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Familiarity is related to conceptual implicit memory: An examination of individual differences

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Abstract

Explicit memory is thought to be distinct from implicit memory. However growing evidence indicates that explicit familiarity-based recognition memory judgments rely on the same process that supports conceptual implicit memory. We tested this hypothesis by examining individual differences using a paradigm wherein we measured both familiarity and conceptual implicit memory within the same participants. In Experiments 1a–b, we examined recognition memory confidence ROCs and remember/know responses, respectively, to estimate recollection and familiarity, and used a free association task to measure conceptual implicit memory. Results demonstrated that, across subjects, familiarity, but not recollection, was significantly correlated with conceptual priming. In contrast, in Experiment 2, utilizing a similar paradigm, a comparison of recognition memory ROCs and explicit associative cued recall performance indicated that cued recall was related to both recollection and familiarity. These results are consistent with models assuming that familiarity-based recognition and conceptual implicit memory rely on similar underlying processes.

Keywords

familiarity; recollection; implicit memory; conceptual priming; associative cued recall

It has long been thought that declarative, or explicit, memory is supported by processes reliant on the medial temporal lobes whereas nondeclarative, or implicit, memory is supported by neocortical regions (e.g., Gabrieli, 1998; Schacter, Chiu, & Ochsner, 1993; Squire, 2004). An alternative possibility, however, is that familiarity-based recognition and implicit memory rely on a common underlying process (e.g., Jacoby, 1991; Mandler, 1980; Wagner & Gabrieli, 1998; Yonelinas, 2002). For example, it has been suggested that the same process that leads an item to seem familiar on an explicit recognition memory test may also lead an item to come to mind more readily in a conceptual implicit memory test, such as an implicit exemplar generation task (Wagner & Gabrieli, 1998; Wang, Lazzara, Ranganath, Knight, & Yonelinas, 2010; Yonelinas, 2002; but see Donaldson, Petersen, & Buckner, 2001).

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Consistent with the hypothesis that conceptual implicit memory and familiarity are supported by the same underlying process, both forms of memory are sensitive to behavioral manipulations of attention, study duration, and depth of encoding (e.g., Challis & Sidhu, 1993; Hamann, 1990; Mulligan & Stone, 1999; Light, Prull, & Kennison, 2000; Srinivas & Roediger, 1990; for a review, see Yonelinas, 2002). In contrast, perceptual implicit memory as measured on tasks such as word fragment completion are generally unaffected by these manipulations suggesting that these forms of implicit memory are distinct (Gabrieli, 1998; Schacter, Chiu, & Ochsner, 1993). Moreover, patient and neuroimaging studies have demonstrated that the perirhinal cortex, a medial temporal lobe region adjacent to the hippocampus, is critical for both familiarity (Yonelinas et al., 2002; for reviews see Diana, Yonelinas, & Ranganath, 2007; Eichenbaum, Yonelinas, & Ranganath., 2007; Yonelinas, Aly, Wang, & Koen, 2010) and conceptual implicit memory (e.g., Blaxton, 1992; O'Kane, Insler, & Wagner, 2005; Voss, Hauner, & Paller, 2009; Wang et al., 2010; but see Levy, Stark, & Squire, 2004).

In the current study, we adopted a novel approach to test the hypothesis that conceptual implicit memory and familiarity rely on the same underlying process. Rather than examining how these types of memory respond to different experimental variables, or looking to determine the brain regions involved in these processes, we sought to investigate whether participants with greater familiarity would exhibit more conceptual implicit memory than participants with less familiarity. In the experiments reported below, participants incidentally encoded a list of words by judging whether each word was abstract or concrete. Afterwards, they were given a recognition memory test containing studied words intermixed with new words and asked to make either recognition confidence or remember/know judgments which were used to derive estimates of recollection and familiarity (see Yonelinas, 1994, 1999, 2001). In the last phase, participants completed an implicit free association task in which they were presented with non-studied words and asked to produce the first related word that came to mind. These words were selected to be associated with specific target words, some of which had been studied and some of which were not. Priming was measured as the proportion of studied target words generated relative to unstudied target, or baseline, words.

If the same process supports both conceptual priming and familiarity, then we expect these forms of memory to be positively correlated across participants. In contrast, we do not expect to see a strong relationship between implicit memory and recognition responses that were based on recollection, because recollection is generally associated with processes supported by the hippocampus rather than the perirhinal cortex (for reviews, see Diana et al., 2007; Eichenbaum et al., 2007; Yonelinas et al., 2010). Experiment 1a assessed recollection and familiarity using an ROC confidence rating method, whereas Experiment 1b tested the generalizability of these results using a remember/know method. Experiment 2 replaced the implicit test with a comparable explicit cued recall test to determine how recollection and familiarity were related to explicit recall.

