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The Relation between Remembering and Knowing as Bases for Recognition: Effects of Size Congruency

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In three recognition memory experiments, subjects studied a list of randomly generated geometric shapes, followed by a recognition test in which old items were either size congruent (same size at study and test) or size incongruent. In Experiment 1, the process dissociation procedure (Jacoby, 1991) showed that changing the size of the items led to a decrease in both recollection and familiarity. In Experiment 2, the remember/know procedure (Tulving, 1985) showed that recollection, as indexed by the proportion of "remember" responses, decreased with size incongruence, but familiarity, as indexed by the proportion of "know" responses, increased. The latter effect along with other problems with the remember/know procedure were found to arise because of the procedure's underlying assumption that recollection and familiarity are mutually exclusive. When an independence assumption was combined with the remember/know data (IRK), results agreed with those of the process dissociation procedure. In Experiment 3, receiver operating characteristics (ROCs) were examined using the remember/know procedure and showed that familiarity was well described by a signal detection process that was independent of recollection. © 1995 Academic Press, Inc.

"He *looks* familiar but I can't recollect having met him before." Such examples of familiarity in the absence of recollection have been popular with memory theorists, dating back, at least, to Wundt (1912). In this paper we examine past treatments of such examples and argue that a major difference among treatments is in the relationship that they postulate as existing between recollection and familiarity. We begin with a discussion of the process dissociation procedure (Jacoby, 1991), which assumes that recollection and familiarity are independent, and then discuss the remember/know procedure (Tulving, 1985) which assumes the two processes are mutually exclusive. We then contrast the procedures in three experiments by examining the claim that perceptual characteristics are important for the feeling of familiarity—a notion implied by our first example and one that has been adopted by many dual process theorists (e.g., Gardiner, 1988; Jacoby & Dallas, 1981; Mandler, 1980).

The effects of perceptual characteristics are examined by manipulating size congruency between study and test. The size congruency manipulation is useful because different assumptions about the relationship between recollection and familiarity lead to radically different conclusions about the variable's effect, showing the importance of distinguishing between the alternative

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assumptions. Before we examine the effects of size congruency, let us describe the process dissociation and the remember/know procedures, as well as the evidence in favor of their underlying assumptions.

The Process Dissociation Procedure: An Independence Assumption

Mandler (1980) discussed examples of recollection without familiarity and, as have others (Jacoby & Dallas, 1981), argued that familiarity and recollection serve as independent bases for recognition memory. Familiarity is held to be a relatively automatic, fast basis for responding that requires few cognitive resources whereas recollection requires the same attention-demanding retrieval processes as do tests of recall.

Jacoby (1991) made use of the independence assumption and developed the process dissociation procedure to derive quantitative estimates for the contribution of recollection and familiarity to recognition memory performance. Estimates for recollection and familiarity were gained by contrasting performance in an inclusion condition, where both processes act in concert, to performance in an exclusion condition where the two processes act in opposition. In phase one of that study, subjects read a list of words under incidental encoding conditions. In phase two, subjects heard a different list of words and were instructed to remember them for a later recognition test. At test, subjects were presented with a list containing words that were earlier seen, earlier heard, as well as new words, and were given either "inclusion" or "exclusion" instructions. In the inclusion condition they were instructed to call a word old if it was in either the seen or heard list. In the exclusion condition they were instructed to call a word old only if it was in the heard list. Furthermore they were told that if they could recollect that the word was seen they could be sure the word was not heard and they should call it new. In this way subjects included seen words in the inclusion condition and excluded those words in the exclusion condition.

Performance in the inclusion and exclusion conditions for the *seen* words was used to derive estimates for recollection and familiarity in the following way. If the two processes are independent, the probability of responding "old" to a seen item in the inclusion condition will be equal to

$$R + F - RF,$$

the probability that the item is recollected (R) plus the probability that it is familiar (F), minus the probability that the item is recollected and familiar ($R \times F$). That is, a seen item can be accepted as old if it is recollected as having been seen, or if it is sufficiently familiar.

The probability of responding "old" to a seen item in the exclusion condition is equal to

$$F - RF,$$

the probability the item is familiar, minus the probability it is familiar and recollected. That is, subjects will only accept a seen word if it is familiar but they cannot recollect that it was seen. Recollection was calculated by subtracting the exclusion score from the inclusion score [$R + F - R \times F - (F - R \times F) = R$]. Having solved for R, either of the two equations could be used to solve for familiarity [i.e., exclusion/$(1 - R) = F$].

The estimate for familiarity gained from this formulation reflects not only the effect of memory but also the baseline probability of accepting a new item on the basis of pre-experimental familiarity. The effect of the study phase on familiarity can be examined by comparing the estimate of familiarity for studied items to the false alarm rate to new items. Subsequent work with the process dissociation procedure showed that familiarity was well described by a simple signal detection process (Yonelinas, 1994), suggesting that familiarity might be best measured in terms of d′. We return to this issue in Experiment 3 where we examine the relationship between the familiarity of old and new items by analyzing receiver operating characteristics.

The estimates derived by the process dissociation procedure rely on the validity of the assumption that recollection and familiarity are independent. However, several lines of evidence suggest that the assumption is a reasonable one. Probably the strongest support for the independence assumption comes from dissociations between recollection and familiarity. If the two processes are independent then it should be possible to find variables that influence one process but leave the other in place. Several such variables have been found. For example, using the process dissociation procedure, Verfaellie and Treadwell (1993) found that amnesia dramatically reduced recollection but left familiarity intact. A similar, although less dramatic effect, was found with aging (Jennings and Jacoby, 1993). Dividing attention has also been found to selectively influence recollection (Jacoby 1991). Other variables like increasing memory load (list length) and decreasing retrieval time by speeding responses are also found to reduce recollection but to leave familiarity intact (Yonelinas & Jacoby, 1994). The opposite dissociation was found examining ROCs in recognition. Relaxing response criterion was found to lead to an increase in the proportion of items accepted on the basis of familiarity but to leave recollection intact (Yonelinas, 1994). That study provided further support for the independence assumption by showing that a model based on the independence assumption accurately predicted the slopes and intercepts of ROCs.

Although there is considerable support for the independence assumption, a very different assumption is often made when examining subjective reports of recollection and familiarity.

The Remember/Know Procedure: An Exclusivity Assumption

Although examples of familiarity without recollection have been popular with theorists for some time, Tulving's (1985) innovation was to turn such subjective reports into a tool for investigating the processes underlying memory, with the introduction of the remember/know procedure. After having studied a list of words, subjects were given a test of recognition memory and were asked to introspect about their phenomenological experiences during recognition. They were asked to respond "remember" if they could recollect the prior presentation of the item, to respond "know" if they thought the item was presented earlier but they could not recollect its occurrence, and to respond "new" if they thought the word was not presented earlier. Remembering occurs if the subject becomes consciously aware of some aspect of what happened or what was experienced at the time the item was studied. Knowing occurs when the item is recognized as having been presented in the study list, but in the absence of any recollection of what happened or what was experienced at the time of study. The remember responses are thought to arise from an episodic memory system that reflects conceptual processing, whereas the know responses arise from a procedural system that reflects perceptual processing (see Gardiner, 1988).

