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From detection to identification: Response to multiple targets in rapid serial visual presentation

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In four experiments, words were presented visually at a high rate; as has been found previously, subjects could identify individual target words and must therefore have gathered some information even about the unreportable nontargets. The novel feature of this study was that there were frequently two targets in the list; the occurrence of the first target disrupted identification of the second for a subsequent period of more than half a second. This happened whether the target word was designated by a single physical feature or by the semantic characteristic of belonging to a specified category. The two situations did differ, however, in that unidentified targets of the first type still disturbed an accompanying second target, whereas those of the second type did not. The results are interpreted as meaning that a simple undemanding process of detection triggers other and more demanding processes of identification, so that the occurrence of the latter for one target interferes with their occurrence for another.

A decade ago, many experiments employed forms of the detection task in which a reaction had to be performed if a target was present, but nontargets could be ignored. Paradigm studies are those of Ostry, Moray, and Marks (1976), Pohlmann and Sorkin (1976), or Schneider and Shiffrin (1977). Particular interest attached to the fact that practiced subjects showed evidence for parallel encoding of simultaneous events occurring at the senses. Thus, the number of visual nontargets became irrelevant to the detection of the target, and instructions to perform a second auditory detection task ceased to reduce the probability of a hit in the first task. Such results suggested originally that the complete sequence of processes, following the arrival of a stimulus, might become "automatic"; that is, that practiced stimuli might give rise to a response without interfering with response to other stimuli (Shiffrin & Schneider, 1977).

More recently it has become clear that such a view is too extreme. Perhaps the key paper is that of Duncan (1980), who reviewed the earlier literature and drew attention to the fact that simultaneous *targets* do very much interfere with each other. When, for example, Shiffrin, Dumais, and Schneider (1981) reported instances of two search tasks performed without mutual interference, the arrival of targets was always controlled so that one task presented nontargets at the moment when the other task was presenting a target. In many of the studies reviewed by Duncan, showing interference of one target with detection of another, motor and other peripheral response factors might have explained the decrement. Duncan himself, however, performed fresh studies with an appropriate variation of the technique of Shiffrin and Gardner (1972), which controls such factors, and confirmed that, indeed, there is interference between two simultaneous targets.

There was earlier evidence of such interference even in some of the conditions of Schneider and Shiffrin (1977); and more has been added by Hoffman, Nelson, and Houck (1983). We have to suppose, therefore, that the parallel initial encoding of many events, shown by the literature of the 1970s, is succeeded by a more limited set of processes. Entry to these is more selective, and Duncan (1980) suggested that one should speak of the "selection schedule" that picks the particular information required for admission. In some cases, the schedule might be based on spatial location, in others on color or on category membership. Duncan himself held that the full identity of all sensory events is computed before the selection schedule is applied, so that the identity can be used to determine which events reach the later stage; that is, he held a "late selection" theory . This is useful for explaining the efficient detection of digits among letters (e.g., Duncan, 1983); on the other hand, it is possible to argue that digits and letters can be discriminated by the use of very few features (D. E. Broadbent, in press; Krueger, 1984). Either view is consistent with the general distinction of an early, relatively unlimited stage of encoding and a later, more restricted stage.

Such a distinction also fits well with the approach of Treisman and Gelade (1980). They suggested that the presence or absence of individual visual features can be encoded in parallel, but that more complex computations involving conjunctions of several features can be carried out only by a limited system. A number of phenomena of visual search can be handled by such a view, particu-

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larly if different categories of elementary feature are taken into account (Treisman & Paterson, 1984; Treisman & Souther, 1985). Full identification of complex events would, in this framework, require mechanisms that are not required for simple detection. There is also the possibility that an early elementary scan of the visual field in parallel may cause later and more limited resources to be applied to events found of interest by the early stages, so that an interplay may result between mechanisms originally conceived as sharply distinguished "automatic" or "attention-demanding" ones (Johnston & Dark, 1986; Shiffrin, in press).

