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Automatic Memory Search and the Effects of Information Load and Irrelevant Information

John Palmer
University of Washington

John Jonides
University of Michigan

If automaticity is identified with both light capacity usage and little attentional selectivity, then an automatic process should be symptomatized by both small effects of concurrent information load and large susceptibility to interference by similar but irrelevant information. Several experiments are reported that test this prediction for memory search among sets of words. For well-learned memory sets, a small effect of information load co-occurs with a large effect of irrelevant information. By contrast, for arbitrary sets, a large effect of information load co-occurs with a small effect of irrelevant information. These results do confirm the correlation between effects of information load and irrelevant information as a hallmark for identifying automatic processes.

What identifies a process as automatic? From the earliest discussions of automatic processing (James, 1890) to the more recent revival of interest in this topic (e.g., Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977), answers to this question have typically included the view that an automatic process is identified by a confluence of several symptoms. No one characteristic of processing has been seen to be individually sufficient to characterize a process as automatic. Rather, automaticity has been viewed as an emergent feature of a process when it conforms to several processing characteristics.

What are the individual symptoms which, when combined, are jointly necessary and sufficient to identify a process as automatic? There is no general agreement about this issue. However, two particular features of processing do seem to co-occur quite frequently when a process is argued to be automatic. The first of these is that performance is relatively insensitive to manipulation of the amount of concurrent information load in a task. The second is that performance is not greatly affected by the amount of voluntary control exerted by a subject in the task in question.

These two general features of processing have been operationalized in a variety of ways in actual task contexts. For example, the issue of insensitivity to concurrent task load has been addressed by using a secondary task procedure, by manipulating the amount of simultaneously presented information that must be evaluated before processing can continue, and by introducing a probe response procedure to assess the difficulty of processing at any point in time. Likewise, the issue of voluntary control has been evaluated by presenting subjects with irrelevant information during processing that must be ignored, but that one has reason to believe may be processed automatically. In addition to this technique, this criterion has been operationalized by examining the stereotypy of performance, and by having subjects try to interrupt performance that is presumably automated. Whatever the operationalization, though, these two features of processing seem to be frequently cited as evidence of automaticity. And, they are cited together, as if their joint occurrence is a hallmark of automaticity.

A clear example of the co-occurrence of these two features of processing comes from a series of experiments by Jonides and Gleitman (1972, 1976; Gleitman & Jonides, 1976). They showed that in a visual search task, performance in identifying a character of one alphanumeric category embedded among characters of the other category was largely uninfluenced by the number of items in an array, compared with identification of a target item embedded in items from its own category. Correlated with this was the finding that subjects uncontrollably responded to a member of the target's category in the first case, even when that item was not the target. That is, subjects were inclined to respond to an irrelevant item in the same condition in which responses to that item's category were relatively unaffected by the amount of information load in the display.

Another case in which load and irrelevant information effects have been found to co-occur also comes from studies of visual search behavior by Schneider and Shiffrin, from a task in which both visual and memory search were required (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). They manipulated information load by varying the size of the set of items through which subjects searched, and they investigated irrelevant information effects by placing potential search targets in unattended display locations. By contrasting a condition in which items were variably mapped as targets or distractors with a condition in which items were consistently mapped as targets, Schneider and Shiffrin were able to study the relative automaticity of these kinds of search sets. They observed small effects of information load and large effects of irrelevant information to co-occur in

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Correspondence concerning this article should be addressed to John Palmer, Department of Psychology, NI-25, University of Washington, Seattle, Washington 98195.

the consistently mapped condition, compared with the variably mapped condition.

Yet another case of co-occurrence comes from the experiments of Naveh-Benjamin and Jonides (1984). They showed that there was a stage of processing during maintenance rehearsal that had two characteristics: It was relatively low in its demand on processing capacity as measured by a probe reaction-time secondary task; and it was relatively insensitive to voluntary control in the sense that the rehearsal utterances were difficult to interrupt once begun.

The literature is not unanimous in its support of the co-occurrence prediction for tasks that are believed to be automatic, however. Information load and susceptibility to irrelevant information have been measured for a counting task involving categorical difference in the display items (Francolini & Egeth, 1980) and for a naming task (see also Johnston & Dark, 1982; Kahneman & Chajczyk, 1983; Kahneman & Henik, 1981; Regan, 1981; Paap & Ogden, 1981; for a review see Kahneman & Treisman, 1983). Jonides, Naveh-Benjamin, and Palmer (1985) have argued, however, that these failures to confirm the co-occurrence of load and irrelevant information effects may have been the result of a failure to isolate the processes that are automatic in these tasks. The co-occurrence prediction is one that applies to isolated automatic processes, not to entire task performances. Hence, one must take care to study the alleged automatic process without heavy contamination by surrounding processes. One or more of these may not be automatic at all, and consequently not subject to the co-occurrence prediction.

