Dissociations of Processes in Recognition Memory: Effects of Interference and of Response Speed

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Abstract Effects on two bases for recognition-memory judgements were examined using a process dissociation procedure (Jacoby, 1991). In three experiments it was found that increasing the length of a study list interfered with conscious recollection but left familiarity in place. Furthermore, an examination of reaction time distributions as well as results from a response-signal procedure showed that familiarity was faster as a basis for recognition judgements than was conscious recollection. However, both bases contributed to performance on the fastest as well as the slowest responses, suggesting that the two processes were acting in parallel.

For a test of recognition memory, subjects must decide whether a test item was presented in a previously studied list. At least in principle, subjects could base their recognition judgements solely on the familiarity of the test items because, on average, an item that was presented in the study list would be more familiar than one that was not. A rationale of this sort underlies single-factor theories such as signal detection theory (see Swets, 1964; Wickelgren, 1972). However, subjects may not be limited to assessments of item familiarity when making recognition-memory judgements. If some aspect of the study event could be consciously recollected (e.g., 'I remember seeing that word... it was the first word in the list') this could serve as a second basis for responding.

Several researchers have proposed a dual-process view of recognition memory along with criteria that can supposedly be used to distinguish between the two bases for responding. Familiarity is assumed to be a fast basis for responding (Atkinson & Juola, 1974; Jacoby, 1991; Mandler, 1980) that relies on perceptual characteristics (Jacoby & Dallas, 1981; Mandler, 1980) or item-specific information (Humphreys & Bain, 1983), and reflects an automatic or unconscious use of memory (Jacoby, 1991) that is largely spared by amnesia (e.g., Piercy & Huppert, 1972; Verfaellie & Treadwell, 1993). In contrast, the use of recollection is described as a slow, search-like

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process that relies on conceptual processing or associative information and requires attention. Furthermore, recollection is said to be absent or reduced in amnesic patients.

In this paper we examine the two bases for recognition memory by focussing on differential effects of interference, and differences in response speed. Although the examination of interference effects has a long history in recognition experiments, it has received little attention in the context of dual-process theories. Thus we know that manipulations such as increasing the length of the study list (e.g., Strong, 1912) or increasing the delay between study and test (e.g., Strong, 1913) interferes with recognition memory performance, but we do not know whether just one or both of the two bases for recognition are influenced.

To examine interference effects, we varied the length of study lists with the expectation that increasing list length would increase interference. The list length effect was first reported by Strong (1912) who found that as he *increased the number of advertisements a subject studied, the probability of* later recognizing a particular advertisement decreased. Since then the list length effect has been demonstrated numerous times in recognition (e.g., Atkinson & Shiffrin, 1971; Gillund & Shiffrin, 1984; Ratcliff & Murdock, 1976), free recall (Murdock, 1960; Roberts, 1972) and word-fragment completion (Sloman, Hayman, Ohta, Law & Tulving, 1988).

A number of observations led us to believe that recollection might be more susceptible to interference than familiarity. First, the magnitude of the list-length effect is greater in free recall than in recognition. Doubling list length produces a dramatic drop in free recall (Roberts, 1972) but only a small decrease in recognition (Ratcliff & Murdock, 1976). If the recollective process involved in recognition is similar to that of free recall, then it might be this process alone that is producing the list length effect in recognition. Second, Jacoby (1991) found that dividing attention reduced recollection but had no effect on the use of familiarity as a basis for recognition decisions. The greater interference produced by increasing list length might have effects similar to those of dividing attention: reducing recollection but leaving familiarity in place.

In contrast to the effects of interference, differences in processing speed have attracted considerable attention. Because familiarity is generally believed to be the faster of the two processes (see Atkinson & Juola, 1974; Mandler & Boeck, 1974), an obvious test of the dual process theory is to look for dissociations between fast and slow recognition responses. If some variable differentially affects the fast and slow responses, this would lend support to the dual-process claim.

There are a number of studies that suggest that the two processes do differ in terms of speed. For example, Mandler and Boeck (1974) examined response-time distributions and found that slow recognition judgements were more affected by organizational variables than were faster judgements. They argued that this was because recollection, like recall, was influenced more by organizational variables than was familiarity. That is, because recollection was slower than familiarity, the effects of list organization were greater for the slower responses.

Another method that has proved useful for assessing differences in processing speed is the response-signal procedure. With this procedure, the experimenter controls the time allowed for memory retrieval by requiring subjects to respond at a given speed. Each test item is followed by a signal to respond that occurs anywhere from 200 ms to 3 s after its presentation, and, typically, subjects are required to respond within 300 ms of the signal. Using this procedure, Dosher (1984) found that in a word-pair-recognition task, subjects tended to first accept then reject semantically-related lures. This suggests that fast responses were predominately based on familiarity, which did not discriminate between prior semantic associations and associations formed during the study phase; only as the products of the recollection process became available were those discriminations possible. Using a similar procedure, Gronlund and Ratcliff (1989) found that judgements requiring recollection of associative information were more time consuming than were judgements that could be based upon item familiarity.