The usual visual search task, however, is not well adapted to tracking the time course of processes that happen sequentially; nor is it easy to introduce the identification of complex events. A possible solution is to use rapid serial visual presentation (RSVP). In such a task, a series of items is presented sequentially in the same location and the person is asked to react only to a specified target item (Eriksen & Spencer, 1969). The difficulty of the task varies with the extent of processing necessary to discriminate the target from nontargets, and thus to detect it (Eriksen & Collins, 1969). A variant useful for our purpose is to define the target in some way that does not specify its full identity, and then to ask the subject not merely to detect the target but also to identify it. Thus, for example, the person may be asked to identify a picture that carries a particular kind of border (Intraub, 1985); or, in a form used by Lawrence (1971), the series of items consists of words and the subject is asked to identify a particular word. The target may be defined by different "selection schedules"; thus the instruction may be to report a word in capital letters among a series in lowercase print, or to report the name of an animal among words outside that category. Each kind of target can be reported with reasonable accuracy, despite the fact that the subject has little knowledge of the identity of the nontarget words. Thus the nontargets are encoded sufficiently to allow their rejection, but do not seem to prevent identification of the target. This is true even with subjects who have had relatively little practice in the experimental situation; but the reading of text is, of course, highly practiced in everyday life, and has therefore been regarded as "automatic" even without the very high levels of laboratory experience needed for unfamiliar tasks (LaBerge & Samuels, 1974).

Existing studies of RSVP show that it is possible to study the time course of processes following the arrival of a target. Thus, Reeves and Sperling (1986) used an instruction to look for a target and then to identify the event occurring at a different spatial position. They found that subjects produce responses to events somewhat after the objective time of the target. McLean, D. E. Broadbent, and M. H. P. Broadbent (1982) showed that even when events occur at the same place, the color of a target letter, or the letter in a target color, also tended to be that of an event happening at a time later than the objective target. They interpreted this result as due to a delay in the starting of the response-identifying processes until after the target-defining event had been detected.

However, this was true only when the target was a specific event, so that the selection schedule could be based on detection of simple features; if an alternative technique was used, of asking the subject to report the color of a digit among letters without knowing the digit in advance, then the color was as likely to come from times before the objective event as afterward. This result was replicated by Gathercole and D. E. Broadbent (1984) in several ways, including the use of categories of words rather than the suspect use of digits and letters. It seems clear, therefore, that category selection is somewhat different from selection based on simple features, a distinction similar to that between "selective set" and "filtering," rightly emphasized by Kahneman and Treisman (1984) as a fruitful source of discrepancies between experiments. The use of selective set (categoric selection) must allow identification to proceed more in parallel with detection than filtering allows.

Is it possible that selective set allows totally parallel identification, even though filtering may use an earlier stage of detection to call into play the mechanisms of identification? That might logically be possible if, like Duncan (1980), one postulates that the identity of every event is in any case computed before selection. It would be less likely on the view of Treisman and Gelade (1980), since a decision about the category membership of words such as "horse," "house," and "mouse" requires analysis of conjunctions of features. It is also true that Duncan's own experiments showed interference between two targets defined categorically; but they were letters and digits, and possibly detection was occurring by filtering, the detection of specific features, as suggested by D. E. Broadbent (in press).

All these factors suggest that one should examine performance in RSVP with more than one target, arriving at times fairly closely consecutive. It has been shown in a number of unpublished experiments by C. Frankish (personal communication, 1977) that the presence of one target has a marked effect on the identification of another in the same RSVP sequence. Despite the well-established ability of subjects to reject nontargets, therefore, it does seem that the same interference between targets occurs in RSVP as in search among simultaneous events. It is not clear, however, what the limits of this interference are, or whether it will be as large for selective set as for filtering. The following experiments were directed at these questions.

EXPERIMENT 1

Rationale

This study was designed to replicate and extend the results of Frankish (personal communication, 1977). He had found almost total failure to identify both of two words in the same RSVP list when words were arriving at a rate of one every 60 msec and the two targets were adjacent or separated by one nontarget word. However, two thirds of the lists experienced by each subject were control ones with only one target (on which performance was approximately 60% correct). It was thought possible, therefore, that subjects might have had a low expectancy for occurrence of targets and abandoned search as soon as one target had been detected. In this experiment, therefore, there were always two targets in every list; subjects were informed of this. In addition, a wider range of temporal separations was used than that employed by Frankish. Throughout the experiment, targets were to be detected by the fact that they were in capital letters rather than lowercase like the nontargets, that is, by simple physical features. Subjects were, however, asked to write down both words after the presentation, and thus had to identify as well as to detect.

Method

Subjects. Twenty female members of the Oxford Subject Panel took part. This panel is made up of members of the general public who have agreed to take part in such studies, and are reimbursed their expenses for attending the laboratory.

Materials. Sixteen experimental lists were assembled, each of 12 five-letter words, with each word being a noun of frequency in the language greater than 10 occurrences per million. No successive words in each list shared identical letters at the same positions. Two words in each list were designated as targets, and they occurred either adjacent to each other or with one, two, or three intervening nontargets. No words occurred more than once in the experiment. Four test sequences were constructed, each to be given to different subjects, so that each pair of targets was presented to a quarter of the subjects at each possible intertarget interval. The first and last three words in the list were never targets, but across the various sequences 24 targets appeared at Positions 4 and 9 in the list and 20 appeared at each of the other positions; thus, target probability was effectively constant throughout the middle of the list.