Unlike the process dissociation procedure, the assumption underlying the Remember/Know (R/K) procedure is that recollection and familiarity are mutually exclusive processes. Because subjects are only allowed to make one response to each item it is unarguable that remember and know responses themselves are mutually exclusive. In fact, knowing is often described as familiarity in the absence of recollection. In remember/know experiments, the probability of a remember response is treated as a measure of recollection and the probability of a know response is treated as a measure of familiarity. Therefore it follows that the two processes must also be mutually exclusive. Although the exclusivity assumption is rarely discussed in remember/know studies see Gardiner and Parkin (1990) for an exception.

Support for the exclusivity assumption is gained from results of direct and indirect tests. Variables that influence know responses tend to influence performance on perceptual indirect tests and variables that influence remember judgments tend to influence performance on several direct tests. For example, levels of processing was found to have a large effect on tasks like free recall, which presumably rely on recollection, but to have little if any effect on performance in perceptual indirect tests like word fragment completion, which presumably are sensitive to increases in familiarity (for a review see Roediger & McDermott, 1993). These results parallel those of Gardiner (1988) who found that deeper levels of processing increased the probability of a remember response but did not influence the probability of a know response. Convergence of this sort would be expected if recollection and familiarity are mutually exclusive and they are the same processes that underlie performance on direct and indirect tests.

However, results from R/K experiments do not always agree with those from perceptual indirect tests. For example, Rajaram (1993) used the R/K procedure and found that deeper levels of processing led to an increase in recollection but also led to a significant decrease in knowing (familiarity). So levels of processing can have different effects on knowing judgments than they have on performance on indirect tests.

Another problematic discrepancy between knowing and performance on perceptual indirect tests arises with respect to the effect of perceptual variables. As the example used to start this paper suggests, familiarity would seem to be sensitive to perceptual similarity such that familiarity increases with similarity to studied items. Such intuitions about familiarity have been adopted by several dual process theorists (Gardiner, 1988; Jacoby & Dallas, 1981; Mandler, 1980). Moreover, indirect tests, which are presumably sensitive to increases in familiarity, are generally found to benefit from perceptual similarity. So for example, performance on a perceptual indirect test, like word stem and word fragment completion, is greater for items studied and tested in the same modality than those for which the modality changes (for a review see Roediger & McDermott, 1993). In contrast, modality is found to have little if any effect on recognition performance (e.g. Challis, Chiu, Kerr, Law, Schneider, Yonelinas, & Tulving, 1993). Moreover, Rajaram (1993) found that neither the probability of an R or K response changed as a function of the match between study and test modality. So the effects of perceptual variables on indirect tests do not converge with those found on "know" responses in recognition.

Even more problematic for the exclusivity assumption are the observed effects of size congruency. Rajaram and Coslett (1992; also see Rajaram & Roediger, in press) presented line drawings of objects to subjects to study for a later test of recognition memory. At test, old objects were size congruent (same size at study and test) or size incongruent (they either became larger or smaller). Despite the fact that subjects were informed that the size may change and that they should ignore the absolute size, subjects were much more likely to respond remember to size congruent items than size incongruent items. Most striking, however, was the observation that size incongruent items led to a higher proportion of know responses than size congruent items. Thus, by the exclusivity assumption, it would seem that changes in size between study and test led to an *increase* in familiarity. Not only does this result conflict with the effects of perceptual similarity in indirect tests but it runs counter to the expectation that familiarity should increase with perceptual similarity.

In the current set of experiments we examined the effect of size congruency on recollection and familiarity using the process dissociation and the remember/know procedures. We show that the problematic conclusions and the inconsistencies found using the R/K procedure arise because of the assumption that the two processes are mutually exclusive. In Experiment 1 we used the process dissociation procedure and found that both recollection and familiarity increased with size congruency. In Experiment 2 we repeated the study using the R/K procedure, and found that the standard treatment of the R/K data leads to numerous problems, but that when the two processes are assumed to be independent (using an independence remember/know procedure—IRK) that the results converge with those of the process dissociation procedure. In Experiment 3 we examined receiver operating characteristics and found further evidence for the independence assumption.

Experiment 1

In Experiment 1 the effects of size congruency on recollection and familiarity were examined using the process dissociation procedure. Subjects studied lists of randomly generated geometric shapes. The subsequent recognition test included a mixture of new and old items. The old items were either size congruent (same size as the study item) or size incongruent (four times or one-fourth the size of the study item). Subjects were told that the size of the shapes would often change but that size was not important.

Although the process dissociation procedure is often implemented by contrasting performance under two different sets of instructions (inclusion and exclusion), in the current study we implement the rationale by a slightly different means. Rather than using inclusion and exclusion instructions, we made use of a list discrimination task and extracted inclusion and exclusion measures from within that task. By this formulation recollection is defined rather strictly as the ability to determine list membership. The procedure has been used before (Yonelinas, 1994; Yonelinas & Jacoby, 1994) and was chosen because it allowed us to collect a large number of responses from each subject using a repeated study-test format.

After the presentation of two study lists, subjects received one of two different test instructions: "Was this item in List#1?" or "Was this item in List#2?" They were told that none of the items were in both lists, and so they should respond yes if the item was from the target list, and respond no if the item was new or if they could recollect that the item appeared in the nontarget list. Furthermore, they were instructed to respond yes if the item was familiar but they could not recollect which list it was in. Responses to items under these two sets of instructions provided inclusion and exclusion measures which were used to derive estimates for recollection and familiarity.

For the inclusion measure we were interested in the probability of correctly accepting items from a target list (list#1 items accepted under list#1? instructions, and list#2 items accepted under list#2? instructions). Under these conditions, subjects could accept a target item either if it was recollected (recollect list membership) or if it was familiar. If the two processes are independent, then the probability of accepting an item is equal to the probability that the item is recollected (R) plus the probability that the item is familiar (F) minus the probability the item is recollected and familiar (RF).

For the exclusion measure we were interested in the probability of accepting an item from the nontarget list (list#1 items accepted under list#2? instructions, and list#2 items accepted under list#1? instructions). Under these conditions, items would only be accepted if they were familiar and not recollected—recollection that the item was from the nontarget list would lead to a no response. Thus, the probability of accepting an item under these instructions is equal to the probability the item is familiar (F) minus the probability the item is both recollected and familiar (RF).

Recollection was estimated by subtracting the exclusion measure from the inclusion measure, and familiarity was estimated by dividing the exclusion measure by the probability that the item was not recollected. Inclusion and exclusion measures for size congruent and size incongruent shapes were used to derive estimates for recollection and familiarity for both types of repeated shape, allowing us to examine how size congruency influenced the two bases of recognition.

Method

Subjects. Sixteen subjects, who were students enrolled in an introductory psychology course at McMaster University, participated in the experiment.

Materials. Geometric shapes were randomly generated by the computer for each subject. Each shape consisted of lines connecting five randomly selected points. Shapes were presented in two sizes that differed by roughly a 4:1 ratio. The small and large shapes were approximately 4×4 cm and 16×16 cm, respectively.

Design and procedure. Materials were presented and responses collected on a Macintosh computer with a monochrome monitor. The viewing distance was approximately .5 m. 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 they would be presented with two lists of geometric shapes and would be required to judge in which of the two lists items had been studied. They were informed that the size of the shapes could vary from study to test but that the size was irrelevant.

