of the words, the mean score of a word in Condition C (control), corrected for group differences, was subtracted from the mean corrected scores for that word in Conditions 1 and 2, and a constant was added to make all the resulting figures positive. All comparisons of thresholds in the context conditions thus use figures which have the thresholds of the words under the control condition as a base-line. In the figures presented, these adjusted threshold measures are treated as being in arbitrary units.

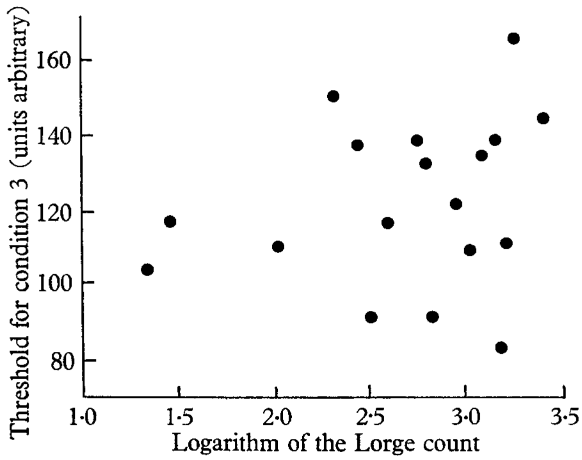

Fig. 1. The relationship between threshold and frequency of word occurrence in the absence of context.

(*b*) *Word differences*

According to Howes & Solomon (see Howes & Solomon, 1951; Solomon & Howes, 1951; Howes, 1954) the visual duration threshold for words has a negative linear relationship with the logarithm of the probability of the words in the language. However, when the thresholds for the control condition, corrected for group differences, were plotted against the logarithm of the Lorge count (Thorndike & Lorge, 1944), no such relationship could be found (Fig. 1). All the words are common ones though, and it is unlikely that effects of differential experience of words, the factor used to explain the result, could operate appreciably within such a small frequency range. There was no relation between threshold and such structural factors as length of word or the number of ascenders and descenders. However, a factor of 'confusability' of the words gave a rank-order correlation with threshold in Condition 3 of $\tau = 0{\cdot}456$ ($P < 0{\cdot}015$). The factor of confusability was estimated by taking the number of different whole words given as incorrect responses under the control conditions.

(*c*) *The effect of context*

The analysis of variance showed a significant difference between the two experimental conditions. In order to examine more closely the relation between threshold and probability, it seemed reasonable to use the results only of those subjects who did exhibit an effect due to context. Thus the four subjects from each group with the largest mean context effects were selected, and their results were treated in the following analysis.

Fig. 2 shows a plot of the mean threshold for the word against the logarithm of the probability ($\log P$). The thresholds have been corrected for group differences and word differences, so they are an estimate of the relative effects of abstracted context-stimulus situations. Each plot is the mean for four subjects. The product-moment correlation between $\log P$ and this threshold measure was $r = 0{\cdot}528$ ($P < 0{\cdot}01$).

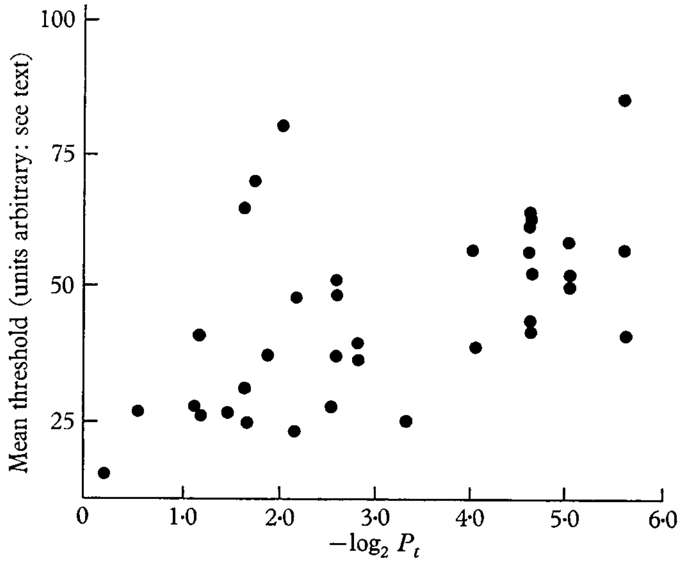

Fig. 2. The relationship between threshold and transitional probability of a word in a sentence context.

