dissolved copper, but it is significant that the amount of copper retained by the spores was greatest in the absence of leaf substrate. Similarly, the supernatant concentration of copper was highest over glass, which suggests that the soluble copper complexes formed from the Bordeaux deposit by leaf and spore exudates are competitively retained by the leaf. At the conclusion of the experiments the spores were washed and their germination capacity determined. Spores which had been incubated with the leaves gave consistently higher germination (65–75 per cent) than did the spores from the glass surface (55–65 per cent): 97 per cent of the untreated conidia were viable.

Solubilization of copper by the leaf therefore reduces both spore uptake and fungicidal activity. The influence of spore exudates is more difficult to determine directly; when the spores were made up to a final volume of 30 ml. with spore exudate instead of distilled water there was a reduction in the copper accumulated by the spores, particularly on a glass surface (Table 2). Similar effects were given by potato leaf exudate.

Table 2. EFFECT OF POTATO LEAF AND SPORE EXUDATES ON THE ACCUMULATION OF COPPER BY *Neurospora crassa* SPORES

Surface	Solution	Spore uptake (μg Cu/million)
Glass	Water	8·5
	* Leaf exudate	5·3
	† Spore exudate	4·0
Potato	Water	3·7
	* Leaf exudate	2·5
	† Spore exudate	3·4

* Fourteen potato leaves shaken in 120 ml. water overnight and 29 ml. of the supernatant added to 1 ml. of *N. crassa* suspension containing 3,000 million spores.

† Spores at 500 million/ml. shaken overnight and 29 ml. of the supernatant added to 1 ml. of *N. crassa* suspension containing 3,000 million spores.

The evidence is that the formation of copper complexes, from the reaction between leaf or spore exudates with a Bordeaux deposit, reduces the uptake of copper by the spores. This suggests that these water-soluble complexes are less effective in penetrating the spore than is the free cupric ion. Thus, there is no necessity to invoke the solubilization hypothesis to explain the fungicidal action of copper in Bordeaux mixture; the simple accumulation of ionic copper[14] is sufficient explanation.

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PSYCHOLOGY

Serial Choice Reaction-time as a Function of Response versus Signal-and-Response Repetition

IN serial self-paced choice reaction, reaction times (RTs) to repeated signals, that is, to a signal identical to the immediately preceding one, are shorter than RTs to new signals, that is, to a signal different from the preceding one, provided the time-lag separating the onset of each signal from the end of the previous response is short. This was shown in tasks involving either two signals and two responses[1,2] or four signals and four responses[2], where repetition of the response was, except for the very rare errors, obtained only through repetition of the signal. The present letter reports a first trial to distinguish the effort of signal repetition, not confounded with that of response repetition, by considering a task where more than one signal is associated with each response. In such a situation, the relationship of a cycle to the preceding cycle can be one of 'identity' (same signal), of 'equivalence' (different signal but same response) or of 'difference' (different response). By comparing RTs on cycles belonging to the first two categories, one could then examine if repetition of the signal has an effect *per se*.

The apparatus, which has been described earlier[1,3], provides a two-responses self-paced task. It was slightly modified in order to give four different signals. The display was a Nixie numerical indicator. The subject responded by pressing one of two keys with one of the two index fingers. The display went off when one of the keys was depressed, and the following signal came 50 msec after it was released. The apparatus stopped automatically after 50 responses.

Four male subjects, aged 17–26, did 20 runs of 50 responses on each of four sessions, 10 under each of two conditions. In condition 24–57, the experimental condition, the four digits 2, 4, 5, 7 could be presented, the correct response being left for 2 and 4 and right for 5 and 7. In condition 2–5, only the digits 2 and 5 were used. This control condition was introduced to provide a measure of the 'repetition effect' in the usual two-signal situation. Under both conditions, signals appeared with equal frequencies in random order. The order of presentation of the two conditions was alternated from session to session.