The present series of experiments is concerned with testing the co-occurrence prediction in a task that requires search through memory, without an accompanying visual search task. As many previous investigators have made clear, this is a task in which the search process can be isolated effectively from the encoding and response processes. Hence, it meets the requirement of Jonides et al. (1985) that the application of operational criteria to the study of automaticity should be effected for individual processes. In addition, this is a task, as amply demonstrated by Schneider and Shiffrin (1977; also Fisk & Schneider, 1983), that appears to be subject to the development of automaticity as assessed by the effect of information load. Practice on this task with consistently mapped target and distractor sets produces a relative insensitivity of performance to the size of the memory set with which the subject is working. Although we have some suggestion that practice also produces a heightened sensitivity to irrelevant information (potentially confirming the co-occurrence prediction), this suggestion, as described earlier, comes from an allied task that involves visual search (see also Logan, 1978). Consequently, for memory search the co-occurrence of the two critical features of processing has not been adequately assessed within the context of the same experimental paradigm.

The present experiments were designed so that effects of information load and irrelevant information could be studied within the same memory search paradigm. Information load was manipulated by varying memory set size (Atkinson & Juola, 1973; Sternberg, 1966). This variable allows one to change the many-to-one mapping of item to response without changing the stimulus or response characteristics of a particular trial. To measure the effects of irrelevant information we chose the noninformative priming paradigm of Posner and Snyder (1975; Meyer, Schvaneveldt, & Ruddy, 1975; Neely, 1977) as a memory analog to the Stroop-like interference (Eriksen & Eriksen, 1974; Stroop, 1935) produced by Shiffrin and Schneider (1977). In particular, we followed previous studies that demonstrated priming with words in memory and categorization paradigms (McKoon & Ratcliff, 1979; Shaffer & LaBerge, 1979). With this technique, a prime was presented just prior to the probe item in a memory search task. Subjects were required to decide whether the probe was a member of the memory set. The prime was chosen from either the same category as the probe (targets or distractors), or it was chosen from a different category. In neither case, however, was the prime informative about the identity of the probe, so it provided subjects with no information about the response that was appropriate to the probe.

The first three experiments reported below were investigations of this noninformative priming measure as a measure of the intrusiveness of irrelevant information. The fourth experiment confirms that our task is subject also to the well-documented effect of memory load. Thus, the experiments taken together provide a test of the co-occurrence of these two features of processing for memory search.

Experiment 1

In the first experiment, the effect of noninformative primes was measured for categorization of words belonging to arbitrary or well-learned categories. The distinction between arbitrary and well-learned categories was chosen for study since Schneider and Shiffrin (1977), Fisk and Schneider (1983), and others have previously investigated the large effect of information load for classification of items into arbitrary categories and the small effect of this variable for well-learned categories. So there is reason to suspect that the latter of these two tasks involves an automatic process. To explore this possibility, we subjected this task to an assessment of the effect of irrelevant information using a noninformative priming procedure. To ensure that subjects paid attention to the primes (they being noninformative about the category of the probe), we required subjects to vocalize each prime after each categorization trial was complete (cf. Smith, Theodore, & Franklin, 1983).

Method

Design. A memory set of four words was followed by a prime word and a probe word. The primes and probes were either members of the memory set or of a distractor set. There were two major variables. The first was the type of category from which the memory and distractor sets were chosen. For the well-learned category condition, the memory set was chosen from a set of three-letter proper names and the distractors were chosen from a set of three-letter words, none of which was a proper name. For the arbitrary category condition, both the memory and distractor sets were chosen from the same set of words, none of which was a proper name. This design is similar to the consistent mapping and variable mapping conditions of Schneider & Shiffrin (1977). The two conditions (well-learned and arbitrary) were presented in separate testing sessions on different days (four in all) in an ABBA sequence, counterbalanced across subjects.

The second variable of interest was the priming condition. Primes were labeled *corresponding* if they were from the same set as the probe word. Correspondence could occur in two ways. If the probe was from the memory set, then a corresponding prime was also from the memory set as given in a particular trial. Alternatively, if the probe was from the distractor set, then a corresponding prime was also from the distractor set. In contrast, primes were labeled *conflicting* if they were drawn from different sets. As with corresponding primes, conflict occurred two ways, either with memory set primes for distractor probes or distractor primes for memory set probes. For example, if the memory set consisted of the names BOB, HAL, JAY, and JIM and the probe was BOB, then the possible corresponding primes were HAL, JAY, or JIM. For this probe, the possible conflicting primes were words from the nonname set (e.g., BAG).

The primes were intended to convey no information regarding the response. Corresponding and conflicting primes occurred equally frequently and unpredictably. So they were of no benefit to subjects in predicting the response on any trial. In addition, primes were never presented that were identical with the probe word. This prevents any priming specific to identical probe and prime words. Despite these precautions, the prime may have allowed a subject to modify his or her strategy; fortunately, such effects were not observed.[1] The different kinds of primes (corresponding and conflicting) were presented in a mixed-list fashion and were counterbalanced with the other variables of the memory task (namely, probe type, items, and serial position).