The experiment was also designed to separate out the effect of the sentences upon the thresholds. However, no significant relationship could be found between the thresholds and the entropy of the context sentences (estimated by $H = \Sigma - p \log P$ over all possible responses to the sentence).

(*d*) *Memory*

The test of memory for the stimulus words, given at the end of the experiment, produced the following results. (i) There was a steady increase in recall with serial order. (ii) Significantly more words were recalled in the context conditions than in the control condition. Ease of recall of the words was highly determined by the relative ease of recall of the context sentences.

(*e*) *Errors*

The errors made by the subjects were analysed in order to provide evidence as to the relative importance of the stimulus and of response bias. The incorrect responses fell into three groups showing the effects of expectancy, of previous stimuli and responses, and of inadequate perception. The first two of these groups do, in one sense, reveal the effects of response bias, in that the influences operating in determining the response are not predominantly those relating to the physical nature of the stimulus. We will, however, account for these errors in terms other than 'response bias' in the 'guessing' sense used by Goldiamond & Hawkins (1958).

Table 5. *Examples of incorrect responses involving a word with a higher transitional probability* (*see also Table* 6)

Condition 2

Stimulus	Response	Stimulus	Response
coat	dress, hat (2)	birds	bells
dance	cinema, theatre (2)	shoes	coat
door	window	shelf	table (3)
cinema	station	film	book

Condition 1

Stimulus	Response
coat	hat
saucer	table (2)
prize	race (3), —ce (2)

Note. A figure following a word indicates the number of times that word was given as a response.

The effect of expectancy

In Conditions 1 and 2, there was a bias towards giving as an incorrect response a word more probable in the context than the stimulus word, compared with a less probable word. In Condition 1 there were seven higher probability words and thirteen lower probability words given as incorrect responses. In Condition 2 the figures were 23 and 32 for higher and lower probability words respectively. All higher probability words given as incorrect responses are shown in Table 5. As there are considerably more lower probability words available as responses in the experimental conditions, it seems as though an expectancy for a more probable word exerts an influence on perception, resulting in a higher proportion of such words being given as incorrect responses than would be expected. Each subject who gave a higher probability word as a response was questioned after the experiment as to the confidence with which this response was made. In most cases they reported that they had been completely certain, and in some cases suspected that the stimulus word had been changed in the middle of a run. It seems clear that the result cannot be explained by saying that the subjects were 'guessing'.

Thirty-five words were given as responses in the context conditions which were nonsense in the context. If the subjects' responses were considered to be guesses determined by the context, they would not have made these responses. This point is considered further in the discussion which follows.

Influence of previous stimuli and responses

Another class of error involving the influence of some kind of set consists of those cases where the response was influenced by a word previously seen in the experiment. These responses, words and parts of words, are shown in Table 6. From the table it is clear that a previously seen, higher probability word is particularly prone to be given as an incorrect response on the next trial. None of the stimulus words which had not yet been seen were given as errors, except in the five cases where they were more probable words. So we can say that the effect is genuinely due to the prior presentation of the word with which the subject responded.

Table 6. *Examples of the influence of a previous stimulus word*

	Conditions 1 and 2		Condition 3	
	Stimulus	Response*	Stimulus	Response
Immediately preceding stimulus word	door	cinema	coat	train
	shoes	prize	dance	saucer
	film	show (shop)	saucer	dance
		----p (shop)	shop	shelf
		---se (noise)	shoes	prize
	noise	fl-- (film)	birds	c---n- (cinema)
Earlier stimulus word	shoes	dress (×2, P 6)†‡	birds	dress (×2, P 7)
		c--- (coat, P 6, H)§	prize	dress P 6)
	dress	coat (P 12)	dress	fl-- (film, P 2)
	coat	dress (P 12, H)	cup	shop (P 4)
	dance	cinema (P 3, H)	picture	-ance (dance, P 3)
	cinema	station (P 12, H)		
	birds	noise (P 6, H)		
	prize	dance (P 6, H)		

* The response word was the previous stimulus word except where a word is given in parentheses. † (P *n*), the word occurred *n* words previously. ‡ (×2), such a response was made by two subjects. § H, a higher probability word.

A similar influence was the effect of a previous incorrect response. One example was that of the subject presented with 'train' in Condition 3 who responded 'sting'. On the next exposure the incorrect initial 's' was retained and the response was 'strain'. Similarly, with a stimulus of 'shelf', the response 'smell' was followed by 'shell'; and 'tree' and 'true' in response to 'cup' led to 'trip' and 'trap' as further responses before the word was reported correctly.