However, in contrast to the results of the above experiments, Gillund and Shiffrin (1984) found no evidence that fast and slow recognition responses had qualitatively different bases. Using a deadline procedure, they required subjects either to respond before a 900 ms deadline or to withhold responding until after a 1 or 1.5 s delay. They compared performance for fast and slow recognition judgements across a number of variables (levels of processing, list length, and number of study presentations) and found that none of the variables interacted with response deadline. Thus, even with variables that might be expected to differentially affect the two processes, the amount of time allowed for judgements did not always dissociate the two processes. For this reason, we chose to rely on an alternative method.

We made use of a process-dissociation procedure (Jacoby, 1991) that allowed us to derive quantitative estimates for the contribution of familiarity and recollection. The procedure involves comparing performance in a condition in which the two processes act to produce the same response, to a condition in which they act in opposition to produce different responses. The procedure, which we will describe shortly, is based on the assumption that recollection and familiarity serve as *independent* bases for responding. Recollection is assumed to be a consciously controlled process that provides qualitative information about the remembered event. This could include such information as the source of the memory, the perceptual aspects of the stimuli, or the conceptual processing associated with the event. Familiarity, on the other hand, is assumed to be an automatic process providing only an overall strength measure of memory. Familiarity is assumed to allow simple memory discriminations (i.e., old vs new), but not to support discriminations requiring qualitative information about the study event. Let us describe the process-dissociation procedure by outlining its use to examine the effects of list length on the different bases for recognition judgements.

In the first experiment, subjects were presented with a list of words, some visually and others auditorily. In one condition (the inclusion condition), subjects were presented with a recognition memory test for the words that they had *seen* earlier. Subjects were warned that the test list would also contain words that they had heard earlier, and that none of the words were both seen and heard. Consequently, if they could recollect earlier hearing a tested word, they could be certain that the word was not seen and that they should respond "no". Put simply, they should include seen words and exclude heard words.

Seen words could be selected either on the basis of recollection (subjects recollect having seen the word) or, alternatively, on the basis of their familiarity. If we assume that recollection and familiarity serve as two independent bases for recognition judgements, then the probability of selecting an old item in the inclusion condition is:

$$\mathrm{R} + \mathrm{F} - \mathrm{RF}$$

the probability that an item is recollected (R) plus the probability that it is familiar (F) minus the intersect of the two.

In another condition (the exclusion condition), subjects were presented with a recognition test for the words that they *heard* earlier (they should exclude seen words and include heard words). For that test condition, seen words that were accepted must have been sufficiently familiar to be selected as old but not been recollected as earlier seen. That is, the probability of responding "yes" to a seen item in the exclusion condition is:

$$\mathrm{F} - \mathrm{RF}$$

the probability that an item is familiar (F) minus the probability of the item being familiar and recollected (RF).

The contribution of recollection to recognition can be estimated by subtracting the probability of selecting an item in the exclusion condition from that in the inclusion condition ((R + F − RF) − (F − RF)). Having found the contribution of recollection, we solve either of the previous equations to estimate the contribution of familiarity (i.e., EXC /(1 − R)).

Familiarity, as estimated by this means, reflects both the effect of memory (M) from the study phase and the base rate familiarity (B) of the items. If we assume that the two effects are additive:

$$\mathrm{F} = \mathrm{M} + \mathrm{B}$$

Given that assumption, one can estimate the increase in familiarity due to the study phase (M) by simply subtracting base rate as measured by responding to "new" test words. An alternative approach would be to apply signal-detection theory (Swets, 1964) to analyze differences in familiarity. For the experiments reported here, the choice between approaches does not influence the conclusions drawn because the base rates remained constant across the experimental conditions. Consequently, subtracting base rate amounts to subtracting a constant and would not change the pattern of results, nor would the application of signal-detection theory.

The estimate of familiarity will also reflect the subjects' willingness to use familiarity in the recognition task. For example, subjects may be less willing to use familiarity as a basis for recognition judgements in some experimental conditions than in others. This could be represented as a bias factor or a response criterion. However, doing so would not influence the conclusions of the current experiments because, as already mentioned, the base rates remained constant across all experimental conditions.