For practice, five similar lists were constructed of four-letter words.

Apparatus. Lists were presented by a Research Machines 380Z microcomputer, which fed a Sony PVM 200CE monitor with diagonal screen measurement of 48 cm. Viewing distance was 90 cm, and at that distance each word subtended an angle of 2.73°. Words were presented each 80 msec throughout the list, the whole list being preceded by a row of fixation points equal to the number of letters in each word of the list. Each display remained visible until the next replaced it within a single scan of the monitor.

The target words were presented in the uppercase character set of the computer; the nontarget words were presented in lowercase. The letters were presented in white on black, and background screen luminance was approximately 6 cd/m^2. The "white" gave 20 cd/m^2 when a large screen area was filled. The ambient illumination was such that a white wall behind the monitor gave 17 cd/m^2.

Procedure. After being shown the first of the practice lists as a demonstration, the subjects practiced on the other four. They were told to write down the words that had been presented in capital letters, and informed of the fact that all lists would contain two such targets. They were encouraged to guess if they suspected the presence of a particular word, even though uncertain. They were not, however, required to write something down on every trial, and in fact often felt they could not.

Results

It is immediately clear that Frankish's findings are confirmed, despite the subjects' perfect knowledge that two signals were present and despite the wider temporal spacing employed in the present case. The probability that both targets will be identified is only 0.062. If this value were the result of two independent processes, then it should be equal to the product of the probabilities of identifying the first and the second targets; but that product is 60% greater than the actual proportion found. For 17 of the 20 subjects, the probability of identifying the second target was less when the first target had been identified than if the first target had failed to give a correct response. Perhaps more surprising are the results for the various separations of the two targets, shown in Table 1.

The probability of identifying both targets shows no sign whatever of increasing up to the largest SOA of 320 msec. There is, however, a drop in performance at long intervals, and a change in the relative numbers of individual correct responses to the first target and to the second. Analysis of variance confirms that the second target gives fewer correct responses than the first [$F(1,16) = 53.62$, $p < .0001$], that there is an effect of interval [$F(3,48) = 3.83, p < .02$], and that there is an interaction [$F(3,48) = 3.33, p < .03$]. Newman-Keuls tests show that the second target is inferior to the first at each of the three longer intervals ($p < .01$), but not when adjacent to it; and that the second target is better when adjacent than at any other interval ($p < .05$). Nonparametric tests give similar results.

This raises the question of whether the low proportion of correct responses to both targets shows a genuine incompatibility between the two identifications or is a consequence of the changing success of the second target as the interval increases. Table 1 also gives the probability of responding correctly to the second target when the first has and has not been identified. It will be noted that when the interval is shortest, correct responses to the second target depend very much on the first target's having been

Table 1
Probability of Report at Various Separations of Two Targets in Experiment 1

Separation	SOA (in msec)	First Target	Second Target	Both	Second Target When: First Correct	Second Target When: First Wrong
Adjacent	80	0.46	0.35	0.075	0.19	0.58
1 Apart	160	0.6	0.15	0.037	0.09	0.2
2 Apart	240	0.54	0.16	0.062	0.10	0.21
3 Apart	320	0.45	0.14	0.075	0.20	0.13

Note—Proportions given in the first two columns include cases when the other was and was not reported.

missed; as the interval increases, there is less difference between the two probabilities. Since it is rare for subjects to respond to both targets, large numbers of subjects fail to provide data in one or the other of the cells, and different individuals do so at each interval, thus making analysis of variance impossible. For the shortest interval alone, however, we can, by nonparametric test, be sure that the probability of a correct second-target response is less when the first response is also correct (sign test, $p < .05$). For longer intervals, the number of subjects providing data becomes too low.

The most plausible way of explaining these results is that whichever of the two targets is encoded first gains an advantage over the other. As Intraub (1985) has shown, the relative time of arrival of different RSVP stimuli is hard to assess; the second of two adjacent stimuli may be encoded first, and thus exclude the other. This would explain the higher rate of success of the second target at the shortest interval, and also the fact that this success is contingent on failure of the first target.

It should be noted, however, that the chance of seeing both targets, although low, is not zero. Nine subjects saw both targets on at least one trial. Furthermore, they were not guessing randomly even among the words presented; after a correct response to the first target, the chance of a correct second response, although low, was greater than that of giving one of the other three words following the target. Of 10 subjects showing a difference, only 1 gave the opposite result ($p < .02$).