Subjects. Subjects were 8 undergraduate students at the University of Michigan. Each had normal vision or vision corrected to normal, and each was a native English speaker. Subjects were paid $3.50 per hour for 4 hr with a $5.00 bonus for completing the experiment.

Apparatus. Individual subjects were seated at a computer terminal in a well-lit sound proof booth. Two different raster display terminals were used for stimulus presentation interchangeably, a Digital Equipment Corpoation VT-52 and a Hewlett Packard 2621A. Individual characters (uppercase letters) subtended about .5° of arc at a viewing distance of about 30 cm. Terminal keyboards were used for response collection.

Stimulus words. The stimuli were drawn from one of two lists. The first list consisted of 10 three-letter proper male names, and the second consisted of 50 three-letter words (see Appendix). The second list contained no proper names, no animal names, and no words judged interpretable as a proper name or an animal name. For example, nicknames and body parts were excluded. In addition, both lists were kept orthographically heterogeneous by requiring that no two words share more than one letter in any position. Thus, BUT and BIT were not both included.

The categories were constructed as follows. For the well-learned category condition, the memory set was always selected from the list of names and the distractor set was always selected from the nonnames. For the arbitrary category condition, memory and distractor sets were selected from the nonnames.

Procedure. A single trial of the experiment consisted of a study period, a warning interval, a stimulus presentation, and a response. The study period, 2 s in duration, consisted of a display containing the four words of the memory set. The warning interval consisted of a blank screen (1350 ms), the word READY (500 ms), a blank screen (150 ms), and a fixation mark (500 ms). The stimulus presentation consisted of the prime word, whose duration was 130 ms, followed by the probe word which remained until a response was made. The offset of the prime was simultaneous with the onset of the probe; the prime was .5° of arc above the fixation point while the probe appeared .5° of arc below the fixation point. Responses were required to both the probe and the prime. First, the subject had to indicate with a key press whether the probe was or was not in the earlier study list. Subjects were instructed to respond as quickly as possible without sacrificing accuracy. Second, subjects had to pronounce the prime word, and their pronunciation was monitored over an intercom. No feedback was provided for the prime response but audio feedback about accuracy was provided for the response to the probe. A trial ended with .5 s of this feedback and a 1-s interval before the onset of the next trial. After 144 trials of practice, subjects participated in 1,024 trials over the course of four sessions.

Results

Overall, subjects committed 3.6 ± .7% errors and had an average reaction time of 945 ± 90 ms.[2] The percentages of errors for well-learned and arbitrary categories, respectively, were 2.2 ± .6% and 5.1 ± 1.0%, a difference of 2.9 ± .9%. Similarly, reaction times were 815 ± 71 and 1,079 ± 116 ms, a difference of 260 ± 64 ms. All reaction-time analyses excluded long responses of 3 s or more (.7% of all trials).

The secondary response of vocalizing the prime word is also relevant to judging overall performance. These responses were recorded only on the first 64 trials and showed 4.7 ± 1.4% errors. There was a marginally reliable difference in the proportion of errors for the arbitrary versus well-learned categories. Although there is some sign of differential performance in vocalizing the prime for the arbitrary and well-learned categories (6.8% vs. 2.4% errors, respectively, difference = 4.4 ± 2.3%, $t[7] = 1.6$, $p < .1$), subjects knew the prime word on more than 90% of the trials in both conditions.

Priming effects on reaction time. Figure 1 illustrates the effect of the prime for each condition. Three results are of interest. First, the priming effect with well-learned categories is 87 ± 19 ms. This is reliably greater than zero, $t(7) = 4.6$, $p < .005$.[3] Second, the priming effect with arbitrary categories is 19 ± 14 ms. This is not significantly different from zero, $t(7) = 1.4$, $p > .1$. Third, the difference in these effects is 68 ± 24 ms. Again, as predicted, this is significantly different from zero, $t(7) = 2.9$, $p < .025$. These results disconfirm any hypothesis that predicts identical priming effects for arbitrary and well-learned categories.[4] Figure 1 also shows the effects separately for positive probe (87 ± 14), $t(7) = 6.2$, $p < .001$ and negative probe (91 ± 31), $t(7) = 2.9$, $p < .025$, respectively.

Priming effects on errors. Figure 2 illustrates priming results for the error measure. There is a priming effect for well-learned categories of 1.9 ± .9%, $t(7) = 2.2$, $p < .05$, and there is no evident priming effect for arbitrary categories: (−1.0 ± .6%), $t(7) = 1.7$, $p > .1$. Furthermore, there is a reliable difference between these priming effects of 2.9 ± .9%, $t(7) = 3.3$, $p < .01$.