The probability of recollection provides a measure of consciously controlled processing defined in terms of selective responding. To the extent that subjects were able to recollect the modality in which a word was earlier presented, they should be able to either include or exclude that word, in line with instructions. For example, if recollection were perfect (R = 1), subjects would always respond "yes" when asked whether words that were earlier heard had been earlier heard (an inclusion test) and never respond "yes" when asked whether those words were earlier seen (an exclusion test). In contrast, familiarity is assumed not to support such selective responding. The contribution of familiarity as a basis for responding is the same on an exclusion test as on an inclusion test. That is, familiarity serves as a basis for responding "yes" regardless of whether that response is correct (an inclusion test) or an error (an exclusion test).

We estimated the contributions of recollection and familiarity to recognition of words from long and short lists. Half of the study lists were short (30 words); 15 of those words were seen and 15 were heard. The remaining lists were long (60 words). Again, half of those words were presented visually and half were presented auditorily. For one type of test, subjects were instructed to select seen words; for the other type of test, subjects were instructed to select heard words. Inclusion and exclusion scores on the short and long lists were used to calculate the contributions of recollection and familiarity to recognition performance for each of the two list lengths.

In the previous example, we focussed on calculating recollection and familiarity values for seen words. However, the same was done for heard words. In fact, the necessary inclusion and exclusion conditions were nested within the previously described test instructions. The instruction "select the heard words" served as exclusion instructions for the seen words and inclusion instructions for the heard words, whereas "select the seen words" served as inclusion instructions for the seen words and exclusion instructions for the heard words.

In Experiment 1, we defined recollection as the ability to remember study modality, and examined the influence of list length on recollection and familiarity. Experiment 2 was the same except that recollection was measured as the ability to remember in which of two study lists an item had been presented. For both experiments, it was expected that increasing list length would interfere with conscious recollection but leave familiarity unchanged. Response time distributions were used to examine the time course of the two bases for decisions. This was done by deriving estimates for recollection and familiarity in the same way as we did for overall performance except that responses were broken into bins in terms of response time so as to map out the contribution of the two bases for responding as a function of response speed. In Experiment 3, we further examined differences in the speed of the two bases for recognition by using a response-signal procedure similar to that used by Gronlund and Ratcliff (1989).

Experiment 1

METHOD

Subjects

Twenty-one subjects, who were students enrolled in an introductory psychology course at McMaster University, participated in the experiment.

Materials

Three sets of 240 words were randomly selected from the Toronto word pool. During study, each set was either presented visually, presented auditorily, or not presented at all. The sets were rotated through each condition such that each set appeared equally often in each condition. The study words were divided into eight short lists (30 words each) and 4 long lists (60 words each). The modality in which the words were presented was alternated from one word to the next. Thus half of the words in each list were presented visually and half were presented auditorily. All the study items were tested. Each test list contained an equal number of heard, seen and new words mixed in a random order.

Design and Procedure

Materials were presented and responses collected on a PC compatible computer with a monochrome monitor. The character size of the stimuli was approximately 5 × 5 mm and the viewing distance was approximately .5 m. Stimuli were presented in lower case letters in the centre of the screen.

Each subject was tested individually. At the beginning of the test session, subjects were informed that they would receive a number of recognition tests.

They were told that for each study list, half the words would be presented visually and half would be presented auditorily. Each list was followed by a recognition test for which subjects were instructed to select words that had been presented in one modality (e.g., heard) and avoid selecting those that had been presented in the other modality (e.g., seen). Subjects were also informed that the number of items in each study list would vary.

The study lists were presented at a rate of 1 word per second, which was approximately the time required to read a word aloud. The presentation modality was alternated from one item to the next, with the first item of each list always presented visually. Each visually presented word appeared on the screen for 1 s followed by 1 s of blank screen, during which time the experimenter read the next word aloud. Eight short lists (30 words) and 4 long lists (60 words) were presented in a random order.

A yes-no recognition test immediately followed each study list. All of the seen and heard words from the list, as well as an equal number of new words, were presented one at a time on the screen in a random order. For example, for the short lists the test list contained 15 seen words, 15 heard words, and 15 new words. For half the lists subjects were instructed to select the seen words and avoid selecting the heard words. The experimenter informed the subjects that they were to respond "yes", by pressing a designated key, only if they had seen the word in the prior list. If it was a new word, then they were to respond "no". Further, they were informed that words were never presented in both modalities and that if they remembered hearing an item they should respond "no", meaning that they had not seen the word. For the other half of the lists, subjects were given the converse instructions: Select the heard words and avoid selecting the seen words. The type of test instruction was randomized such that subjects did not know at the time of study which type of item they would be asked to select for at test.

List length (short vs long) was crossed with study modality (seen vs heard) which was crossed with type of test (seen? vs heard?). All were within-subject factors. Subjects' responses as well as response times were recorded. The significance level for all statistical tests was set at $p < .05$.

RESULTS AND DISCUSSION

An initial analysis revealed that study modality did not significantly influence performance so responses were collapsed over this variable. Because the number of items tested from each long list was greater than the number tested from each short list, only the first half of the items from each long test list was scored.