Discussion

The identification of one word seems to reduce markedly the chance of identifying another, for a surprisingly long period. On top of the detection process that scans nontargets, it seems that targets must start some further process operating that is incompatible with the similar process for another target. Thus far, the results support the analysis of Duncan (1980), although the effects are more dramatic. This can perhaps be ascribed to the length and complexity of the processes involved in word recognition, as opposed to the pressing of a key when a digit is present.

If, however, the identity of the word has been determined before the selection of an item for entry into the limited-capacity system, as Duncan (1980) suggested, it is curious that two identities can so rarely be reported. A frequent suggestion in the literature, noted with approval by Duncan, is that there is a dissociation between the actual report of a word and the effects of an earlier computation of meaning that is unavailable for report. In the present experiment, the two words were unrelated; if they had been associated, then conceivably the identification of a second word might have been helped by even partial identification of the first target word. The next experiment examined this possibility.

EXPERIMENT 2

Method

Subjects. A fresh sample of 40 female members of the Oxford Subject Panel took part.

Materials. As in the previous experiment, 16 lists of 12 five-letter words were employed. The target words, however, were novel, being drawn from 16 pairs of highly associated words. For any one subject, 8 lists contained a pair of associated targets and 8 lists contained a pair of nonassociated targets made up by interchanging the second target between pairs. For half of the subjects, the targets that appeared in associated pairs were those given in nonassociated pairs to the other subjects, and vice versa. To make counterbalancing practical, only two separations of targets were employed, the adjacent condition and that with three intervening nontargets from the previous experiment (320-msec SOA). Again, particular pairs were adjacent for half the subjects and three apart for the other half. Targets were always at Positions 4, 5, 8, or 9 in the list; when the longer separation occurred, the first target was at one of the earlier positions and the second at one of the later, but overall the probability of a target was reasonably constant as a function of serial position.

The lists of associates from Jenkins (1970) and Keppel and Strand (1970) were scanned for any pair in which the stimulus and the most common associate were each five letters long and shared no letter in the same position. After eliminating words that were in more than one pair, this gave only 15 pairs. One further pair was accepted in which the response word was the second commonest associate; the 16 could then be divided into two sets matched for strength of association, and these formed the basis of the counterbalancing.

Apparatus and Procedure. The apparatus and procedure were as for Experiment 1. Again as before, the targets were specified by being in capital letters and both words were to be reported. The subjects were not told of the associations between some pairs.

Results

Again, the reporting of both targets (0.0625) was far worse than would be expected from the product of the probability of detecting the first and second targets (0.114). It is still clear that reporting one target impairs reporting the other. The detailed results are shown in Figure 1; it is particularly striking that there is no sign of any difference between associated and nonassociated pairs, even when the second target follows more than a

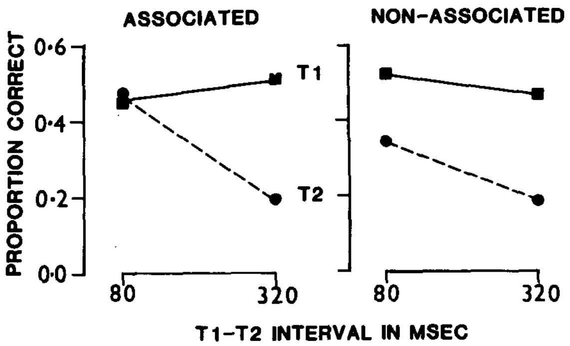

Figure 1. Correct responses to the first (T1) and to the second (T2) of pairs of targets in Experiment 2. Scores include all trials regardless of the correctness of the response to the other target. Note that association between the targets appears to have little effect.

quarter of a second after the first. Analysis of variance showed that the first target was better reported than the second [$F(1,36) = 40.82$, $p < .001$] and adjacent targets were better reported than the separated ones [$F(1,36) = 24.11$, $p < .001$]. There was a significant interaction [$F(1,36) = 8.67$, $p < .01$], that is, the disadvantage of the second target was most marked when it was more widely separated from the first. There was, however, no main effect or, at usual levels of significance, any interaction involving the factor of association.

Since the thrust of this paper is to argue against analysis of both targets, we ought to consider even borderline evidence against our conclusions. It is therefore proper to consider one suspect interaction for which $p = .051$ [$F(1,36) = 4.99$]. This involves association, first/second target, and spacing. If there is any beneficial effect of association concealed in this, it is in the performance on second targets; and this prompted two further analyses. The first was of second targets alone, but cases in which the first target had and had not been correctly identified were separated. Only 17 of the 40 subjects provided data in every cell, because of the usual problem that many individuals gave no instances at all in which both targets were correct; the 17 gave once more an effect of interval [$F(1,13) = 5.47$, $p < .04$], and they confirmed, as in Experiment 1, that response to Target 2 was better if Target 1 was incorrect [$F(1,13) = 7.04$, $p < .02$]. Once again, however, there was no effect or interaction of association ($p > .1$ in every case).