Perceptual errors

The errors can also be classified in terms of what appear to be various kinds of perceptual error. In many cases an error may be classified in more than one category, and may also have been classified above. Examples of these errors are given in Tables 7 (i) to (v). The five categories in Table 7 are considered in paragraphs (i) to (v) below.

(i) The most common error, totalling 176, involves the correct perception of beginning and/or the end of the word, while the remainder of the word is incorrectly reported. In over half these errors the response word was the same length as the stimulus word.

(ii) Ascending and descending letters were confused on 138 occasions. Thus 't', the most frequent of the ascending letters, was mistaken for another ascending letter 17 times, and reported as being seen when absent on 44 occasions. No reliable conclusions may be drawn as to the effects of letter frequency in this situation, however, since there was no control of the number of occurrences of the different letters, or of the various other influences mentioned.

The last three categories of error are examples of what might be called 'stimulus disorientation'. It would appear that the shape of the word or the form of a letter have been perceived correctly, but an error has been made in either the horizontal or the vertical orientation of a generalized shape category.

Table 7. *Examples of perceptual errors*

	Stimulus	Response		Stimulus	Response
(i) Incorrect centres	coat	coot, soot, roat	(iii) Inversions of ascending and descending letters	dance	pence, grace, gence, p---ance, p----
	door	dear		shop	prop
	birds	bards, bands, beads		dress	grass
	shop	sharp		picture	lecture, structure
	cup	cap, crap		train	grain
	picture	puncture			
(ii) Confusions of ascending and descending letters	cost	coal	(iv) Inversions of w, n and u	window	windem
	dance	trance, trace, tence		train	treasu, ----u
	door	bear, boar		dance	---use, --u--
	shelf	shell, shield		picture	--tn-
	film	tile (2), table			
	dress	stress, class	(v) Word reversals	coat	t---(2), to--
	train	brain		shop	p---

(iii) On 32 occasions, ascending letters were seen as descending letters, in 12 cases the reverse was found. The most common inversion was 'd' seen as 'g' its exact inversion in the print used, apart from the curl in the tail.

(iv) Other inversions involved 'w' seen as 'm' and confusions of 'u' and 'n'.

(v) In 32 cases it seemed as if a word had been reversed. It was judged so when a word with an initial ascending or descending letter was seen as having a final ascending or descending letter, or vice versa.

The justification for regarding the last three categories as cases of stimulus disorientation lies in the unambiguous examples such as 'train' reported as ending in 'u' and 'coat' as beginning with 't'. The phenomenon of stimulus inversion was most strikingly demonstrated by one subject who was presented with the word 'dress' in the control condition. Her responses alternated between 'dress' and 'grass' five times before she settled for the correct response. She commented that she had had no idea which way up the initial letter was.

The types of errors reported here are substantially the same as those noted by previous workers such as Pillsbury (1897) and Vernon (1929). Although the conditions of perception in the present experiment are widely different from those experienced in reading, Morton (1961, 1964) has shown that the same kinds of error occur in both situations.

VI. Discussion

The minimal role of response rise in the experiment

A relationship has been shown between the transitional probability of a stimulus and its visual duration threshold. This effect would be predicted on the basis of the previous experiments showing the effects of context on perception which were cited above. The validity of ascribing some of these effects to perception has been challenged by Goldiamond & Hawkins (1958). Their subjects were first given a training session in which they repeated nonsense syllables at different frequencies. They were then told, in a recognition session, that these words would be flashed subliminally; they were to guess until accurate. Accuracy was defined as responding with the word on the experimenter's score sheet. Blank exposures were presented throughout. The experiment mimics an ascending Method of Limits with 'accuracy' terminating a series, and a negative linear relationship was found between the logarithm of frequency of training and 'threshold'. The authors regard their results as challenging a perceptual interpretation of the word-frequency-threshold relationship, suggesting that 'response bias' could explain the results adequately. (Note: for the moment, the traditional perceptual-response dichotomy is accepted without comment.)

Since their subjects were specifically instructed to guess, their use of the term 'response bias' is a very special one. The following points may be made in asserting that this kind of response bias played a small part in the present experiment.

(i) The subjects were specifically instructed not to guess.

(ii) The 'accuracy' criterion in the present experiment was for two successive correct responses, and on several occasions the subjects reported uncertainty as to the nature of the stimulus on the exposure following a correct response.