[1] If a prime was from the memory set, then that word was never presented as a probe. Thus a subject could reduce his or her relevant memory set from four to three items. Such a strategy is only effective for trials with primes from the memory set and thus predicts an effect for the prime word itself rather than its correspondence to the probe. Such a pattern of results was never obtained.

[2] All summary statistics in this article are sample means with the associated standard errors of the mean.

[3] Multiple *t* tests were used throughout rather than an analysis of variance because of the nonhomogeneity of variance typical of reaction time measures. All results reported as significant were also significant using an analysis of variance, but the variability estimates were misleading.

[4] The results are reinforced by the fact that the smaller priming effect is associated with the longer reaction times, ruling out the possibility that a simple scaling artifact was the cause of the smaller priming effect for the arbitrary categories.

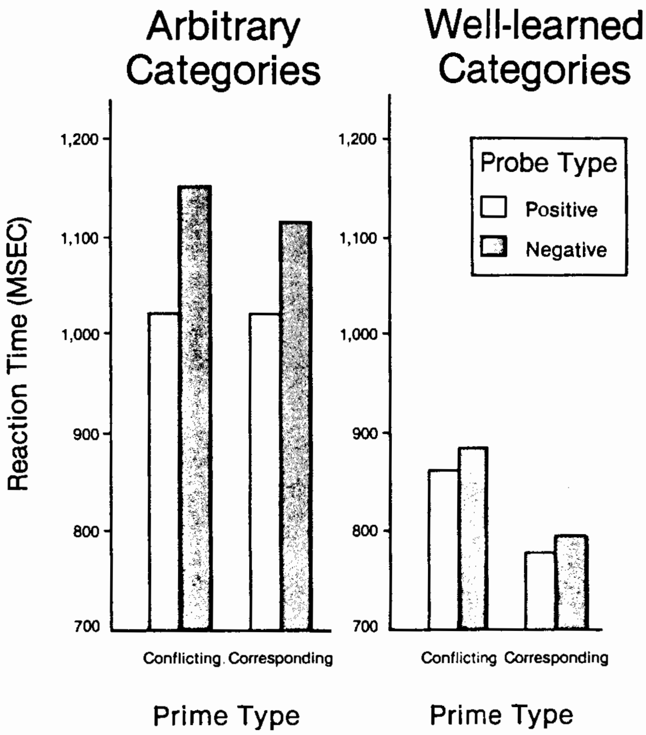

Figure 1. Noninformative priming effects on reaction time for two kinds of categories (Experiment 1).

Thus, both dependent measures show the same pattern of effects.

Summary and results from Experiment 1. Overall performance was quite accurate and showed that subjects did pay attention to the primes. The principal result was that priming effects were consistently found for the well-learned categories and were not found for the arbitrary categories. This was true both for reaction time and error measures. These results are in accord with the co-occurrence prediction that performance with well-learned categories should be susceptible to significantly larger effects of irrelevant information than performance with arbitrary categories.

Experiment 2

In the first experiment, the expected priming effects were found under conditions in which subjects had to pay attention to the primes by virtue of the required vocalization task. These effects were replicated in Experiment 2 without using the vocalization task to direct attention to the primes. In this experiment, we presented the same series of stimuli as before, but we instructed subjects to ignore the primes rather than to vocalize them. Moreover, we further studied the performance of three subjects in the first experiment whose results had not been consistent with the overall pattern that we reported above.

Method

A total of 4 subjects participated, 1 with considerable experience in these tasks and 3 from Experiment 1 who had shown signs of anomalous performance. Two of these subjects had shown indications of priming in the arbitrary category condition, and 1 had shown no priming in the well-learned category condition. These subjects were included in the present experiment to determine if these anomalous individual results were reliable or due to chance. In summary, Experiment 2 was identical to Experiment 1 except for the unusual subject sample and the elimination of vocalization.

Results

The results of Experiment 2 differed in only one respect from Experiment 1: The mean reaction time was reduced to 612 ± 75 ms from the 945 ± 90 ms of Experiment 1. The means in Table 1 show that there are significant priming effects on reaction time for well-learned categories, $t(3) = 4.6, p < .01$, and no such effects on reaction time for arbitrary categories, $t(3) = 0.9, p > .1$. Analyzing the well-learned condition by positive and negative probes, the prime effects were 40 ± 3 and 6 ± 9, respectively. Furthermore, these results obtained for the individual subjects as well. For well-learned categories, six of the eight possible tests (four each for reaction times and errors) proved significant, whereas for arbitrary categories none were significant. Thus, the effects are present without the vocalization task.