This result, that correctness of Target 1 did not interact with association, then justified a second analysis, which considered only those cases of response to each target in which response to the other was *not* correct. This allows 30 of the 40 subjects to provide data, but removes the variability due to correctness on Target 1. The results are shown in Table 2. The familiar findings appear; Target 2 is inferior to Target 1 [$F(1,26) = 19.89$, $p < .0001$], and adjacent targets are better than separated ones [$F(1,26) = 10.10$, $p < .004$]. Now, however, there is a comfortably significant interaction of association, interval, and target [$F(1,26) = 6.7$, $p < .02$]. A Newman-Keuls test of this interaction shows, first, that the longer interval is worse than the corresponding shorter interval except for associated first targets; second, that the first target is better than the second except for the associated adjacent case; and, finally, that the difference between associated and unassociated pairs is significant at the .05 level for the second target at the shortest interval, but in no other case.

Table 2
Probability of Correct Response to Each Target in Experiment 2, Given That the Other Target is *Not* Correct

		Adjacent	3 Apart
First Target	Associated	0.50	0.43
	Nonassociated	0.56	0.35
Second Target	Associated	0.54	0.21
	Nonassociated	0.37	0.18

This last effect does provide evidence that, even when the first target is not correctly identified, sufficient information has been extracted from it to assist response to an associated and immediately adajcent second target. Although the finding is somewhat post hoc, it resembles the more satisfactory priming effects found by P. McLeod (personal communication, 1987) in a number of analyses of a similar situation, and may thus be given more credence than this evidence alone would warrant. It should be emphasized, however, that the "assistance" is a reduction of interference, not an advantage over what the level of performance might have been if the second target had occurred in isolation. In this experiment, there were no instances in which the first target was omitted; such a condition will be included in Experiment 4. The present finding is consistent with an impairment of the second target by arrival of the first, partially offset by the fact that the first is arousing the same semantic network.

Discussion

The picture thus far is that the processes unleashed by the arrival of a target do, indeed, make it very difficult to respond to some other target. Furthermore, the second target is worse affected when the first target is identified than when it is not. The latter point fits with the view that the interference is due to the actual process of computing the identity of the first target. The duration of the effect and the fact that it shows no sign of disappearance at the longest interval must, however, create a suspicion about our interpretation. Perhaps it is not the process of analysis of the first target that creates the problem, but the fact that holding a representation of the first is incompatible with holding a representation of the second—a memory rather than a perceptual difficutly. Memory for two words may seem a small load, but it must be remembered that memory for one word must be combined with search for the other. If that were the problem, then no matter how long the separation between targets the same findings should appear. Accordingly, the next experiment used longer lists and therefore wider separations.

EXPERIMENT 3

Method

Subjects. A fresh sample of 12 female members of the Oxford Subject Panel took part.

Materials. Thirty-six lists were constructed, each consisting of 24 five-letter words of a frequency greater than 10 per million. Given that only 294 such words can be found in the count of Owsowitz (1963), this meant that each word had to be repeated three times during the experiment. However, the repetition of a set of words was always in a different order. Each list contained two targets, and the same word never occurred twice as a target. Targets were separated by a number of nontargets ranging from 1 to 16, the first target occurring at a position in the list ranging from 4 to 10 and the second at a position ranging from 6 to 21. Thus, again, the probability of a second target at any point was relatively constant, although to secure this it was necessary for the first targets to be in the first half of the list. Separations of targets were divided into eight groups of increasing length, and four pairs of targets were given in each group. To keep up the number of targets late in the list, an extra four were given in the group that were separated by 11 or 12 intervening nontargets.

Two test sequences were constructed, each to be given to half the subjects. The four pairs of words given at a short separation in one list were given at a longer separation in the other list, and vice versa. In the two sequences, the first member of each pair was given at a different position in the test list.

Apparatus. In this case, a Sinclair Spectrum computer was used; this fed a Sony monitor Type CVM-110K with a diagonal screen measurement of 28 cm. Since the screen was smaller, the viewing distance was only 60 cm for approximately the same angle subtended by the word—2.48°. The characters were presented as black (7 cd/m²) on white (20 cd/m²).

In this experiment, targets were designated by the presence of a hyphen (-) on each side of the word, and both targets and nontargets were presented in the lowercase character set of the computer. As these presentation conditions were harder than those of earlier studies, words were presented at 120-msec intervals to give approximately the same performance as previously. Each word was removed for the last 20 msec of the interval before the next appeared, and was replaced by the white screen.