The last 5 runs of session 4 were recorded with a pen recorder, which gave RTs to the nearest 25 msec. The first RT of each run and those corresponding to false reactions were excluded from the sample. Medians for the different transition categories were calculated by linear interpolation within measurement intervals, and are shown in Table 1 together with error percentages.

Table 1. MEDIAN CORRECT REACTION TIMES AND PERCENTAGE ERRORS FOR THE DIFFERENT TRANSITION CATEGORIES

Condition	Transition category	Subjects 1	2	3	4
2–5	Different (D)	513 (6·3)	525 (8·0)	482 (10·7)	453 (11·7)
	Identical (I)	415 (0)	405 (0·8)	380 (0·8)	348 (3·9)
	D–I	98	120	102	105
24–57	Different (D)	498 (7·5)	535 (11·7)	485 (13·0)	483 (5·5)
	Equivalent (E)	382 (0)	418 (2·0)	403 (5·7)	413 (5·6)
	Identical (I)	378 (0)	405 (1·6)	380 (0)	378 (0)
	D–E	116	117	82	70
	E–I	4	13	23	35

The first numbers are RTs in msec. Those between parentheses are error percentages. Theoretical sample size is about 61 for categories E and I of condition 24–57, 123 for all other categories. Real sample size is reduced by the number of errors.

The usual repetition effect, shown by the difference between RTs on different and identical cycles, is observed under condition 2–5. Under condition 24–57, a difference of the same order of magnitude is observed between RTs on different and on both equivalent and identical cycles. RTs to identical signals are slightly shorter than RTs to equivalent signals. The difference, tested by Mann–Whitney's U test, is significant for subjects 3 ($P < 0·02$) and 4 ($P < 0·001$), not for the other two. The repetition of the signal, apart from that of the response, can thus exert some effect. It is clear, however, that in this situation the main effect is linked to the repetition of the response.

Under both conditions, the vast majority of errors are observed on 'different' cycles, that is, they consist of repeating the response when the other response is required instead. This phenomenon has been observed, although not reported, in all previous experiments on the subject. It is interesting to note that the two subjects who react significantly more slowly to equivalent signals also make erroneous responses to these signals.

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Effect of Verbal Context on Latency of Word Selection

GOLDMAN-EISLER[1,2] found that low transition probabilities between words were associated with the occurrence of pauses in speech, both for the original speaker selecting words spontaneously and for subjects guessing missing words from the same verbal context. We can assume that differences in latency reflect, however crudely, something of the search or word retrieval system used in selecting words. Oldfield and Wingfield[3] have recently used it to throw light on object naming, using a range of objects the names of which varied in frequency of occurrence in the language. They found a linear relation between latency of naming and the logarithm of the frequency of occurrence of the object's name. A comparable investigation is reported here on latencies for guessing words removed from a number of different verbal contexts the redundancy of which varied from that of random words to a passage of coherent prose.

The passages used were a set of statistical approximations to English[4] constructed by the method described by Miller and Selfridge[5]. Two passages of normal prose were also used, one very simple extract from a children's story about camping and the other a more difficult passage from Joseph Conrad's novel, *Lord Jim*. Two samples of ten words each were removed from the passages, each sample being guessed by a different group of thirty-five subjects. One set consisted of the seventh and succeeding tenth words of each passage and the other of the fifth and succeeding tenth words, so that each group of subjects would have available a context of up to nine consecutive words on either side of the word he was trying to supply. The probabilities of these missing words in their verbal contexts had been estimated from their frequencies in a set of 100 guesses made by another group of subjects given the same set of passages with missing words[6]. The mean information content of the missing words was calculated ($\log_2 p$) and so was the mean entropy of the distribution of guesses for each blank ($\Sigma p \log_2 p$). These values are given in Table 1.