Experiment 3

In Experiment 3, the priming effect was investigated further for the well-learned categories. The effect was measured in a new set of subjects who did not have concurrent experience

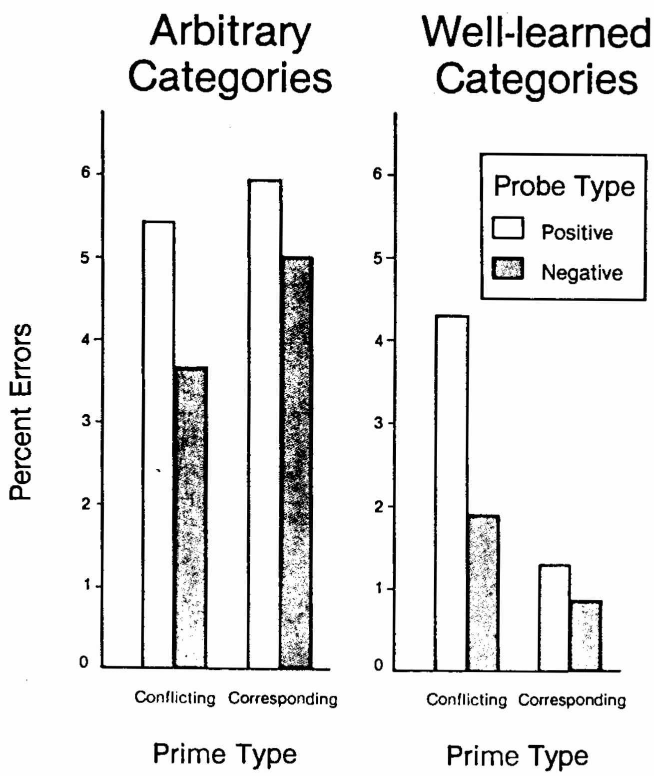

Figure 2. Noninformative priming effects on errors for two kinds of categories (Experiment 1).

Table 1
Priming Effects Without Vocalization

Subject	RT Conf.	RT Cor.	RT Diff.	% E Conf.	% E Cor.	% E Diff.
			Arbitrary category			
BB	455	461	−5 ± 10	7.3	7.8	−0.5 ± 0.5
DT	987	1006	−19 ± 25	0.8	1.1	−0.3 ± 0.8
AS	753	722	31 ± 24	3.7	3.9	−0.2 ± 1.6
SA	624	622	2 ± 14	5.0	3.9	1.0 ± 1.6
M	705	703	2 ± 11	4.2	4.2	0.0 ± 0.3
			Well-learned category			
BB	428	418	10 ± 4	3.1	3.1	0.0 ± 1.0
DT	605	571	33 ± 7	0.5	0.0	0.5 ± 0.3
AS	612	584	28 ± 12	4.2	1.4	2.8 ± 1.0
SA	479	460	19 ± 5	5.2	1.8	3.4 ± 0.9
M	531	508	23 ± 5	3.3	1.6	1.7 ± 0.8

Note. Conf. = conflicting primes; Cor. = corresponding primes; Diff. = difference.

with the arbitrary categories. Also, a neutral condition was included to allow a cost–benefit analysis of the priming effects (Posner & Snyder, 1975; but see Jonides & Mack, 1984).

Method

Six subjects participated in an experiment that was similar in procedure to Experiment 1, except that only the well-learned category condition was included. Each of the subjects had some previous experience in memory search tasks. For this experiment, subjects participated in only 1 day of 152 practice trials plus four blocks of 72 experimental trials each. The only significant change in procedure from Experiment 1 was the inclusion of pronounceable nonwords as primes on one third of the trials to serve as a neutral comparison condition (see Appendix). Subjects were required to vocalize the nonword primes as they did the other primes.

Results

The priming effects were replicated again. For these well-learned categories, the reaction time difference between consistent and conflicting primes was 77 ± 17 ms, $t(5) = 4.5$, $p < .01$, and the error difference was 2.4 ± .4%, $t(5) = 6.8$, $p < .001$. Thus, the priming effects do not seem to depend on any contrast between well-learned and arbitrary categories because there were no arbitrary categories in this experiment. For positive and negative probes, the priming effects were 105 ± 20 ms and 67 ± 20 ms, respectively. Table 2 displays the cost–benefit analysis of these effects. The reaction-time cost proved significant, $t(5) = 2.1$, $p < .05$, and the other three comparisons each show marginally significant effects ($p < .1$). There is also no significant difference between costs and benefits (for reaction time, 12 ± 32 ms; for errors, 0.3 ± 1.4%). Hence, this analysis shows that the priming effects are probably both facilitory and inhibitory given the particular neutral condition (see Jonides & Mack, 1984). This result is in conflict with the claims about finding no costs in noninformative priming (Posner & Snyder, 1975).