Response Accuracy

An analysis of variance was performed on the probabilities of responding "old" (Table 1) for items in long and short lists under inclusion instructions

TABLE 1
Proportion of Items Selected and Parameter Estimates for Long and Short Lists for Experiment 1

	List Length	
	Short	Long
Inclusion	.58	.50
Exclusion	.23	.25
New	.18	.20
Recollection	.35	.25
Familiarity	.35	.33

(heard words accepted as heard and seen words accepted as seen) and under exclusion instructions (heard words accepted as seen and seen words accepted as heard). The analysis revealed that list length interacted with test condition, $F(1,20) = 25.04$, $MS_e = .005$. For the inclusion condition, more items were selected in the short lists than in the long lists, $F(1,20) = 22.21$, $MS_e = .003$. For the exclusion conditions, an equal number of items were accepted in the long and short lists, $F(1,20) = 2.11$, $MS_e = .002$. Similarly, for new items, an equal number were accepted in the short and long lists, $F(1,20) = 2.71$, $MS_e = .004$.

Of main interest are the contributions of recollection and familiarity to recognition performance (see Table 1). Recollection values were calculated by subtracting the probability of selecting an item under exclusion instructions from the corresponding probability under inclusion instructions. Familiarity values were calculated by dividing the exclusion scores by one minus the estimated recollection scores. An analysis of variance was performed on the recollection values as well as the familiarity values, which were calculated for each subject.

There was a significant list length effect on the recollective component of recognition, $F(1,20) = 25.64$, $MS_e = .009$. Familiarity, on the other hand, was not significantly affected by list length, $F(1,20) = 3.083$, $MS_e = .002$. The familiarity of old items (.34) was significantly higher than the false alarm rate to new items (.19). For twenty of the twenty-one subjects, old items were more familiar than new items, showing that familiarity did significantly contribute to performance.

A conditional analysis was carried out equating for study-test lag (the number of items encountered between the presentation of the item in the study list and the presentation of the item at test), to determine if the list length effects were due to differences in the average delay between study and test. For the long lists, only items that were studied in the second half of the study list (study position > 30) and that were tested in the first half of the test (test position < 46) were included in the analysis. However, the estimates for

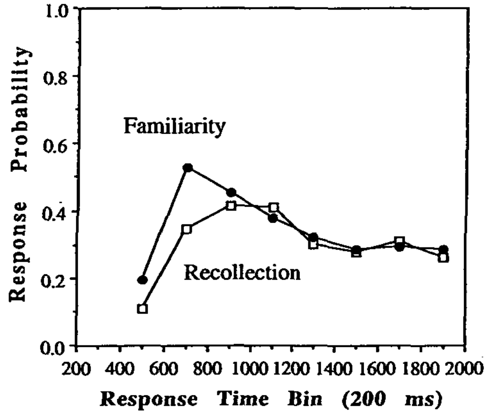

Fig. 1 Response latency distributions for familiarity and recollection for Experiment 1. Each point reflects estimates based on 200 ms wide response time bins.

recollection and familiarity did not differ from those of the previous analysis, suggesting that the list length effect was not due to differences in the number of items that intervened between study and test.

Response Latency

Responses in the inclusion and exclusion conditions were grouped into bins on the basis of response time. From those scores, estimates for recollection and familiarity were derived in the same manner as was done for the overall data. Each bin was 200 ms wide with the first bin beginning at 400 ms. Thus the first bin contained responses between 400 and 600 ms. All responses were used in the response time analysis. Responses were collapsed over subjects as well as study modality and list length because the response time distributions did not differ greatly from one condition to the next.

Figure 1 presents the estimates for recollection and familiarity as a function of response time. An examination of that figure showed that the contribution of familiarity was at its greatest between 600-800 ms, whereas recollection reached its peak between 800-1100 ms. Beyond these points the contribution of both of these processes decreased similarly. This pattern was seen for the majority of the subjects: For only 2 of the 21 subjects did recollection peak before familiarity. Thus familiarity had a speed advantage over recollection. However, recollection and familiarity contributed to recognition performance throughout the range of response times. This was true of the fastest as well as the slowest responses. This would not be expected if recollection was initiated only after an assessment of familiarity had failed, as was suggested by Atkinson and Juola (1974). Rather, it would seem that both processes are contributing to performance in parallel.

Experiment 2

Experiment 2 was designed to test the generality of the findings from Experiment 1. In Experiment 1, subjects were required to select for or against items previously presented in a particular modality. Thus recollection was measured as subjects' ability to respond selectively on the basis of the modality in which words were initially presented. In the current experiment, all items were presented visually but the study session consisted of two separate lists. Recollection was measured as the ability to determine list membership and to respond accordingly. As another test of the generality of the findings in Experiment 1, recognition was measured using a forced-choice procedure rather than a yes-no procedure.