Twenty shapes were presented in each study list. Half of the shapes were large and half were small. Shapes were presented at a 5 s rate. After the first list was presented there was a 5 s delay, and subjects were informed that the first list had ended. This was followed by the presentation of the second list. For the test phase, subjects were presented with 60 shapes one at a time. The test list consisted of 20 shapes from list#1, 20 from list#2, and 20 new shapes presented in a random order. Half of the shapes from each list were the same size as they had been at study, and half were presented either four times as large or at one-fourth the size. Half of the small study items were small at test and half were large. Similarly half of the large study items were small at test and half were large. Of the new items, half were large and half were small.

The experimental session consisted of four study-test blocks. New shapes were constructed for each study-test block. For two of the tests, subjects were instructed to respond "yes" if the shape was in list#1. They were informed that the size of the shape did not matter and that they should respond yes if it was the same or different size as at study. If the shape was new they were to respond "no," and if they could recollect that the shape was in the inappropriate list, they were also to respond no. Furthermore, if the item was presented previously but they could not recollect which list it was in, they were to respond yes. For the other two tests, the instructions were reversed and subjects were instructed to respond yes if the shape was in list#2. The order of the test instructions was randomized and the subjects were not told how many study-test blocks they would receive. Further, they did not know which test instructions they would receive until the test began.

The experiment was based on a 2×2 within-subject design. Size congruency (same vs. different size at study and test) was crossed with type of measure (Inclusion vs. Exclusion). List number (list#1 and list#2), as well as study and test size were counterbalanced across all experimental conditions. The inclusion measure reflected the probability of accepting a list#1 item under list#1? instructions or a list#2 item under list#2? instructions. The exclusion measure reflected the probability of accepting a list#1 item under list#2? instructions or accepting a list#2 item under list#1? instructions. The significance level for all statistical tests was set at $p < .05$.

Results and Discussion

The inclusion and exclusion scores for size congruent and size incongruent shapes are presented in Table 1. Although the size congruent shapes led to a slightly higher inclusion score than the size incongruent shapes, the reverse was true for the exclusion scores. This was reflected in a significant size by test measure interaction, $F(1,15) = 16.21$, $MS_e = .006$.

Of most interest are the estimates for recollection and familiarity (see Table 1). Inclusion and exclusion scores were used to derive estimates for recollection and familiarity as discussed earlier. Estimates were derived for size congruent and size incongruent items for each subject. The probability of recollection was greater for size congruent items than for size incongruent items, $F(1,15) = 16.17$, $MS_e = .012$. Similarly, the probability that items were accepted on the basis of familiarity was greater for size congruent than for size incongruent items, $F(1,15) = 7.79$, $MS_e = .007$. Further, the familiarity estimates for size incongruent items, as well as size congruent items were greater then the false alarm rate to new items, ($F(1,15) = 6.42$, $MS_e = .006$, and $F(1,15) = 9.12$, $MS_e = .020$, for size incongruent and congruent items respectively), showing that old items were more familiar than new items. If prior presentation of items did not increase their familiarity we would expect the familiarity estimates to be equal to the false alarm rate. A number of further analyses were carried out to examine the effects of study list, test instructions, study size, and test size. However, the pattern of results did not show any systematic change across any of these factors.

TABLE 1
RECOGNITION ACCURACY AND ESTIMATES OF RECOLLECTION AND FAMILIARITY FOR SIZE CONGRUENT AND SIZE INCONGRUENT SHAPES IN EXPERIMENT 1

	Size congruent		Size incongruent
Inclusion	.68		.55
Exclusion	.42		.45
New		.42	
Recollection	.26		.10
Familiarity	.57		.50

The results of the experiment are in agreement with the notion that familiarity increases as a function of the perceptual similarity between the study and test stimulus (Gardiner, 1988; Jacoby & Dallas, 1981; Mandler, 1980). However, recollection was also found to benefit from perceptual similarity, as it also increased with size congruency.

EXPERIMENT 2

Experiment 1 showed that both recollection and familiarity increased with size congruency. However, as previously discussed, Rajaram and Coslett (1992) used the R/K procedure and found that size congruent items were more likely to be recollected, but were *less* familiar than size incongruent items. They examined recognition for line drawings of objects and found that the proportion of remember responses was greater for size congruent than incongruent items, but that the probability of a know response was lower for size congruent items than size incongruent items. We begin by examining the effect of size congruency using the remember/know procedure and then more closely examine the assumptions underlying the remember/know and the process dissociation procedures.

Method

Subjects and materials. Sixteen subjects, from the same subject pool as in the previous study participated in the experiment. The materials were the same as those in the previous experiment.

Design and procedure. The design and procedure were similar to those of the previous experiment. Subjects were informed that they would receive a number of recognition tests. They were told that they would be presented with two lists of geometric shapes and that they would receive a recognition test after the two lists were presented. It was explained that the list was presented in two parts so as to allow them a short break in the middle of the study list. They were told that the size of the shapes could vary from study to test but that the size was not important. The presentation of the study lists was the same as in Experiment 1.

At test, subjects were instructed to make remember, know, or new judgments for each item. Instructions were adapted from Gardiner (1988). Subjects were to press an "R" key if they could recollect having seen the item in either of the two study lists, press "K" if they knew the item was in the study list but they could not recollect it, and press "N" if they thought the shape was not studied.

Results and Discussion

The proportions of remember and know responses for size congruent, size incongruent, and new shapes are presented in Table 2. The probability of responding "remember" to an old item was greater for congruent than for incongruent shapes, $F(1,15) = 42.71$, $MS_e = .005$, showing that recollection increased with size congruency. In contrast, the probability of responding "know" to an old item was less for size congruent than for size incongruent shapes, $F(1,15) = 5.71$, $MS_e = .004$, suggesting that familiarity decreased with size congruency. Moreover, new items were as likely to elicit a "know" response as were old size congruent items (.36 for both new and size congruent old items), suggesting that repeated size congruent items were no more familiar than new items.

TABLE 2
THE PROBABILITY OF RESPONDING "REMEMBER" AND "KNOW" TO SIZE CONGRUENT, SIZE INCONGRUENT, AND NEW ITEMS IN EXPERIMENT 2

	Size congruent	Size incongruent	New
Remember	.45	.30	.08
Know	.36	.41	.36

The results of Experiment 2 replicated those of Rajaram and Coslett (1992) in showing that although recollection increased with size congruency, knowing decreased. Thus, for randomly generated geometric shapes as well as line drawings of objects, changing size led to a decrease in remembering, but to an increase in knowing. In contrast, when the process dissociation procedure was used (Experiment 1), changing size led to a decrease in recollection as well as in familiarity.

Why did the remember/know and the process dissociation procedures lead to different conclusions? As previously discussed, one important difference between the two procedures is the assumed relationship between recollection and familiarity. By the process dissociation procedure, the two processes are assumed to be independent. Thus recollection can occur with or without familiarity, and vice versa. However, by the remember/know procedure the two processes are assumed to be mutually exclusive. Remembering and knowing can never co-occur, because, for each item, subjects respond either R or K, never both. If the proportion of R and K responses are taken as measures of recollection and familiarity then it must be assumed that the two processes are also mutually exclusive. However, what if the processes underlying the remember and know responses are not mutually exclusive?

Independence remember/know procedure. If the two processes are independent then the remember and know responses cannot be directly mapped onto recollection and familiarity. Although remember responses should provide a relatively pure measure of recollection (provided subjects respond R when and only when they recollect), know responses will not provide a pure measure of familiarity. Rather, know responses reflect familiarity in the absence of recollection (F(1 − R)). In fact, this is what is suggested when subjects are instructed to respond K only when an item is familiar (F) but not recollected (1 − R).