Experiment 4

In order to complete the test for the co-occurrence prediction, the effects of information load and irrelevant information must be shown to co-occur in the predicted manner. Our first experiments have established that performance with well-learned categories is more susceptible to effects of irrelevant information than is performance with arbitrary categories. We must show also that information load has a greater effect for arbitrary than for well-learned categories. Such a difference has been demonstrated repeatedly in the literature in similar tasks with different materials (Brand, 1971; Fisk & Schneider, 1983; Jonides & Gleitman, 1972; Schneider & Shiffrin, 1977; Sperling, Budiansky, Spivak, & Johnson, 1971). Nevertheless, there is value in replicating this effect under our particular experimental conditions.

Replication also provides an opportunity to entertain alternative accounts of the effect of information load in this task. By the traditional account, the "category effect" is presumed to be due to differences in categorization processes for well-learned versus arbitrary categories. Well-learned categories are assumed to be processed without selective attention or capacity limits, whereas less-known categories require attention and tax capacity. In the context of our task, however, there are two alternative accounts of the category effect that warrant control. First, if the well-learned and arbitrary categories include items with different characteristics, then subjects may focus on those characteristics as a basis for decision. If these characteristics are not comparable for the two types of categories, then there is a confound with category difference. To minimize this possibility, we chose exactly the same memory set items for both well-learned and arbitrary categories (similar to the oh-zero control of Jonides & Gleitman, 1972).

Second, we ensured that subjects in the well-learned category condition be responsible for remembering the memory set throughout each trial. In principle, this is not required, because subjects could respond merely to the probe's category membership regardless of the items in the memory set, thereby rendering the memory requirements of the two conditions unequal. In the present experiment, this potential difference between conditions is neutralized by equating the memory requirement of the two conditions. We accomplished this by occasionally asking for recall of the memory set instead of presenting a probe. Demonstrating similar recall for memory sets in the two conditions may not have equated the memory load entirely, but it certainly made it much more similar for the two conditions.

Table 2
Cost–Benefit Analysis of Priming Effect With Well-Learned Categories

	RT	% E
Conflicting	933	2.8
Neutral	888	2.8
Corresponding	857	1.4
Cost	45 + 21	1.1 ± .6
Benefit	31 ± 21	1.4 ± .8

Method

The methodology followed in Experiment 4 was the same as in Experiment 1. Eight subjects were chosen from the same pool, the same apparatus was used, and a similar procedure was followed. The following sections highlight the specific differences between the present experiment and Experiment 1.

Design. There were two manipulations in this experiment: category type and memory set size. The category manipulation included the same arbitrary versus well-learned category conditions used throughout, but the two conditions were tested by using a between-subjects design. The second manipulation was the size of the memory set drawn from the underlying categories, and it was varied randomly from trial to trial within a subject. Memory sets were restricted to two and five items in size.

Procedure. In this experiment, we introduced occasional trials—1 in 10—on which subjects had to recall that trial's memory set rather than respond to a probe item. These recall trials were interleaved randomly among the probe trials. Until the probe was due to appear, the recall trials were in all ways identical to the standard probe trials. Instead of a probe, however, an instruction appeared on the display screen demanding recall of the memory set. Recall was accomplished by having subjects type the memory set words into their computer terminal. This was done without any time pressure. The procedure was also different from that of Experiment 1 in that there were no primes or prime vocalization responses. The primes were replaced in the stimulus presentation sequence by a blank interval of corresponding duration. Overall, a session consisted of 320 trials presented in blocks of 40. Subjects participated in six to eight sessions, with the first two sessions considered as practice.

Stimulus words. The experiment included two lists of 20 names and two lists of 20 nonnames (see Appendix). For the well-learned categories, memory sets were drawn from one of the name lists and distractors were drawn from one of the nonname lists. For arbitrary categories, the memory sets and distractors were drawn from one of the name lists. The assignment of lists to conditions was counterbalanced across subjects. This procedure resulted in exactly the same words appearing in memory sets for the arbitrary and well-learned categories.

Results

Overall, errors were infrequent in this experiment, occurring on 3.2 ± 1.0% of the trials. The reaction times were fast, 565 ± 65 ms, and there were very few responses over a 3-s cutoff criterion (14 in over 10,000 trials or 0.1%). The recall task, by contrast, was relatively difficult and resulted in 12 ± 5% errors. Separated by well-learned and arbitrary categories respectively, the response errors were 2.0 ± .1% versus 3.3 ± .5%, reaction times were 560 ± 57 versus 571 ± 68 ms, and recall errors were 21 ± 9% versus 6 ± 2%. These recall error percentages may seem somewhat large, but they are based on a very conservative scoring criterion; subjects had to type all memory set members correctly and in the right order for a response to be considered correct. The recall measure indicates that even in the worst condition subjects recalled 79% of the memory sets perfectly.