Table 1. ESTIMATES OF THE PROBABILITY, INFORMATION CONTENT AND DISTRIBUTION ENTROPY OF MISSING WORDS IN THE EXPERIMENTAL PASSAGES

	Prose (easy)	Prose (Conrad)	16th order	8th order	6th order	4th order	2nd order	1st order
Mean probability of correct word	0·567	0·405	0·350	0·320	0·191	0·128	0·072	0·009
S.E.	0·064	0·090	0·061	0·075	0·053	0·037	0·006	0·004
Mean information in correct word	1·09	2·60	2·32	3·33	3·57	3·91	4·84	9·21
S.E.	0·22	0·55	0·41	0·59	0·44	0·37	0·40	0·64
Mean entropy in all first choice guesses	1·74	3·05	2·98	3·32	4·23	4·46	5·03	5·37
S.E.	0·23	0·36	0·25	0·34	0·30	0·15	0·12	0·20

Subjects were asked to read each passage to themselves and as they came to each blank to decide on a word which would fit the context and make a good approximation to coherent English, taking into account the succeeding as well as the preceding words. When they had chosen the word, they were to say it aloud, then read on and repeat the procedure with the next blank. A recording was made of the experiment and the time between each spoken choice was measured.

Possible models for word retrieval systems can be grouped into two main classes: (1) non-informational models; and (2) information-processing models. Some examples of non-informational processes for word retrieval are: (*a*) a linear search in which words in the store are first ordered in decreasing order of probability and then examined in succession; (*b*) a random search through all possible words in succession—the least efficient method; (*c*) a simultaneous search in which a multi-channel system might generate all possible words simultaneously. An information-processing system can be either: (*a*) simple, generating one word only for each verbal context; or (*b*) complex, generating a sample of possible words from which the final single choice is made. What light do the results throw on these possibilities?

(1) *Non-informational models.* (*a*) Sequential search in rank order of probability: on this hypothesis subjects search through all the words in decreasing order of probability, taking an extra unit of time for each word. The difference in latency between a high and a low probability word depends on the number of words in the intervening ranks, and one would expect a wide range of average latencies for word ensembles of different sizes. This was found in the results, as discussed hereafter. However, the model predicts that any word which is clearly more probable than all others in its ensemble will have a latency independent of its absolute probability; words with a probability above 0·5 would share the same latency. The mean latencies for words which ranked first in guessing frequency over the group of 100 subjects (and at least 7 per cent above their nearest competitors) were averaged over the different passages. They came to 5·5, 6·2, 7·2, 7·6 and 7·9 sec at mean probabilities of 0·85, 0·65, 0·45, 0·30 and 0·20, respectively. These latencies do not differ from the means for words of equivalent probabilities. Although this is not a rigorous test, since subjects may differ somewhat in their rank ordering of words, it certainly provides no support for this hypothesis. (*b*) Random search, and (*c*) simultaneous processing: with both these strategies the latency would be independent of the word's information content and of the distribution entropy. The random search should give long delays in some cases and a large variance, while simultaneous processing would show no differences in latency between different words for any given subject. Both models are excluded by the results. The graph in Fig. 1 shows the regression of latency on information

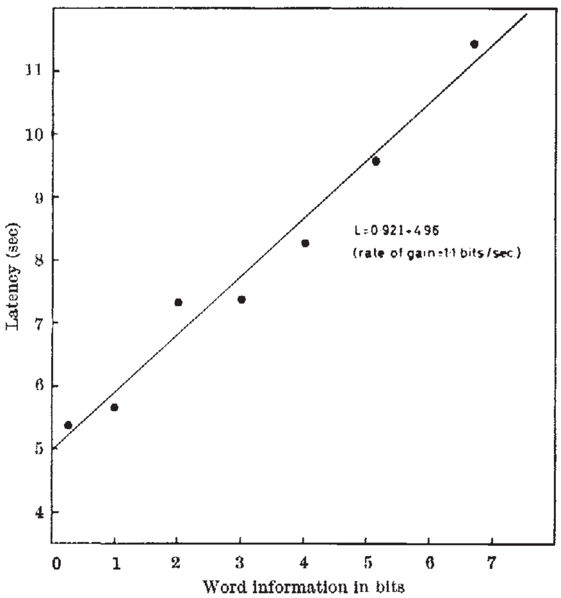

Fig. 1. Relation of guessing-latency to word information