Results

The probability of correct report for each separation is given in Figure 2. At long intervals, it can be seen that the probability of reporting both targets is close to that of reporting each; in fact, it is well up to the level that would be predicted by supposing that each report was independent. There is therefore no reason to believe that reporting one target interferes with reporting the other.

At the shortest intertarget interval, there are, as usual, far more reports of single targets than of both, every subject showing nonindependence; and at the interval of 480 msec, longer than any used previously, the probability of reporting both is still less than would be predicted from the probability of reporting neither ($p = .012$ by sign test). Nevertheless, the number of detections of the second target has improved as compared with 240 msec ($p < .01$ by sign test). By the interval of 720 msec, there is no significant impairment on the second target, even though, numerically, performance is still worse than it is on the first target; and the probability of getting both is actually higher than would be predicted from independence.

Contingency analysis is, in this case, less useful than it was previously; since, at the shortest interval, no subject ever identifies the second target correctly at all, they can scarcely show any difference as a function of their correctness on the first. Similarly, only 3 subjects provide data at the 480-msec point. At the 720-msec point, there are 7 subjects for consideration, and they actually give an insignificantly higher score on Target 2 when Target 1 was correct (0.571) than when it was incorrect (0.476). As noted above, however, by that length of interval the two targets are behaving independently.

Discussion

It is clear, therefore, that the interference between two targets has been shown only at intervals of less than half a second; there is no sign that holding a representation of one word impairs the identification of another. Rather, it is the process of identifying the first that gives the deterioration on the second. The experiments thus far have, however, used the "filtering" form of task, in which the target is indicated by a feature independent of those that identify the response. As was said earlier, there is already evidence that this kind of selection triggers later processes of identification; the novel feature of the present study

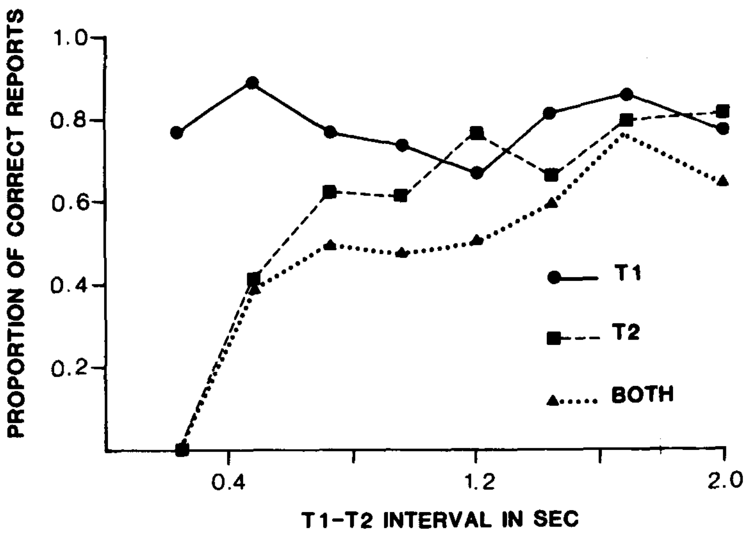

Figure 2. Performance on the first and on the second of pairs of targets in Experiment 3. As in Figure 1, the scores for each target include all cases; the proportion of trials on which both targets were correct is also shown. Note that signs of nonindependence between the targets persist until the T1-T2 interval is 720 msec.

is to show that these processes produce interference. The results of McLean et al. (1982) and of Gathercole and D. E. Broadbent (1984), however, show that the other kind of selection task, "selective set," allows identification to start earlier. Is it possible that targets selected in this way would interfere less or even not at all? It is, moreover, only with this kind of selection that we can be sure that nontargets are being rejected, and on some theories therefore identified, throughout the list.

Accordingly, the final experiment used both kinds of selection, with subjects never knowing which kind of target might appear.

EXPERIMENT 4

Method

Subjects. A fresh sample of 24 female members of the Oxford Subject Panel took part.

Materials. In this case, each list contained only 12 five-letter words, but there were 72 lists presented to each subject. Thus, the same nontargets could be used as in Experiment 3 (eliminating animal names). There were six types of list, those containing one animal name target in lowercase, those containing one capital-letter target, and each of the four possible combinations of two targets. When there were two targets, they were always separated by one nontarget. The second target, and the single target if there was only one, occurred in Positions 6, 7, 8, or 9 of the list.