Set size effects on reaction time. Figure 3 shows the reaction time for each category at set sizes of two and five. The important result is that the set size effect is greater for arbitrary categories than for well-learned categories. In terms of additional time per item (slope), the effects were 26 ± 5 and 6 ± 1 ms, for arbitrary and well-learned categories respectively, a difference of 20 ± 5, $t(3) = 3.92$, $p < .025$. Because this experiment includes more practice than the priming experiments, it is important to check

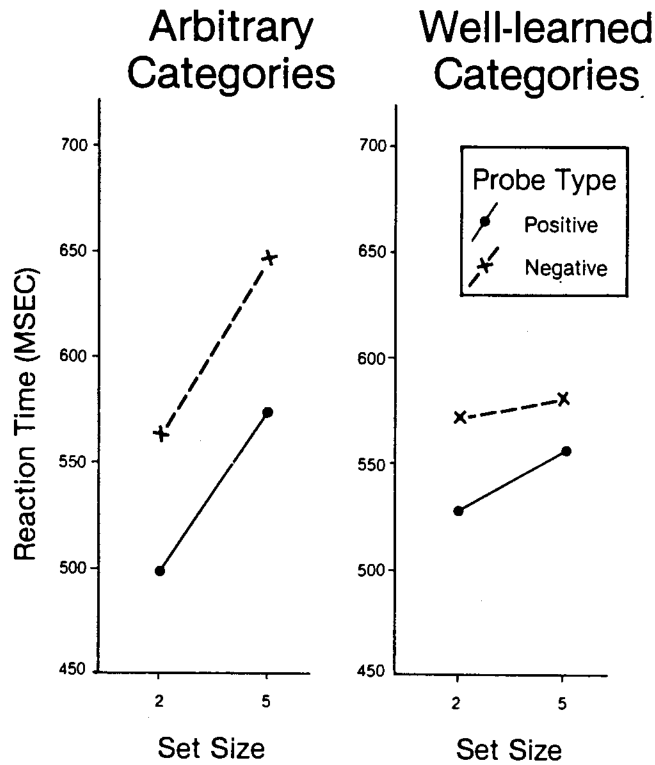

Figure 3. Memory set size effects on reaction time for two kinds of categories (Experiment 4).

that the slope differences are found in the first few sessions as well. For Sessions 2 through 4, the slopes were 27 ± 4 and 10 ± 2 for arbitrary and well-learned, respectively.[5] In summary, the usual difference in set size effects was replicated despite the introduction of recall trials.

Set size effects on errors. Similar effects on errors are shown in Figure 4. Errors increased with increasing set size and increased more for arbitrary categories than for well-learned categories. These effects were not statistically significant; they do, however, support the reaction-time results by mitigating the possibility of a speed–accuracy tradeoff.

Summary of results from Experiment 4. The primary result was that larger set size effects were found for arbitrary categories than for well-learned categories. The result held even under conditions of high accuracy, and when we ensured that item and memory load differences between conditions played only a minor role.

General Discussion

The preceding experiments support the co-occurrence prediction for categorizing members of arbitrary versus well-learned categories. There were greater information load effects and smaller effects of irelevant information for the arbitrary cat-

[5] Session 1 was excluded because early blocks were excluded from Experiment 1. For Session 1, the slopes were 51 ± 7 and 38 ± 17 for arbitrary and well-learned categories, respectively.

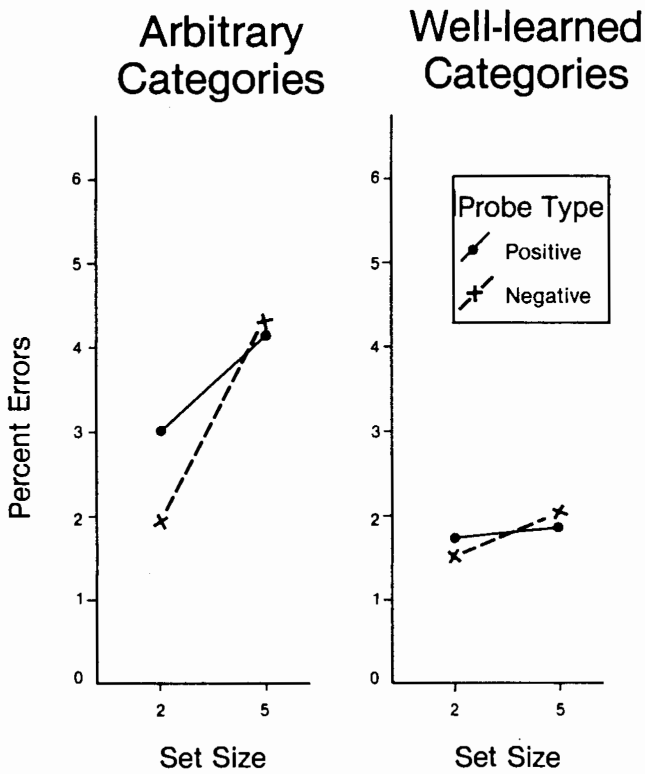

Figure 4. Memory set size effects on errors for two kinds of categories (Experiment 4).

egories than for the well-learned categories. These effects were obtained in a variety of situations: The priming effects were demonstrated both with a secondary task of vocalizing the prime and with subjects told to ignore the prime. The memory set size effects were demonstrated under conditions controlling for item and memory load artifacts. Taken together, these results support a common account of these two phenomena.