(iii) The mean transitional probabilities of the words in Conditions 1 and 2 were 0·334 and 0·049 respectively. Following the Goldiamond and Hawkins result we would expect the proportion of correct to incorrect initial responses in the two conditions to be approximately 35:65 and 5:95, i.e. 1:1·8 and 1:19, respectively, if a response bias determined the response. In fact, these proportions were only 1:0·45 for Condition 1 and 1:0·65 for Condition 2.

(iv) The subjects often reported that the words which were given as incorrect responses were seen quite clearly. Only occasionally was a response prefaced by 'I think it was...'; and the response which followed was as often correct as incorrect.

The use of visual cues in determining the response

If the effect of context upon threshold is accepted as a perceptual phenomenon, then we can state that in the context conditions a subject will perceive a word at an exposure time which would be inadequate for the perception of that word in the absence of a context. In other words, the presence of a context reduces the number of visual cues necessary for the correct identification of the word.

By considering that a high proportion of the errors result from a response being made on the basis of insufficient visual cues, it seems possible, from the nature of these errors, to say something about the order of emergence of stimulus detail with exposure time, i.e. to rank those stimulus properties which seem to determine a response. Two factors are considered.

(*a*) A large number of the errors involved the confusion of ascending or descending letters. In addition, a high proportion of error words were the same length as the stimulus word. We can consider the two properties of configuration, that is the position of ascending and descending letters, and the length of the word, as specifying the *shape* of the stimulus. In terms of the figure-ground relationship, this is the 'contour' (cf. Vernon, 1952, p. 43).

(*b*) The largest category of error consisted of correctly reporting the beginning or the end of a word, while incorrectly identifying the interior letters. It may be noted that Woodworth & Schlosberg (1954, p. 104) refer to the phenomenon of the relative masking of the interior letters in a sequence. They refer to the effect as occurring in peripheral vision only, but their hypothesis that the effect is due to a differential brightness contrast could be applied equally well to foveal vision with very short exposures.

Certain of the errors were analysed in order to test whether the properties of shape and the relative ease with which outside letters are perceived had any special significance. These errors consisted of the first incorrect whole word responses in any run in the Control Condition, excluding responses of a previous stimulus word. In this way, as many errors as possible were excluded which could be attributed to the influence of set. The 87 responses which were thus chosen were analysed as follows:

(*a*) Nineteen responses had the correct configuration, 22 the correct length and a further 28 were correct in both respects. Thus a total of 69 of the 87 errors were correct with respect to some aspect of the shape.

(*b*) Twenty had the correct initial letter, 33 the correct final letter, and a further 12 had both letters correct—a total of 65 of the 87 responses.

(*c*) Only eight of the responses had none of these elements in common with the stimulus word.

When the 159 whole word errors in the Context Conditions are analysed, we find 88 with some aspect of the configuration matching the stimulus and 80 with either or both of the initial or final letter correct. Forty-nine of the responses had none of these factors in common with the stimulus, though of these about half were classified as involving stimulus inversion or reversal; the rest were mainly previous responses or highly probable words in the context.

To establish the significance of these findings would require a control experiment of some complexity in design, but it remains reasonable to suggest that these properties have a certain priority in determining the response.

It seems advisable to restate the present position.

(1) It was suggested that in the presence of context, fewer visual cues are required for a word to be perceived and reported correctly.

(2) It has been demonstrated that the errors made cannot, in the main, be attributed to the operation of a response bias, and must therefore be due to perceptual effects. This accepts the traditional perceptual-response dichotomy.

(3) It was suggested that the errors result from responses being made on the basis of insufficient visual cues, and certain properties of the stimulus have been identified which might be so utilized.

The effect of set

We now return to the main result of the present experiment and consider it further. It was established that context has the effect of reducing the visual duration threshold of a word, and that the amount of this reduction is related to the transitional probability of the stimulus word. Now the measures of transitional probability were established by presenting 100 subjects with the incomplete sentences and summing their responses. This we will term a *Generation Situation.* In assuming a communality of response probability for the population, we are stating that the transitional probability values measure the relative strengths of the response biases (in the sense used by Goldiamond & Hawkins) of any subject, given the context.

However, we have established that the responses in the experimental situation, which we will call a *Recognition Situation*, are not appreciably determined by response bias. Hence, we can state that the processes which operate to determine the response bias of a word in a context also operate to produce a reduction in threshold of the word in that context. These processes are concerned with the sequential relationships between linguistic units, and the nature of their operation presumably derives from an individual's experience of language. These processes will be called the *Sequential Processes*.

The result of the operation of these processes is the same in both the generation and recognition situations—the response of a word.