For the animal names, 12 names were found that possessed five letters. The same names were used for each subject five times, once for each type of list with one animal target and twice in the type of list that had two. For the capital-letter targets, different targets were used for each type of list. There were three sequences of list, given to different subjects, such that the capital-letter targets used alone with one subject were those used to follow an animal target for another subject, and so on. Different animal-animal pairs were used in the three sequences.

Apparatus and Procedure. The apparatus and procedure were the same as for Experiment 3, except that the feature-defined targets were presented without hyphens, as capital-letter words in the character set of the Spectrum. This was because the previous results had found capital letters to be easier, the double task was likely to be harder, and it was undesirable to decrease the rate of presentation even further.

The subjects were told that there might be either one or two animal names in each list and either one or two capital-letter words. They were also informed that some lists had only one target. As previously, they were given four practice lists of four-letter words, with animal-name targets as well as capital-letter ones.

Results

The results of greatest interest are those for the second target, and these are shown in Figure 3. In the first place, it is quite clear that a preceding animal-name target does have a major effect on a subsequent target, whether it be animal-name or capital-letter. As in the case of a preceding capital-letter target, these effects are significant ($p < .01$ by sign test). Thus, the detection mechanism, by which nontargets are scanned to exclude them from the animal category, must be different from the identification mechanism that comes into play when a member of the positive set is detected.

If we then consider the four cases of paired targets, there appear to be some differences that merit an analysis of

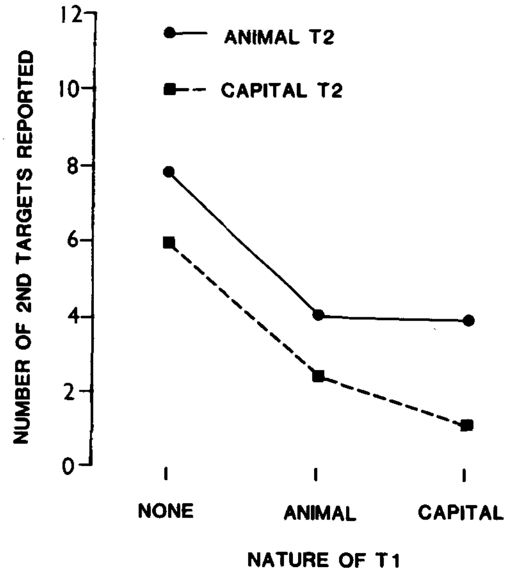

Figure 3. Performance in Experiment 4, on targets designated by being animal names or by being in capital letters. Only the second target in each trial is shown, separated by the nature of the first target. Note that both types of first target impair both types of second target, although a capital first target is particularly disruptive for similar second targets.

variance of the scores on the second target alone. There are main effects of the nature of the second target [$F(1,23) = 19.90$, $p < .0002$], the nature of the first target [$F(1,23) = 4.82$, $p < .05$], and an interaction of the two [$F(1,23) = 4.98$, $p < .05$]. The first of these is of little interest; the animal targets form a small and repeated set, and it is not surprising that they are easier to identify than the completely open set of capital-letter targets. The second and third effects are more intriguing; a first capital-letter target is more disruptive than an animal one, and, as Figure 3 shows, the interaction means that this is true only when the second target also is a capital-letter one. From this analysis alone, it is not clear whether this is because the capital-letter targets require a different selection schedule, or whether it is merely because they happen to be harder. As in Experiment 3, this prompts a closer analysis of performance conditional on the correctness or incorrectness of the response to the first target, and this is shown in Table 3.

If we look at the case when the first target is *not* correctly reported, there is clearly worse performance if that

Table 3
Probability of Reporting Second Target in Experiment 4, Conditional on Report/Nonreport of First Target, and Whether Each Kind of Target is an Animal Name (Categoric Search/Selective Set) or Word in Capital Letters (Filtering)

	First Target				
		Incorrect		Correct	
Second Target	None	Capital	Animal	Capital	Animal
Capital	0.49	0.19	0.34	0.02	0.12
Animal	0.65	0.34	0.51	0.31	0.22

target was a capital-letter one than if it was an animal name. This is true whichever type of second target is considered and if both together are examined ($p < .03$ in every case by sign test). The extent of the difference seems to be as great for either type of second target. Indeed, there is no proof that the second targets are impaired at all by a preceding undetected animal name. Although there is a numerical difference from the control condition, it is quite insignificant statistically whether by sign or parametric tests. Thus, the reason for the large impact of the capital-letter target seems to be that it impairs performance even if not correctly reported.

When one turns to the case in which the first target was reported correctly, the type of first target has an effect depending on the type of second target. Reporting a capital-letter target has a bigger effect than reporting an animal name, but only on other capital-letter targets, for which $p = .012$ by sign test. On animal targets, the effect is insignificantly in the opposite direction. On parametric test, the interaction of the nature of the first and second targets is significant [$F(1,23) = 7.29, p < .02$].