The categorization of items into well-learned categories is mediated by an automatic process, automatic in the sense that the process is relatively unaffected by the number of items in the category, and that the prior occurrence of an item of the same category facilitates categorization of the target item. It is the co-occurrence of these features of processing that leads to the view that categorization is more automatic in this case than with arbitrary categories.

Isolating the Processes of Memory Search

A key point in interpreting these experiments is to establish that the observed priming effects are specific to the process of memory search or categorization. Let us consider the alternatives.

One possibility is that the prime words affect encoding rather than categorization. In the experiments, corresponding primes are semantically related to probes for well-learned categories but not for arbitrary categories because, for well-learned categories, the corresponding primes and probes are either both names or both nonnames. Thus, there is a partial confounding of category type and semantic relatedness of the primes and probes. This confounding provides an alternative mechanism that may account for the priming effect: The prime could facilitate the encoding of the probe word. This alternative hypothesis yields a further prediction that can be disconfirmed, however. For the well-learned category, there is only a semantic relation between prime and probe when the probe yields a positive response. Therefore, the priming effect should be obtained only when the probe is positive. However, this was not so; priming effects were observed for both positive and negative probes. This was especially true for Experiment 1, in which the effect for negative probes was as large as for positive probes (87 ± 14 and 91 ± 31 ms). Furthermore, Experiment 3 replicated the priming effect for negative probes. (Experiment 2 did not show a significant effect of negative probes, but it involved fewer subjects.) Thus, although there is a partial confounding of semantic relatedness with the well-learned versus arbitrary categories, the confounding does not provide a satisfactory account of our data.

Another possibility is that the primes affect response processing rather than categorization. In the experiments, corresponding primes and probes require the same categorization responses. As a result, covert processing of the prime might lead to preparation of a correct response for the probe when it belongs to the same category as the prime. Although such a covert response-repetition hypothesis can explain memory search priming in general, it cannot explain the observed pattern of priming. This hypothesis predicts that priming should be found for all types of categories. After all, processing of arbitrary category primes could also yield a covert response. Thus, a covert response-repetition hypothesis must be elaborated to include the categorization process before it can account for the current data. As such, this hypothesis becomes quite similar to one based on priming in the categorization process alone.

Conclusion

For categorization, the phenomena of selectivity and capacity co-occur. Large effects of irrelevant information covary with small effects of information load and visa versa. Previous evidence for this co-occurrence is largely from visual search; the current study provides similar evidence from memory search. Such a co-occurrence is predicted by models of the development of automatic processes that entail multiple behavioral manifestations.

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Appendix

Stimulus Words and Nonwords

Experiments 1, 2, and 3					Experiment 4			
					List 1		List 2	
Names	Nonnames			Nonwords	Names	Nonnames	Names	Nonnames
Bob	Ash	Gel	Ore	Cor	Ann	Age	Amy	Ash
Hal	Awl	Ham	Out	Dis	Ben	Arm	Art	Axe
Jay	Axe	Hex	Pox	Fes	Bob	Bus	Bud	Bag
Jim	Bag	Hut	Pun	Gol	Dot	Fig	Dan	Car
Joe	Boy	Ill	Rig	Moc	Flo	Gem	Eva	Cup
Ken	Car	Imp	Rum	Neg	Gus	Hip	Fay	Elm
Roy	Cup	Inn	Sad	Nos	Jan	Jet	Hal	Fib
Sam	Dye	Ivy	Sea	Sep	Jim	Lid	Ira	Fog
Ted	Ebb	Jaw	Six	Sik	Joe	Log	Jon	Ham
Tom	Elm	Jot	Sly	Tiz	Joy	Map	Ken	Jaw
	End	Key	Tug		Kay	Mud	Kim	Key
	Err	Kid	Urn		Lou	Owl	Leo	Kid
	Few	Leg	Vow		Mae	Pew	Liz	Leg
	Fib	Lip	Wax		Max	Pin	Pat	Oak
	Fog	Nab	Wit		Pam	Pot	Ron	Oil
	Fry	Oak	Zoo		Ray	Rag	Roy	Pun
	Fur	Oil			Rob	Rib	Sam	Rig
					Ted	Rut	Sue	Rum
					Tim	Rye	Tod	Sea
					Vic	Ski	Tom	Wax

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Donald J. Foss
Department of Psychology
University of Texas
Austin, Texas 78712

Other members of the search committee are James J. Jenkins, Jean Mandler, J. E. R. Staddon, and Saul Sternberg.