If the two processes are independent there will be some proportion of items that are both familiar and recollected (a possibility not allowed by the exclusivity assumption). For these items, subjects will respond remember, even though the items are also familiar. Consequently, the proportion of know responses will underestimate the probability that an item is familiar. To determine the probability that an item is familiar (F), one must divide the proportion of "know" responses (K) by the opportunity the subject has to make a "know" response (1 − R):

$$F = K/(1 - R).$$

Given this equation, one can use the data from the remember/know experiment to calculate the probability that items are familiar. Using this IRK procedure produces results that are in agreement with those of the process dissociation procedure experiment. Results show that familiarity increased from .58 to .65 for incongruent to congruent items. Deriving estimates for each subject showed that the difference was significant, $F(1,15) = 5.750$, $MS_e = .006$. Furthermore, for every subject, the estimate for familiarity for both size congruent and size incongruent items was greater than the false alarm rate to new items, showing that old items were more familiar than new items.

Thus the pattern of results produced by the IRK procedure converged with those of the process dissociation procedure; changing object size between study and test decreased recollection and familiarity, and old items were more familiar than new items. However, an examination of Tables 1 and 2 shows that the absolute estimates for recollection and familiarity were greater in the remember/know experiment than in the process dissociation experiment. We discuss these differences after presenting data from a final remember/know experiment.

The conclusions drawn for the independence assumption as applied to the inclusion/exclusion and the remember/know procedures are in agreement with claims that familiarity benefits from perceptual similarity as well as with the notion that repeated items are more familiar than novel items. The exclusivity assumption, on the other hand, leads to the paradoxical conclusions that as items become more perceptually similar at study and test, they become less familiar, and that repeated shapes are more familiar than new shapes only when the size of the shape changes between study and test. We believe that the problems that arise with the exclusivity assumption provide good reason to seriously question that assumption.

EXPERIMENT 3

In Experiment 3 we examined the effects of size congruency using the R/K procedure in conjunction with a confidence rating procedure. This allowed us to plot ROCs and examine familiarity as a function of response confidence using the independence (IRK) and exclusivity (standard R/K) assumptions. Doing so served two purposes. First, by examining ROCs we tested the notion put forth previously (Jacoby, Toth & Yonelinas, 1993; Yonelinas, 1994) that familiarity reflects a signal detection process that is independent of recollection. Second, we hoped that plotting ROCs for know responses might provide some insight into the problems encountered by the exclusivity assumption.

What is the nature of the processes that underlie remember and know responses? One possibility is that remembering and knowing are discrete mental states. That is, if the recollection process is successful then the item is remembered, if the familiarity process is successful then the item is known, otherwise both processes fail and this leads to a "new" response. However, this view contrasts with the notion that recognition judgments reflect an assessment of a continuous familiarity dimension. Such a view underlies the application of signal detection theory to recognition memory, and has received considerable empirical support (e.g., Murdock, 1965; Norman & Wickelgren, 1965; Swets, 1986).

Although it seems reasonable that recollection is a discrete state—subjects either succeed or fail to retrieve something about the study event—there does not seem to be any one state of familiarity. Rather, the level of familiarity appears to vary continuously. In support of these notions, Yonelinas (1994) used the process dissociation procedure and found that, as response criterion was relaxed, the probability of accepting items on the basis of familiarity increased gradually, as would be expected if familiarity reflected the assessment of a continuous strength dimension as described by classical signal detection theory. Recollection, on the other hand, led to very high confidence recognition judgments, and showed little sign of increasing as response criterion was relaxed, suggesting that recollection did not reflect the assessment of a continuous strength dimension, but rather reflected a threshold or all-or-none retrieval process.

If familiarity reflects a classical signal detection process, then the function that relates the proportion of old to new items accepted on the basis of familiarity (the familiarity ROC), will be highly constrained. To see how, consider Fig. 1, which represents a classical Gaussian equal variance signal detection model. The horizontal axis reflects the level of familiarity, and the vertical axis reflects probability density. By this model, all items are assumed to have some level of preexperimental familiarity. However, there is variability in the level of familiarity such that the new items can be represented by the Gaussian distribution on the left. Studying items temporarily increases familiarity by some constant, thus the old item distribution is shifted to the right, and has the same shape (variance) as the new item distribution. Thus the old items are, on average, more familiar than the new items, but the two distributions overlap.

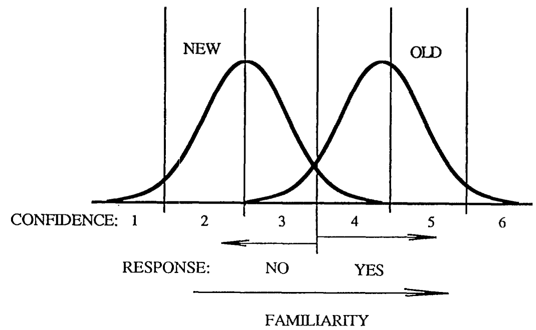

FIG. 1. Familiarity distributions representing old and new items in a Gaussian equal-variance signal detection model.

In a standard "yes/no" recognition test, subjects accept as old all items exceeding some criterion level of familiarity. If subjects are required to rate the confidence of their recognition judgments, then familiarity is used as a basis for confidence judgments such that higher levels of familiarity lead to higher levels of response confidence. When hits (proportion of old items accepted as old) are plotted against false alarms (proportion of new items accepted as old) as a function of response confidence, the model produces a symmetrical function like that in Fig. 2a. The function is referred to as symmetrical because it begins at the intercept and increases gradually, forming a curve that is symmetrical along the negative diagonal. By rotating Fig. 2a by 45 degrees, such that the diagonal is horizontal, one can see the symmetry more easily.

By replotting the ROC in terms of z scores (Fig. 2b) rather than proportions, the function becomes a straight line, such that the intercept of the line reflects discriminability (d′), and the slope of the line reflects the symmetry of the curve. A perfectly symmetrical curve will have a slope of 1 when plotted on z coordinates. A nonsymmetrical or "skewed" ROC like the upper

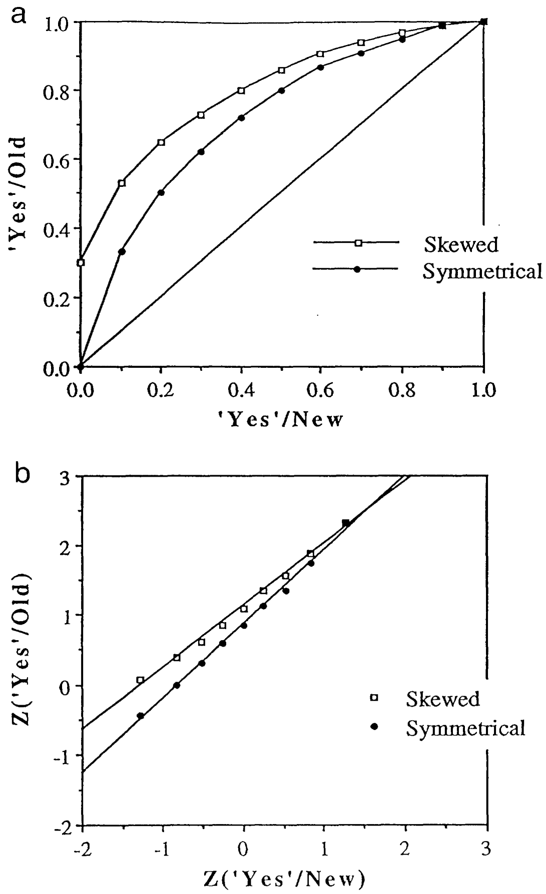

FIG. 2. Symmetrical and Skewed ROCs plotted on (a) probability coordinates and (b) z coordinates.

curve in Fig. 2a will have a slope of less than 1 when plotted on z coordinates. Nonunity slopes can be produced by the signal detection model, but only by introducing an additional factor or parameter, such as the ratio of the old to new item variance (see Swets, 1986).