METHOD

Subjects and Materials

The subjects were from the same pool and materials were the same as those used in the previous experiment. Twenty-four subjects participated in the experiment. For each subject 400 words were randomly partitioned into 8 short lists (10 words each) and 8 long lists (20 words each). The remaining words served as test lures.

Design and Procedure

Both the design and procedure of the current experiment were similar to those of the prior experiment with the following changes: At the beginning of the experimental session subjects were instructed to think of the meaning of each of the words that they studied as this would promote better recognition performance. The study phase began with the presentation of a cue identifying the list ("List # 1") which was followed by the first list of words presented one word at a time at a rate of one word per second. Immediately following this was the cue for the second list ("List # 2") followed by the second list of words. Half of the time the two lists were long, and half the time the two lists were short.

The presentation of study lists was followed by a two-alternative, forced-choice recognition test. A pair of words appeared on the screen and remained there until the subject made a response, at which time the next pair appeared. Subjects responded by pressing one of two designated keys on the keyboard, selecting either the right or the left word. For the first 10 test pairs (containing 5 words from List #1 and 5 from List #2, in a random order) of half of the test lists, subjects were instructed to select items from the first study list and avoid selecting items from the second study list. That is, they were told that if they could recollect an item as presented in List 1, they were to select the item; whereas if they could recollect an item as presented in List 2, they were to select the other item in a pair (which, unbeknownst to subjects, was always a new word). For the next 10 test pairs, subjects were

TABLE 2
Proportion of Items Selected and Parameter Estimates for Long and Short Lists for Experiment 2

	List Length	
	Short	Long
Inclusion	.77	.72
Exclusion	.39	.45
Recollection	.38	.27
Familiarity	.61	.61
	(.63)	(.62)

Note. Parameter estimates in parentheses were calculated using the overall means rather than the subject averages.

instructed to select words from the second list and avoid selecting words from the first list. The order of test instructions was reversed for the other half of the test lists.

The test order was randomized such that subjects did not know which list they would be asked to select for first. This procedure was repeated 8 times, 4 times with short lists and 4 times with long lists in a random order. Unlike the previous experiment, an equal number of items were tested in long and short lists. List length (short vs long) was crossed with study list (List 1 vs List 2) which was crossed with type of test (List 1? vs List 2?). All were within-subject factors.

RESULTS AND DISCUSSION

Response Accuracy

An initial analysis showed that list number (list 1 vs list 2) did not significantly influence performance so responses were collapsed over this variable. Table 2 presents the probabilities of responding "old" for items in long and short lists under inclusion instructions (list 1 items accepted as from list 1 and list 2 items accepted as from list 2) and under exclusion instructions (list 1 items accepted as from list 2 and list 2 items accepted as from list 1). An analysis of variance revealed that list length interacted with test condition, $F(1,23) = 13.55$, $MS_e = .005$. For the inclusion condition, slightly more items were selected in the short lists than in the long lists, however, the effect did not reach significance, $F(1,23) = 3.90$, $MS_e = .006$. For the exclusion conditions, fewer items were selected in the short lists than in the long lists, $F(1,23) = 6.64$, $MS_e = .004$.

Recollection and familiarity values were calculated in the same manner as in the previous experiment. An analysis of variance was performed on the recollection values as well as on the familiarity values. As in the previous experiment, increasing list length interfered with recollection but left

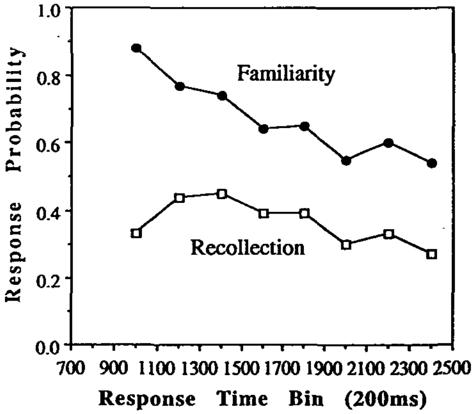

Fig. 2 Response latency distributions for familiarity and recollection for Experiment 2. Each point reflects estimates based on 200 ms wide response time bins.

familiarity in place. Recollection was greater in the short lists than in the long lists, F $(1,23) = 13.41$, $MS_e = .010$. In contrast, the estimates for familiarity were equal in short and long lists, F < 1. As in the previous experiment, familiarity contributed to the recognition of old items. For 21 of the 24 subjects, the estimated probability of selecting an item on the basis of familiarity was above chance (.61 compared to .50).