Experiment 1a Method

Participants & Materials

A total of 53 undergraduates participants (M age = 19.83, *SD* = 2.35; M education = 13.53, *SD* = 1.49; 37 females) were recruited from the psychology participant pool at the University of California, Davis in exchange for course credit. Five participants were excluded from the data analysis: one due to software malfunction, and four because of chance performance in the recognition memory test.

Materials consisted of 320 cue-target word pairs with a mean forward association strength of .38 (*SD* = .11) (i.e., for a given cue, the target has a 38% chance of being produced). The word pairs were compiled from the Nelson, McEvoy, & Schreiber (1998) database and divided into four lists of 80 pairs each for counterbalancing purposes. Each list served in each of the four conditions described below. All stimuli were presented and keyboard responses recorded on a Dell PC. Verbal responses from the free association task were digitally recorded and transcribed.

Design & Procedure

First, participants incidentally encoded 160 target words from the word pairs by judging if the words were abstract (e.g., EFFECT) or concrete (e.g., LEMON). Each word was presented for 1,200 ms, with a 200 ms fixation cross between stimuli. In the second phase, participants completed a surprise recognition memory test for 80 of the studied target words (e.g., LEMON) and 80 unstudied target words (e.g., CLAY). For each word, participants responded on a 6-point confidence scale, from *1-sure new* to *6-sure old*. Participants were allotted 1,500 ms for each recognition judgment, with a 500 ms fixation cross between words.

In the final phase, participants were given a free association task wherein they were presented with all 320 of the unstudied cue words. For each cue, participants were instructed to respond verbally with the first strongly-associated word that came to mind. Each cue was presented on the screen for 3,000 ms, with a 1,500 ms fixation cross between stimuli. One set of 80 cue words was paired with target words that were in *both* the encoding and recognition phases (EncRec; i.e., associate of LIME? Target: LEMON). Another set of 80 cues was paired with targets that had appeared *only* during the encoding phase (Enc; i.e., associate of CAUSE? Target: EFFECT). A third set of 80 cues was paired with targets that appeared *only* in the recognition phase (Rec; i.e., associate of POTTERY? Target: CLAY). The remaining 80 cues were paired with the unstudied targets that did not appear in the experiment (e.g., associate of FORTUNE? Target: FAME). These unstudied pairs served as a baseline, and the difference between the baseline generation rate and the generation rate for the other three conditions served as measures of conceptual implicit memory (EncRecP, EncP, RecP). Following the free association task, participants were administered an awareness questionnaire to assess whether they utilized explicit strategies during the task (adapted from Bowers & Schacter, 1990).

Experiment 1a Results

Recognition confidence ratings were used to plot receiver-operating characteristics (ROCs) that were fitted by minimizing the sum of squared errors in the dual-process signal detection (DPSD) model to derive estimates of recollection and familiarity (see Yonelinas, 1994, 1999; 2001; the average ROC is presented in Figure 1a). The left-most point in the figure reflects the proportion of old items receiving a 6 response (i.e., hits) against the proportion of new items receiving a 6 response (i.e., false alarms). Each consecutive point reflects a more lax scoring criterion (i.e., in the second point, 6s and 5s are treated as hits and false alarms). The ROC for each participant was fit with the DPSD model to estimate the contribution of recollection, which approximates the *y*-intercept, and familiarity, which is related to the curvilinearity of the function. The individual ROCs were consistent with those seen in prior studies, and there was little evidence of floor, ceiling, truncation or limited-range effects, that can compromise the ROC analysis (Yonelinas & Parks, 2007). The average probability estimate of recollection was .37 (SD = .28) and the average familiarity d' measure was .95 (SD = .65).

Conceptual implicit memory was measured as the proportion of baseline target words generated relative to the proportion of studied target words generated (Table 1). Studied items were broken down into those that had been presented in both the encoding and recognition phases (EncRec), those presented only in the encoding phase (Enc), and those presented only in the recognition test (as lure items, Rec).In order to investigate the relationship between recognition memory and conceptual implicit memory, estimates of recollection and familiarity were correlated with each of the priming measures. Because there were no significant differences in the correlations between the different priming and explicit memory measures, we only describe the correlations with average priming.