If familiarity reflects the Gaussian equal variance signal detection process and subjects are responding *only* on the basis of familiarity, then the ROC should be symmetrical and thus have a slope of one. However, if subjects are also responding on the basis of recollection, then the ROC should become skewed such that the slope will drop below 1. To see why, consider the case in which a subject successfully recollects something about a study item. One would expect recollection to lead to a highly confident recognition judgment. If recollection and familiarity contribute independently to recognition, then when we introduce the recollected items to the symmetrical ROC produced by the familiarity process, we will increase the number of high confidence hits. This will tend to push the ROC up and produce a skewed curve with a slope of less than one.

In the current experiment we made use of the IRK procedure in conjunction with a confidence rating procedure to test the notion that familiarity reflects a signal detection process. Like the standard remember/know procedure, subjects responded "R" if they recollected an item. However, rather than making a simple know/new discrimination for the remaining items, they rated on a 6-point scale how sure they were that the item was previously studied. In this way we could examine familiarity as the response criterion was varied. For example, using a strict criterion we included only the most confident responses as a "know" response (responses eliciting a "6"). Using the IRK procedure we estimated the probability of accepting an old item on the basis of familiarity. We then derived estimates for familiarity using a slightly more lax criterion—accepting all items eliciting a "6" or a "5" response. We did this for each point along the confidence scale which provided five estimates for familiarity, each successive estimate representing the probability of familiarity as response criterion became more lax. By plotting the estimates for familiarity against the false alarm rate to new items, we were able to determine if the ROC for familiarity was in agreement with that predicted by the signal detection model described earlier.

To summarize, performance in a modified R/K procedure was used to examine ROCs in a recognition memory test. Performance was plotted as a function of response confidence, and was used to derive estimates for familiarity based on the independence and exclusivity assumptions. It was expected that if familiarity is a signal detection process that is independent of recollection then overall recognition performance should produce an ROC that has a slope of less than 1. Moreover, when we algebraically remove recollection (IRK) and examine just the familiarity process then the ROC slope should be equal to one. Beyond testing the signal detection notion, we also examined the ROCs in light of the exclusivity assumption, by plotting the proportion of know responses to old items against that for new items as a function of confidence.

Method

Subjects and materials. Seventeen subjects from the same subject pool as the previous experiment participated in the current study. The materials were the same as those in the previous experiment except that the shapes were made more distinctive. Shapes were constructed by joining 4, 5, 6, or 7 randomly selected points.

Design and procedure. The design and procedure were the same as the previous experiment with the following changes. Subjects were presented with eight study-test blocks. Each study list contained 24 shapes. Each test list contained 24 old and 24 new shapes. At test, subjects were instructed to respond by pressing an R key if they could recollect having seen the item at study. Otherwise they were to rate how familiar (known) the item was in the context of the study list. In other words, they were to indicate how sure they were that the item was in the study list. Familiarity ratings were made by responding on a 6-point scale from "sure it was on the list" to "sure it was not on the list."

Results and Discussion

To compare performance to that of the previous experiment, scores were collapsed across levels of confidence (items eliciting a 4, 5, or 6 response were counted as know responses) and are presented in Table 3. In agreement with the prior experiment, the probability of remembering an item was greater for congruent than for incongruent items, $F(1,16) = 41.41$, $MS_e = .002$. However, the proportion of "know" responses for the congruent and incongruent items did not differ significantly, $F < 1$. This is in contrast to the results of the previous experiment where incongruent items were found to lead to more "know" responses than the congruent items. However, the reason for this inconsistency became apparent when ROCs were examined (see subsequent discussion).

Estimates for familiarity based on the IRK procedure were in agreement with those of the previous two experiments; size congruent shapes (.65) were more familiar than size incongruent shapes (.55), $F(1,16) = 9.81$, $MS_e = .006$. Moreover, for all subjects, old items were more familiar than new items. Thus by the independence assumption, size congruency led to an increase in recollection as well as familiarity, and studied items were more familiar than nonstudied items.

ROC Analysis. An initial ROC analysis was conducted on overall recognition performance. Figure 3 presents the ROCs for size congruent and size incongruent shapes. The curves were plotted by treating the recollected items as the most confidently remembered items.[1] Thus the left most point on each function represents the proportion of old items receiving an R response plotted against the proportion of new items receiving an R response. The next point includes the R responses as well as the most confident K responses. Thus moving left to right on the ROC reflects performance as response criterion is relaxed.

Across the range of false alarm rates, the

[1] The remembered items were treated as the most confident responses because results from process dissociation studies (Yonelinas, 1994) as well as remember/know studies (Yonelinas & Jacoby, in prep) showed that recollection leads to the highest level of recognition confidence. Moreover, the "remember" category was found to have the lowest false alarm rate of any response category, which would be expected if it reflected the highest level of response confidence.

TABLE 3
THE PROBABILITY OF RESPONDING "REMEMBER" AND "KNOW" TO SIZE CONGRUENT, SIZE INCONGRUENT, AND NEW ITEMS IN EXPERIMENT 3

	Size congruent	Size incongruent	New
Remember	.37	.27	.03
Know	.41	.40	.36

Note. Know responses reflect items eliciting a 4, 5, or 6 on a 6-point confidence scale.

hit rate for size congruent items was greater than for size incongruent items, showing that overall performance was greatest for size congruent items. Moving from left to right, the curves gradually increased, and exhibited a skew, such that the functions were not symmetrical. To measure the skew, the curves were plotted on *z* coordinates. The transformed curves exhibited a slight "U" shape but were fit very well by straight lines (R^2 = .99 for both size congruent and size incongruent functions). The ROC slopes were significantly less than 1.00, $F(1,32) = 69.63$, $MS_e = .009$, showing that the ROCs were skewed. Moreover, the slope did not differ between congruent (.82) and incongruent items (.81), $F < 1$. The intercept was greater for size congruent (1.16) than size incongruent items (.83), $F(1,16) = 34.36$, $MS_e = .028$, showing that performance was greater for size congruent

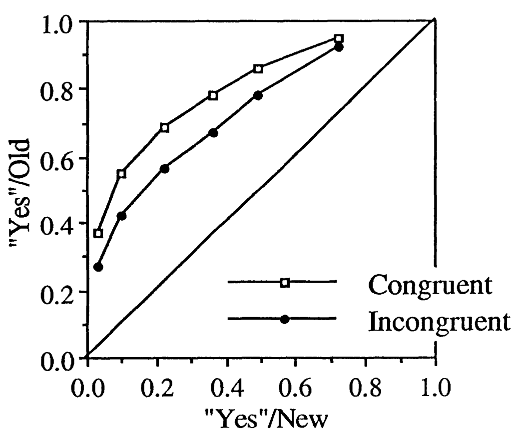

FIG. 3. The average recognition ROCs for size congruent and size incongruent items in Experiment 3.