Response Latency

Response time data were used to examine the speed of the two processes. Beginning at 900 ms, responses in the inclusion and exclusion conditions were grouped into 200 ms wide bins. From those scores, estimates for recollection and familiarity were derived as was done for the overall scores. Responses were collapsed over subjects as well as study list and list length because the response time distributions did not differ greatly between conditions.

Figure 2 presents the estimates for recollection and familiarity as a function of response time. The functions were similar to those of the previous experiment. Familiarity produced its greatest contribution to performance very early – having peaked in the first response bin (900-1100 ms). Recollection, on the other hand, did not peak until 1300-1500 ms after stimulus presentation. This supports the claim that familiarity is the faster of the two processes. Furthermore, both processes contributed to the fastest as well as the slowest responses, suggesting that the two processes were operating in parallel.

The functions in the current forced-choice experiment are "flattened out" and shifted to the right compared to those of the previous yes-no experiment. However, this can be understood as a product of the different demand characteristics of the two types of test procedure. Because the forced-choice procedure required subjects to make a decision about two items, compared to the one item in the yes-no procedure, it is understandable that responses were slowed. Another difference between the two sets of functions was that the familiarity function in the forced-choice experiment was considerably elevated above the recollection function, unlike in the first experiment. This can be understood as reflecting the higher base rate in the forced-choice procedure (i.e., chance performance is .50 compared to the base rate in Experiment 1 of .19).

In both previous experiments, we found that increasing list length interfered with recollection but left familiarity unchanged. Moreover, examination of reaction time distributions revealed that familiarity had a speed advantage over recollection. However, these results would seem to conflict with those of Gillund and Shiffrin (1984) who found that list length did not interact with test speed. If recollection alone is responsible for the list length effect and it is the slower of the two processes, then one might have expected Gillund and Shiffrin to find a larger list length effect for the slower recognition condition. One possible explanation is that the two processes do not differ in retrieval speed but that, under unspeeded conditions, such as in our experiments, subjects were just slower to use recollection than familiarity. Another, more plausible, explanation is that the difference in retrieval speed is not large enough to produce the interactions that Gillund and Shiffrin sought. One should note that the dual process model of Atkinson and Juola (1974) proposed that recollection was only initiated if an assessment of familiarity failed to support a fast response, thus the fastest responses should be based almost entirely upon familiarity whereas the slower responses should be based almost entirely upon recollection. Given such a model, one would expect list length to interact with test speed. However, if as our results suggest, the two processes are not sequential but operate in parallel, the interaction may be considerably reduced. A final experiment was conducted to address this issue.

Experiment 3

In Experiment 3 we examined the effect of list length on familiarity and recollection using a response signal procedure. In a design similar to that of the previous experiments, subjects were tested with a yes-no recognition procedure in which they were required to determine list membership (list 1 vs list 2). However, in this experiment, each test item was followed by a signal to respond. The response signal was presented either 600 ms (fast) or 1600 ms (slow) after the presentation of the test word. Subjects were encouraged to respond as soon as they heard the signal. If the two processes did not differ in terms of processing speed, then the contributions of both processes should increase equally with retrieval time. If, however, familiarity is the faster of the two, then it should be less affected by the response-signal manipulation than recollection.

METHOD

Subjects and Materials

Sixteen subjects from the same pool as the previous experiments participated in the current experiment. Words (598) were randomly selected form the Toronto word pool and were partitioned into 4 pairs of short lists (16 words in each list) and 4 pairs of long lists (32 words in each list) for each subject. The remaining words served as practice items and test lures.

Design and Procedure

The design and procedure of the current experiment were similar to those of the prior experiments. As in Experiment 2, subjects studied pairs of lists: two short lists (16 words in each list) or two long lists (32 words in each list). Each word was presented for 2 s, and there was a 3 s delay between lists. As in Experiment 1, subjects were tested using a yes-no recognition procedure. For half of the tests, subjects were required to respond "yes" if the word was from List #1 and to respond "no" if it was from List #2 or if it was a new item. For the other half of the tests, the instructions were reversed. Subjects were instructed to respond "yes" if they thought the word was presented but could not recollect which list it was in. Subjects completed nine study-test blocks, the first of which was used as a practice phase to familiarize the subjects with the procedure. Responses from this test were not collected. Furthermore, the first 2 items of each test list were also treated as practice items – they were always new items. Apart from the two practice items, each test list included 16 items from list 1, 16 items from list 2, and 16 new items mixed in a random order.

The critical difference in the current experiment was that subjects heard a signal to respond either 600 ms (fast) or 1600 ms (slow) after each test item appeared. If they responded before the signal or later than 300 ms after the signal, an error tone would sound and an error message ("too slow" or "too fast") would appear on the screen. The delay was randomized such that the subjects did not know until they heard the signal how long they would have to respond on any item. List length (short vs long) was crossed with signal speed (fast vs slow) which was crossed with type of test (inclusion vs exclusion). Because list number (list 1 vs list 2) did not influence performance in the previous experiment, this factor was not analyzed. However, it was fully counterbalanced across all experimental conditions. All factors were varied within-subject.