It should be emphasized that the performance on the second target is always numerically worse when the first target has been reported than when it has not, and significantly so for the animal-animal and capital-capital combinations ($p < .002$ by sign test in each case) and for the animal-capital combinations ($p < .04$). The capital-animal sequence, however, did not give a significant effect of the correctness of the first target.

Discussion

These results confirm that there are important differences between types of selection. The "filtering" task triggers further activity when a target occurs, even if the first target was not itself identified. The further activity may perhaps have been due to detection of the target-defining feature alone without enough information being available to report the first target. The "selective-set" task, on the other hand, triggers enough activity to interfere only if the first target is, in fact, correctly identified. Yet, correctly reported targets still have more impact than missed ones; so selective set cannot operate totally in parallel with other processes.

The following tentative account of events departs from the analysis of Duncan (1980), and rather resembles that of Hoffman (1978, 1979), which differs in important respects. Both views distinguish an early parallel stage of analysis of input and a later stage of relatively limited capacity that receives at any one time only part of the information that reaches the senses. For Duncan at that time, however, the later stage is needed only for targets, and nontargets can be rejected earlier; the first stage in fact completes input analysis, and the later stage is needed only for storage, rehearsal, or report (Duncan, 1980, p. 285). For Hoffman, on the other hand, the first stage carries out rough discriminations and the second conducts finer ones on the most plausible inputs; thus, both stages form part of input analysis, and nontargets will enter the second stage in the absence of a target (Hoffman, 1979, p. 8). On Hoffman's view, therefore, one target will damage the chances of detailed processing of another. Let us restate the resulting view.

As all theorists agree, the elementary physical features of each word are encoded unselectively as a first stage of processing. We might add in this first stage (to accommodate the slight signs of associative priming in Experiment 2) a noisy or partial semantic analysis in which various words similar to the objectively presented stimulus begin to arouse their associates without any one of them being definitively the perceived word. However, a second stage of processing, needed to report the word, occurs only when some trip-wire has been activated by the presence of enough features in a possible target. With the filtering schedule, this would happen quite frequently, even though some features necessary to report the target had not in fact registered. With selective set, however, it would happen only if a larger number of features had been picked up correctly, and these features would be the same ones needed to construct a correct report.

Such a view would be very harmonious with the approach of Treisman and Gelade (1980), since the original trip-wire could be seen as being based on isolated features and the later report as being based on computation of the conjunction of features actually present in the word.

It is less clear how a trip-wire approach would fit with the view that supposes all word identities to be available before target selection. Presumably the process of report would still be regarded as dissociated from this preattentive analysis of identity. In that case, however, why does not the preattentive analysis sometimes occur without the process of report? Yet, if so, there should be interference by unreported targets in the case of selective set, and there is not.

GENERAL DISCUSSION

At the simplest level, these results confirm and amplify the contention of Duncan (1980) that events requiring a response have quite different effects on the person from events that do not. The effects are more dramatic than his, as none of his conditions gave results comparable to our almost total inability to report two words, nor did he show such a long duration of the effect. The key difference in the paradigms is probably the amount of information needed for correct response in the present case; as pointed out by D. E. Broadbent (1982) and by Kahneman and Treisman (1984), recent fashions for using binary responses have tended to reduce, if not eliminate, interference. They would, however, have been expected to do so since the 1950s.

The production of an accurate report, then, requires something more than the discarding of irrelevant events as needing no report. When events are selected for report, then the nature of the selection schedule makes a difference. Selection by a single feature, filtering, can fire off the processes that interfere with other reports even though those processes do not issue in a correct report. Selection by category membership, on the other hand, does not.

What can we say about the interfering processes? The most massive of the results is the fact that correctly reported targets are more disruptive than incorrectly reported targets. Yet, this is not because the latter have simply been missed; with filtering, even incorrectly reported targets have some effect. Thus, the interference with one target appears to be related to successful achievement of identity for the other. It is unlikely to be, for example, a generalized reaction to the difficulty of the task, since in that case the unreported (and therefore more difficult) targets should interfere more than those that do produce response.

Finally, there is little sign in these results of effects of identity before a verbal report. With selective set, unreported targets show no interference with detection of other targets. If a computation of identity is supposed in order to explain the fact of category detection, it must also be supposed to be largely independent of the overt report that has these other dramatic effects. It seems most parsimonious to believe that the identification process itself is the cause of the mammoth interference that results from reportable targets, and that the early parallel stages consist only of encoding of isolated and unconjoined features, as is supposed by Treisman.

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