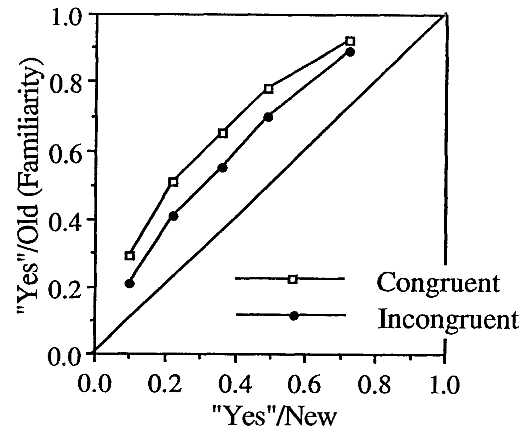

FIG. 4. The average familiarity ROCs for size congruent and size incongruent items for Experiment 3, based on the independence assumption. Estimates of familiarity are plotted against false alarms.

items. Thus, for overall recognition performance, as size changed, d′ dropped, and the slope of the ROCs remained constant at approximately .80. The same pattern of results has been found with increases in study time. (Egan, 1958; Ratcliff, Sheu, & Gronlund, 1992; Yonelinas, 1994). A slope of less than one is expected if subjects are relying on a signal detection process as well as an independent recollection process.

The independence assumption. Figure 4 presents the estimates of familiarity using the IRK procedure for size congruent and incongruent items across levels of confidence. Familiarity scores for each level of response confidence were calculated by dividing the proportion of "know" responses by one minus the proportion of "remember" responses in each condition, and were plotted against the proportion of new items incorrectly eliciting an "R" or "K" response.[2]

Figure 4 shows that across the range of response confidence, the size congruent items held a familiarity advantage over size

[2] A subsequent analysis was conducted whereby familiarity estimates for new items were calculated, just as they were for old items, and these estimates were used to plot the ROCs rather than the raw false alarm rates. However, because the proportion of false recollections was low (.03), the replotted ROCs were not noticeably different from the original ROCs.

incongruent items. Moreover, the ROCs for both types of item were symmetrical, as would be expected if familiarity was an equal variance signal detection process. The average slopes of the z score functions for congruent and incongruent items were 1.03 and 1.00 respectively, and neither differed significantly from the predicted value of 1.00, Fs < 1. Thus, in agreement with prior work with the process dissociation procedure (Yonelinas, 1994), the familiarity ROC was symmetrical as would be expected if familiarity reflected a Gaussian equal variance signal detection process that was independent of recollection. The discriminability afforded by familiarity in terms of d′ (the intercept) was greater for the size congruent (.79) than the incongruent items (.53), $F(1,16) = 11.97$, $MS_e = .047$. Thus by the independence assumption, size congruent items were more familiar than size incongruent items across the full range of response confidence.

The exclusivity assumption. Figure 5 presents the estimates of familiarity using the exclusivity assumption (proportion of know responses) for size congruent and incongruent items across levels of confidence. The proportions of know responses to size congruent and size incongruent shapes were

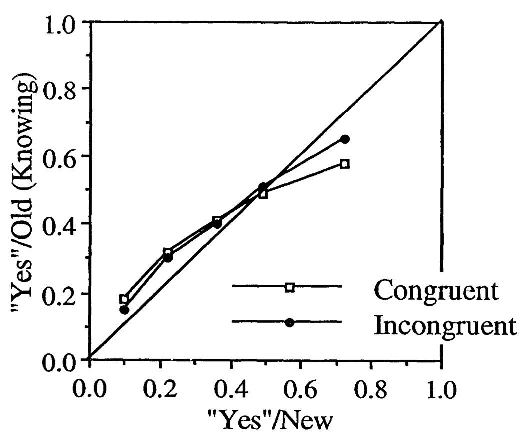

FIG. 5. The average familiarity ROCs for size congruent and size incongruent items in Experiment 3, based on the exclusivity assumption. Estimates for familiarity ("know" responses) are plotted against false alarms.

plotted against false alarms. For both congruent and incongruent items the proportion of know responses increased gradually, but both functions crossed the diagonal as response criterion was relaxed. Points below the diagonal indicate that more new items led to know responses than did old items. This means that using a strict response criterion, old items were more familiar than new items but that at a lax response criterion old items were less familiar than new items. We have found this pattern before (for a particularly striking example see Jacoby, Yonelinas, & Jennings, in press).

Moreover, the relationship between congruent and incongruent shapes reversed as criterion was varied. Figure 5 shows that when the response criterion was strict (leftmost points), size incongruent shapes led to a lower level of knowing than size congruent shapes. However, when the response criterion was lax (rightmost points) size incongruent shapes led to a higher level of knowing than did size congruent shapes. This latter pattern was seen in the Rajaram and Coslett (1992) study as well as Experiment 2 of the current paper, suggesting that under standard remember/know instructions, subjects adopted a relatively lax response criterion for responding know.

Why did the exclusivity assumption lead to such a complex pattern of results? The results are easily explained if know responses reflect not just familiarity, but familiarity in the absence of recollection. Because subjects only respond know when an item is not recollected, recollection imposes a functional ceiling on the number of possible know responses to old items. For example, if the probability of recollection is .7 then the maximum observable level of knowing for old items is .3. Because subjects falsely recollect very few new items, the proportion of new items that can be accepted as known can increase beyond .3. Thus as response criterion becomes more lax, the probability of responding know to the new items can become greater than that for the old items. This is what we saw for both congruent and incongruent items. Moreover, the greater the probability of recollection, the lower will be the ceiling on knowing. Thus because size congruent items had the highest level of recollection, they were influenced most by the ceiling effect, and as response criterion was relaxed, the size congruent items lost the know advantage they had over incongruent items.

The effect of recollection on know responses is not limited to cases where the hit rate is very high. As long as the probability of recollection is greater than zero, know responses should underestimate familiarity. It is this underestimation that led to the conclusions in Experiment 2 that familiarity (knowing) decreased with perceptual similarity and old items were more familiar than new items only when their size changed between study and test.

In summary, the results of Experiment 3 support the notion that familiarity is a signal detection process that is independent of recollection. In agreement with the results of Experiments 1 and 2, when the independence assumption is adopted, changes in size were found to decrease both recollection and familiarity, and repeated shapes were found to be more familiar than new shapes. Moreover, the ROC analysis showed that size congruent items were more familiar than size incongruent shapes across the range of response confidence and that the familiarity ROCs were as predicted by a Gaussian equal variance signal detection model.

The exclusivity assumption, on the other hand, led to a number of paradoxical conclusions. The effect of size congruency was found to be extremely sensitive to changes in response criterion. Size congruent items led to fewer know responses than incongruent items when a lax criterion was adopted, but this pattern reversed as the response criterion became more strict. Moreover, repeated items held a know advantage over new items when using a strict response criterion. However, this pattern reversed as response criterion became more lax. The ROC analysis showed that the problematic results based on the exclusivity assumption arose because the know responses systematically underestimated familiarity.