RESULTS AND DISCUSSION

The results of Experiment 3 are presented in Table 3. The values reported represent average performance on all tested items. An initial analysis based only on the responses that fell within the response window (after the response signal and no later than 300 ms after the signal) was conducted but produced

TABLE 3
Proportion of Items Selected and Parameter Estimates for Long and Short Lists with Fast and Slow Response Signals for Experiment 3

	List Length			
	Short		Long	
Response Speed	*Fast*	*Slow*	*Fast*	*Slow*
Inclusion	.70	.77	.66	.72
Exclusion	.36	.34	.40	.38
New	.14	.15	.16	.15
Recollection	.34	.43	.26	.34
Familiarity	.55	.58	.53	.57
	(.55)	(.60)	(.54)	(.58)

Note. Parameter estimates in parentheses were calculated using the overall means rather than the subject averages.

the same pattern of results as the overall data. An analysis of the probabilities of responding "old" revealed that the instructions (inclusion vs exclusion) interacted with list length, $F\ (1,15) = 6.662$, $MS_e = .008$, and signal speed, $F\ (1,15) = 7.986$, $MS_e = .007$. Inclusion scores increased from long to short lists and from fast to slow response speeds. Exclusion scores showed the opposite effects, decreasing from long to short lists and from fast to slow signal speeds. The only other significant effect was that of instructions, $F\ (1,15) = 75.551$, $MS_e = .049$. More items were correctly called old in the inclusion condition than were incorrectly called old in the exclusion condition. The probability of incorrectly accepting a new item was .15 and was not influence by condition (all effects $F < 1$).

A separate analysis was conducted on the inclusion scores to determine if signal speed interacted with list length. There was no such effect. Although there was an effect of list length, $F\ (1,15) = 7.725$, $MS_e = .004$, and of signal speed, $F\ (1,15) = 14.022$, $MS_e = .005$, the interaction was nonsignificant, $F < 1$. This is in agreement with Gillund and Shiffrin (1984) who found that list length did not interact with response speed. However, does this mean that the two processes did not differ in terms of processing speed?

An examination of the estimates for recollection and familiarity showed that despite the lack of an interaction between list length and response speed for the inclusion condition, familiarity was faster than recollection. An analysis of the estimated recollection and familiarity values revealed that recollection increased significantly from fast to slow response conditions, $F\ (1,15) = 8.048$, $MS_e = .015$, but that familiarity did not, $F\ (1,15) = 1.988$, $MS_e = .009$. Recollection increased from .30 to .39 but familiarity showed only a modest increase from .54 to .58. This pattern suggests that the process of recollection was still largely unfinished at 600-900 ms, compared to familiarity which did not show a sizable increase after that time. These results are in agreement with a number of previous response-signal studies in finding that familiarity is the faster of the two processes (Dosher, 1984; Gronlund & Ratcliff, 1989). Furthermore, the same pattern of results was reported by Toth (1993) who also used a response signal procedure in conjunction with the process dissociation procedure.

The effects of list length replicate those of the previous two experiments. Increasing list length interfered with recollection, $F(1,15) = 6.649$, $MS_e = .015$, but left familiarity unaffected, $F < 1$. As in the previous experiments, old items were more familiar (.56) than were new items (.15). For 15 out of 16 subjects the estimate for familiarity was greater than the false alarm rate to new items. There were no other significant effects (all Fs < 1).

GENERAL DISCUSSION

The results of the current experiments provide evidence that increasing list length affects only the recollective processes in recognition memory, leaving familiarity largely unaffected. This was found with yes-no and forced-choice recognition test procedures, for fast and slow recognition judgements. Furthermore, it was found when recollection was measured as the ability to selectively respond on the basis of study modality as well as when recollection was measured as the ability to respond on the basis of list membership. Although the list length effect has been found a number of times in recognition memory performance (e.g., Ratcliff & Murdock, 1976; Atkinson & Shiffrin, 1971; Gillund & Shiffrin, 1984), the differential effect on the processes underlying recognition performance has not previously been demonstrated.

An examination of the response-time distributions of Experiments 1 and 2 suggested that familiarity held a speed advantage over recollection. Results gained in Experiment 3 using the response-signal procedure showed that only recollection was significantly reduced by requiring subjects to respond quickly, providing further support for the claim that familiarity is the faster of the two processes (Atkinson & Juola, 1974; Mandler, 1980). Moreover, in Experiments 1 and 2, both recollection and familiarity contributed to the fastest and the slowest responses, as would be expected if the two bases for responding operate in parallel (cf. Atkinson & Juola, 1974).