Let us now differentiate between those subprocesses in the brain which operate terminally to make different words available as responses, and call them *units*. These 'units' are similar to those suggested by Treisman (1960) as the components in some 'dictionary' of known words. The units may be regarded as having a threshold of activation; when the threshold is exceeded, the unit fires, and the corresponding word is available as a response. Normally, different units have different levels of activation, determined, for example, by their frequency of usage. (We may alternatively regard them as having different thresholds; that is, at the present time, purely a matter of taste—the principle of operation remains the same.)

Since the presence of a context makes certain words more likely to be given as responses, we can say that the Sequential Processes operate to increase selectively the level of activation in certain units.

In a *Generation Situation*, a selection mechanism operates to choose a word in such a way that the relative probability of different words being chosen depends upon the levels of activation in the corresponding units. From such responses we estimate the transitional probabilities, i.e. in Goldiamond & Hawkins's terms, the response bias.

In a *Recognition Situation*, we suggest, sensory information is fed into the set of units, or dictionary, as it becomes available. This input increases the level of activation of particular units until a unit fires. The word is then available as a response. The increase in activation of any unit will be a function of the degree of similarity between the stimulus and the word associated with the unit; that is, the number of 'visual cues' they have in common. In the presence of a sensory input into the dictionary the subjects report the available word as having been 'perceived'.

In this system, if a word is very highly probable in a context, then its unit will be at a high level of activation. Therefore minimal activation from the sensory input would be likely to trigger the unit, resulting in a lower threshold for the higher probability words and giving rise to incorrect responses of the first group mentioned.

The effects of previous responses may be predicted by considering that the threshold-frequency effect has been obtained with nonsense syllables by differential training immediately before measuring the thresholds (Solomon & Postman, 1952; Baker & Feldman, 1956; King-Ellison & Jenkins, 1954). Such training involved seeing and saying the syllables at different frequencies, which, from the differential effect on threshold, may be said to have differentially increased the activation level in the different units. We can then accept that perceiving and responding with a word in the present experiment will also temporarily raise the activation level in the appropriate unit. Thus the unit will be more likely to fire when sensory information is fed in, giving rise to incorrect responses of the second class. It might also be noted that similar errors occurred in a reading task where a class of intrusive errors was found consisting of words which had previously occurred in the passage, usually on the same line (Morton, 1961, 1963). This form of activation may be contrasted with the more permanent effects attributed to differential experience of different words in the language.

It was noted above, that high probability words which had previously occurred were particularly prone to be given as incorrect responses. In terms of the model this would indicate that the various activation effects are cumulative.

The third group of errors, perceptual errors, would be expected from the suggested mode of operation of the sensory input. The greater the similarity between a word and the stimulus word, the more the appropriate unit will be activated and the more likely will the word be given as a response.

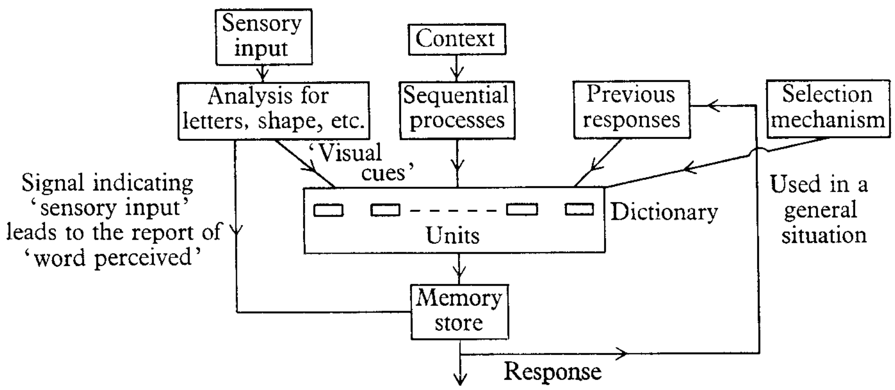

Fig. 3. A model for word recognition.

The model is presented in the form of a flow diagram in Fig. 3. Its main virtue in its present form is that it eliminates the difficulties implicit in an arbitrary linear separation of stimulus and response effects. In the model, both effects take place at the same level, and the 'perception' of a word is only different from the generation of the same word in that there is an input from the sensory mechanisms in the first case, and an input from some Selection Mechanism in the second.

In its present form, the model is sufficient to account for the main results of the experiment and the errors made by the subjects. It is developed more formally elsewhere (Morton, 1961).

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