General Discussion

Appeal to examples showing familiarity in the absence of recollection, such as the one used to begin this article, has been common in discussions of recognition memory. Such examples show the necessity of a distinction between recollection and familiarity as bases for recognition. What has been difficult is finding experimental procedures to separate the contributions of the two. An obvious solution to that problem is to rely on subjective reports. That people find examples of familiarity in the absence of recollection to be compelling implies that they are capable of distinguishing between the subjective experiences that reflect the two bases for recognition. However, subjective reports have not been used as a major source of data for separating bases of recognition. Although Mandler (1980) popularized an example of familiarity in the absence of recollection, his experimental procedures did not rely on subjective reports to separate the two. Tulving (1985) and others (e.g., Gardiner & Java, 1993) have investigated the effects of various factors on subjective reports but have done little to relate those effects to signal detection theory.

To separate the contributions of different bases for responding, it is necessary to start with an assumption about the relationship between underlying processes. The IRK procedure and the inclusion/exclusion procedure are both based on the assumption that recollection and familiarity serve as independent bases for recognition memory. First, we discuss similarities and differences between the IRK and the inclusion/exclusion procedures. Next, we turn to the more general question of the relation between recollection and familiarity as bases for recognition memory.

IRK vs Inclusion/Exclusion

The IRK and the inclusion/exclusion procedures are both aimed at dissociating processes within a task, and thus can be seen as process dissociation procedures, but they do so by different means. Whereas the IRK procedure relies on subjective reports to measure recollection, the inclusion/exclusion procedure measures recollection as a bases for control. If subjects recollect an item they can either include or exclude it when instructed to do so. Alternatively they can use recollection as a basis for subjective reports when asked to make remember/know judgments. Thus it should not be surprising that the inclusion/exclusion and IRK procedures lead to the same conclusions regarding the effects of size congruency on recollection and familiarity.

Although the pattern of results was the same with regard to effects of size congruency, the estimated probability of recollection was higher by approximately .20 for the IRK procedure (Experiment 2) than for the inclusion/exclusion procedure (Experiment 1). In part, at least, this is because the definition of recollection was more stringent for the inclusion/exclusion procedure. To count as recollection for that procedure, information that was recollected had to be sufficient to specify the list membership of a tested shape—subjects were to include or exclude a shape on the basis of its list membership. In contrast, for the IRK procedure, recollection that did not allow list discrimination would count. For example, suppose that a subject recollected coughing during the study presentation of a shape. Although this might not support list discrimination and consequently, would not be measured as recollection by the inclusion/exclusion procedure, the same recollection could be used as a basis for remember responses in the remember/know procedure. That is, the inclusion/exclusion procedure measured recollection of list membership whereas the IRK procedure measured overall recollection. This is not a necessary difference between the two procedures. Inclusion/exclusion can be defined with reference to occurrence of an item in the experimental setting so that it too measures overall recollection. When that is done, estimates gained from the inclusion/exclusion procedure are found to be near identical to those gained from the IRK procedure (Jacoby et al., in press).

That the inclusion/exclusion procedure did not exhaustively measure recollection might be used to question its validity as a means of measuring familiarity, because estimates of recollection were used in the computation of estimates of familiarity. In particular, what effect on the estimate of familiarity is produced when subjects recollect an item as old but are unable to recollect in which list the item was presented? One possibility is that such partial recollections are measured as familiarity and consequently inflate the estimate of familiarity. However, against that possibility, estimates from the inclusion/exclusion procedure were lower than those from the IRK procedure, whereas the opposite should be true if they were inflated by partial recollection. It is possible that partial recollection was not great enough to produce sizable effects, or that subjects simply ignored partial recollection when it occurred. Regardless, the convergence of results across procedures shows that any bias in estimates produced by partial recollection in the inclusion/exclusion procedure was not a serious one.

Convergence of results across the inclusion/exclusion and IRK procedures provides evidence of the validity of the assumptions underlying the procedures. However, the two procedures should not always be expected to produce the same results. This is true because the inclusion/exclusion procedure measures control whereas the IRK procedure measures awareness via subjective report. The possibility of dissociations between awareness and control suggest parallels with observations with frontal patients. One of the most interesting findings with those patients is their deficit in controlled responding despite relatively preserved awareness. For example, on the Wisconsin Card Sorting Task, frontal patients can often explicitly state the principles of the underlying task, thus showing awareness, yet fail to use these principles in their actual performance (Stuss & Benson, 1984). Comparisons between results from the IRK and inclusion/exclusion procedures may be useful in examining the relation between awareness and control in healthy as well as patient populations.

The Relation between Recollection and Familiarity

One cannot separate the contributions of recollection and familiarity without making an assumption, at least implicitly, about the relationship between the two types of processes (Jacoby et al., in press). Jones (1987) has discussed three fundamental relations: exclusivity, redundancy, and independence. Here, we focus on the choice between exclusivity and independence, and then briefly discuss the possibility of a redundancy relation between recollection and familiarity (for further discussion of the choice between redundancy and independence assumptions see Jacoby et al., 1993; Jacoby, Toth, Yonelinas, & Debner, 1994; Joordens & Merikle, 1993).

Independence vs exclusivity. When describing subjective experience, exclusivity seems an obvious choice for the relation between recollection and familiarity. However, by this assumption, recollection and familiarity can never co-occur, and this seems counter to subjective experience. To account for the co-occurrence of recollection and familiarity one could assume that the two processes act fully independently of one another. However, a possible complaint is that by this assumption recollection should some times occur in the absence of familiarity. Although, based on the authors introspections, recollection in the absence of familiarity does occur, others have argued this point. Without getting into extended debates about phenomenology, how can one choose between assumptions regarding the relation between the two bases for recognition? One important criterion is that results produced by a model must be reasonable in terms of extant theories. If this criterion is used with regard to effects of manipulating size congruency on the two bases for recognition, the independence assumption clearly wins. Results from the exclusivity assumption defy extant theories by leading to claims that familiarity increases as an item's size changes between study and test, that old items are more familiar than new item's only when the item changes size, and that new items become more familiar than old items when response criterion is relaxed. The independence assumption leads to the more reasonable conclusion that both recollection and familiarity increase with increased similarity between studied and tested versions of an item, and old items are more familiar than new items across the entire range of response confidence.

Another criterion used to gain support for an independence model, which we discussed earlier, is the ability to find process dissociations. If recollection and familiarity are independent, it should be possible to find manipulations that influence recollection but have no effect on familiarity, and vice versa. In support of the independence assumption, manipulations identified with automaticity, such as aging, amnesia, dividing attention, speeding responding, and increasing memory load have been found to produce process dissociations when that assumption is adopted.[3] In contrast to ma-

[3] Gardiner and Parkin (1990) report the same pattern of results for dividing attention during study using the remember/know procedure. However, use of IRK to compute estimates shows that in their experiment dividing attention reduced both recollection and famil-

nipulations associated with automaticity, shifts in response criterion are found to influence familiarity while leaving recollection in place (Yonelinas, 1994).

Those using the remember/know procedure have also sought these types of dissociations but it is not clear why they have done so. A finding, for example, that a manipulation has an effect on estimated recollection but no effect on estimated familiarity does not provide any support for the validity of an exclusivity assumption. Rather, by that assumption, one should usually expect to find an inverse relation between recollection and familiarity. Manipulations that increase recollection should decrease familiarity if the two processes are mutually exclusive.