An important assumption that underlies the process-dissociation procedure is that recollection and familiarity serve as *independent* bases for judgements. If the two processes are independent then it should be possible to find variables that influence one process while leaving the other invariant. Several such variables have been identified. For example, dividing attention at time of test reduces recollection but leaves familiarity in place (Jacoby, 1991), as does aging (Jennings & Jacoby, 1993), and amnesia (Verfaellie & Treadwell, 1993). List length interference and response speed add to the list of variables that produce such dissociations.

A potential criticism of the procedure used in the current experiments is the possibility of partial recollection. It is likely that subjects occasionally recollect information about a studied word that does not support the source discriminations that we required. For example, the subject may remember that they coughed as the word was studied but this information would not allow the subject to determine which list the item was in. Such partial recollection would not be captured by our estimate of recollection and might contaminate estimates of familiarity. That is, if these items were treated as familiar then our estimate of familiarity would reflect familiarity plus some partial recollection. If this occurred, our estimates of familiarity would begin to look like our estimates of recollection; manipulations like list length should affect the estimates for both processes in a similar manner. However, examination of the data in the current experiments as well as those previously mentioned shows little evidence of such contamination. One possibility is that partial recollection is relatively rare in comparison to the measured recollection. In fact, when subjects are instructed to remember study modality, and are repeatedly tested for just that, it would not be surprising if their ability to recollect task-irrelevant information was quite poor.

Do the results of our experiments generalize to performance on standard recognition tests? In our experiments, subjects could not rely solely on familiarity because they were required to differentially respond dependent on the study modality or the list in which an item had been presented. In traditional recognition experiments, on the other hand, subjects only have to discriminate between old and new items, a task that might be based on assessments of familiarity alone. However, there are a number of reasons to believe that under standard recognition conditions subjects rely on familiarity as well as recollection. First, it is likely that subjects would make use of recollection if they have this basis for responding available to them. Second, if subjects relied solely on familiarity in the standard recognition task, but relied on familiarity and recollection in the current discrimination task, then we would expect to see systematic differences in overall performance of the two types of task, which we do not see. In the current experiments, the magnitude of the list-length effect under inclusion instructions was similar to that found in standard list-length experiments (see Ratcliff & Murdock, 1976). Also, the response time manipulation had effects on performance in the inclusion test condition that were the same as those found for standard recognition by Gillund and Shiffrin (1984). Finally, if performance in the standard recognition experiments was based solely on familiarity, and, as we have shown, familiarity is not affected by list length, then we would not expect to see list length effects in standard recognition tests. However, such effects are consistently found (e.g., Atkinson & Shiffrin, 1971; Gillund & Shiffrin, 1984; Ratcliff & Murdock, 1976; Strong, 1912). Although not logically required to make simple recognition judgements, it seems that recollection serves as a basis for judgements in standard recognition tasks as well as in the tasks used in our experiments.

The finding that recollection and familiarity are differentially affected by list length interference as well as by retrieval speed joins a growing body of literature reporting dissociations within recognition memory. We believe that these results argue against single factor models such as signal detection theory and provide strong support for a dual process view of recognition memory.

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Sommaire

Dissociations en reconnaissance

Au cours de trois expériences, on a eu recours à la méthode de processus de dissociation pour examiner l'influence de la longueur de liste et le temps de réaction dans les processus inhérents à la mémoire de reconnaissance. On a utilisé cette méthode pour en arriver à des évaluations quantitatives de l'apport de la mémoire consciente et de la mémoire épisodique à l'ensemble du rendement de la mémoire. Dans les expériences 1 et 2, on a utilisé les méthodes «oui/non» et à choix forcé, ce qui a permis de démontrer que l'allongement de la liste diminuait la portée de la mémoire consciente mais avait peu d'effet sur la mémoire épisodique. De plus, une étude de la répartition des temps de réaction a démontré que la connaissance épisodique était rappelée plus rapidement que la mémoire consciente lorsqu'il s'agissait de porter jugement *a priori*. Cependant, ces deux facteurs ont contribué au rendement tant dans les réponses lentes que rapides, suggérant du fait que les deux processus agissent parallèlement. Dans l'expérience 3, on a eu recours à une méthode «oui/non» et, là encore, on a constaté que bien que l'ensemble de la mémoire était fortement influencée par la longueur de la liste, la mémoire épisodique échappait à cette influence. De plus, on a soumis les participants à une procédure visant à mesurer le temps de réaction au stimulus, ce qui a permis de démontrer que seule la mémoire était réduite en exigeant que les sujets répondent rapidement, venant ainsi renforcer la théorie selon laquelle la mémoire épisodique est le processus le plus rapide des deux processus étudiés.