A final point that weighs in favor of the independence assumption and against the exclusivity assumption is that it is only the independence assumption that leads to a consistent pattern of conclusions. With respect to the effects of size congruency, the independence assumption led to a consistent pattern of results across experiments, procedures, and changes in response confidence. The exclusivity assumption, on the other hand, led to a range of different conclusions that depended on the experiment and the subject's response confidence.

Similar inconsistencies can be seen across other remember/know experiments. For example, as discussed earlier, Gardiner (1988) found that deeper levels of processing increased the probability of a remember response without influencing the probability of a know response. However, Rajaram (1993) found that deeper levels of processing led to an increase in remember responses accompanied by a significant decrease in know responses.

The inconsistencies found when using the R/K procedure are precisely what would be expected if one were incorrectly assuming exclusivity when the two processes were in fact independent. By the independence model, the proportion of know responses will decrease as recollection increases, thus large effects on recollection will tend to produce large artifactual effects in the opposite direction on know responses. Know responses changed in the Rajaram study because the magnitude of the levels of processing effect on recollection was greater in that study than in the Gardiner study. Manipulating levels of processing led to a difference of .34 in recollection in the Rajaram study versus a .20 difference shown in the Gardiner study.

Is there an effect of levels of processing on familiarity? Using the IRK procedure with Gardiner's (1988) and Rajaram's (1993) data shows that both recollection and familiarity increased with deeper levels of processing. Such results are in agreement with those found in recognition memory using the process dissociation procedure (Jacoby & Kelly, 1991; Toth, in preparation). As well, they converge with results of recognition studies with amnesic patients. These patients are found to exhibit a profound deficit in recollection, but to show normal levels of familiarity (Verfaellie & Treadwell, 1993). Most important is that amnesics recognition performance is greatly improved with deeper levels of processing—in some cases the magnitude of the effect is similar to that found in normals (see, Mayes, Meudell, & Neary, 1980). Thus if amnesics are relying primarily on familiarity to make recognition judgments then familiarity shows a sizable benefit from deeper levels of processing.

The results of several other studies which made use of the remember/know procedure must be reconsidered if one assumes an independence, rather than an exclusivity relation between recollection and familiarity. For example, using the R/K procedure, Parkin and Walker (1992) found that older adults showed poorer recollection than

iarity. Why dividing attention reduced familiarity in their experiment is not clear; however, one factor that we are currently examining is the type of divided attention task used.

younger adults, but that their use of know responses increased. Although it may be comforting to think that memory deficits in recollection are offset by memory improvements in familiarity, this pattern of results would seem to be a product of the R/K procedure, just as was the size congruency effect. That is, the increase in know responses in the elderly may not reflect an increase in familiarity, but may simply reflect the decrease in recollection. Using the IRK procedure on that data shows this to be the case. In further support of this possibility, Jennings and Jacoby (1993) used the process dissociation procedure and found that although recollection decreased with age, familiarity remained unchanged.

Although a number of the conclusions drawn using the remember/know procedure must be reconsidered in light of the independence assumption we would like to emphasize that it is only the treatment of the know responses which is problematic. The estimates of recollection are the same for both the independence and exclusivity assumptions and thus any conclusions drawn regarding recollection are not in question. Moreover, the data collected in those experiments can easily be analyzed in terms of the independence assumption by calculating familiarity from the proportion of remember and know responses ($F = K/(1 - R)$).

Independence vs redundancy. Another possible relation between recollection and familiarity is that of redundancy. It is often a redundancy model that is implicitly adopted in investigations of memory for source. In a typical source monitoring experiment subjects study items from two different sources. They are then given a recognition test for which they must first distinguish old items from new distractor items, and then are asked to judge the source of recognized items. A natural way to think of performance in this task is to assume that recognition judgments measure one type of memory process (familiarity) and source judgments measure another type of process (recollection). Presumably subjects must recognize an item before they can recollect its source, thus items whose source can be recollected form a subset of those that can be recognized. Such a redundancy model holds that recollection is always accompanied by familiarity—an assumption opposite to that of an exclusivity model.

With respect to the effects of size congruency, the redundancy model leads to the same conclusions as does the independence model. By the redundancy assumption, familiarity is measured either by the overall hit rate in the remember/know experiments or by the probability of a hit in the inclusion condition in the process dissociation experiment. In either case, familiarity is shown to increase with size congruency (see Tables 1 and 2). Recollection, on the other hand, would be measured either as the proportion of "remember" responses or as the difference between inclusion and exclusion (recollection). Thus by redundancy and independence, both recollection and familiarity are found to increase with size congruency.

Although the two assumptions lead to the same conclusions with respect to the effects of size congruency, the ROC data in Experiment 3 present problems for current redundancy models. Batchelder and Riefer (1990) proposed several multinomial models of source monitoring that reflect a redundancy relationship. However, Kinchla (1994) showed that ROCs generated by these multinomial models were not in agreement with a large body of data on recognition memory. The difficulty is that the multinomial models are high-threshold models and so must predict linear ROCs, rather than the curvilinear ROCs such as those found in Experiment 3. An even more general problem for redundancy models is their inability to account for our finding that the skew in the ROCs arose because of the contribution of recollection. According to a redundancy model, recollection could not have such an effect because recollection would not increase the number of items called "old" beyond the number of items recognized on the basis of familiarity.

We are currently examining the possibility of modeling performance on standard source monitoring tasks with the independence model discussed in the current paper. By such a model initial recognition judgments are based on recollection and familiarity, but source judgments reflect recollection alone. If familiarity reflects a signal detection process that is independent of an all-or-none recollection process, then one would expect to see the type of curvilinear ROCs that are so problematic for current source monitoring models.

Much more difficult than rejecting the redundancy and exclusivity models is rejecting more complex or "hybrid" dual process models. For example, it is possible that recollection and familiarity are positively correlated but not perfectly so. That is, the truth may lie somewhere between an independence and a redundancy model. If the two processes can be shown to be correlated, this could be modeled by introducing an additional "correlation" parameter to the independence model. However, in light of the independence model's success in accounting for the current data, complicating the model would seem to be premature.

Familiarity and Performance on Indirect Tests

In support of the exclusivity assumption, Gardiner and colleagues have drawn on the similarities between recollection and familiarity on the one hand and direct and indirect tests on the other. Although there are some variables that have parallel effects on familiarity and indirect tests as well as variables that have similar effects on recollection and direct tests, at least as common are variables that lead to divergent results. For example, depth of processing has little or no effect on indirect test performance (see Roediger & McDermott, 1993, for a review). However, as previously discussed, work with the process dissociation procedure, the IRK procedure, as well as evidence from amnesics recognition performance, suggests that familiarity is sensitive to levels of processing. Similarly, the current set of experiments show that familiarity increased with size congruency, which is in contrast to studies of indirect tests where size congruency has not been found to lead to increases in performance (e.g., Cooper, Schacter, Ballesteros, & Moore, 1992; but see Jolicoeur & Humphrey, in press). Finally, modality has a sizable effect on indirect tests (see Roediger & McDermott, 1993, for a review), but has little or no effect on either recollection or familiarity (e.g., Rajaram, 1993).

We have only begun to map out the relationship between familiarity in recognition and performance on indirect tests. If it is true that similar processes underlie performance on these different memory tasks, then it is clear that these processes are not always influenced identically by some experimental variables. However, given the different retrieval cues and processing demands of the two types of test, it should not be surprising that these differences arise.

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