We first examined whether overall recognition discriminability (as measured using d′ at the midpoint confidence level; M = 1.55, SD = .53) was positively related to conceptual priming, and found that subjects with higher recognition also had higher priming ($r(46) = .44$, $p < .005$; Figure 2a). More importantly, consistent with our prediction, recollection did not significantly correlate with priming ($r(46) = -.15$, $p = .31$; Figure 2b), whereas familiarity was strongly correlated with priming ($r(46) = .47$, $p < .001$; Figure 2c). Additionally, these two correlations were significantly different, indicating that familiarity has a stronger relationship with priming than recollection ($t(45) = 2.58$, $p < .05$).

To determine whether the correlation between familiarity and priming was due to the use of explicit memory retrieval during the implicit test, we conducted an additional analysis wherein we excluded participants that reported using explicit retrieval strategies during the free association task (i.e., participants who reported “actively [trying] to remember words” from the study phases). The results indicated that even when explicitly contaminated participants were removed for the analysis, familiarity was still significantly correlated with conceptual priming ($r(29) = .40$, $p < .05$).

A subsequent analysis indicated that recollection and familiarity estimates were negatively correlated across subjects ($r(46) = -.58$, $p < .001$). In general, we have found that these two parameters are not correlated, but that they can become negatively correlated when the number of trials making up an ROC is low (e.g., because there were several necessary conditions in the current study, we included only 80 old trials in each subject-condition). We were therefore concerned that the lack of a correlation between implicit memory and recollection might have been related to a measurement artifact inherent in the correlation analysis that may have acted to mask a true correlation. To address this we first analyzed partial correlations to reveal potential mediation or suppression effects. Consistent with the zero-order correlations, recollection was not significantly correlated with priming when controlling for familiarity ($r(45) = .18$, $p = .23$) whereas familiarity was significantly correlated with priming when controlling for recollection ($r(45) = .48$, $p < .001$). Second, to assess the possibility that the null relationship between recollection and conceptual priming was due to the fact that recollection and familiarity were collinear, we assessed measures of multicollinearity in a mean-centered regression with recollection and familiarity predicting conceptual implicit memory. Consistent with the correlations, familiarity significantly predicted priming ($\beta = .59$, $t(45) = 3.71$, $p < .001$), while recollection did not ($\beta = .20$, $t(45) = 1.22$, $p = .23$), and, measures of multicollinearity were within acceptable ranges (VIF[1] = 1.51, κ[2] = 6.44). Thus, there was little evidence that the correlations we observed were a product of measurement artifacts.

The conclusion that priming is related to familiarity but not recollection relies on the ROC analysis. Although there is a large body of evidence supporting the validity of that approach (e.g., see Yonelinas, et al., 2010) the method relies on numerous assumptions that can be questioned (e.g., see Wixted). Thus, to provide a further test of the results, Experiment 2 addressed the same question but utilized an alternative method of estimating recollection and familiarity; the remember/know procedure (Gardiner, 1988; Tulving, 1985). Although the assumptions of any one procedure may be questioned, if multiple measurement methods converge on the same conclusions one can be more confident in the conclusions. .

Experiment 1b Methods

Participants & Materials

Twenty-nine undergraduate participants (mean age = 19.63, *SD* = 1.17; mean education = 14.04, *SD* = 1.12; 18 female) were recruited from the University of Davis, California, psychology participant pool. Five participants were excluded from the data analyses: three due to experimenter error, one for chance recognition performance, and one for not completing the free association task. The materials were identical to those of Experiment 1.

Design & Procedure

The procedure was identical to that of Experiment 1a, except that the recognition confidence judgments were replaced with remember/know judgments. Rather than instructing participants to respond on a 6-point confidence scale, they were required to respond with a

[1]The variance inflation factor (VIF) is a measure of how much variance is increased because of collinearity. The square root of the VIF indicates how much the standard error has been inflated for each independent variable.

[2]The condition number (κ) is the largest condition index, which is a measure of the collinearity of combinations of independent variables in the model.

remember, *familiar*, or *new* judgment for each presented word. Participants were instructed to respond *remember* when they could, if asked, tell the experimenter the specific details(s) that they recollected when they saw the word (e.g., what it looked like on the screen, thoughts and feelings at the time). Participants were instructed to respond *familiar* if they believed that the word was previously studied, but were unable to recollect any specific details about the study event. Lastly, participants were instructed to respond *new* if they thought that the word was not previously studied. Participants explained their responses to the experimenter during the practice phase to ensure that they understood the instructions. Note that recent studies have indicated that these later instructions are necessary to ensure that subjects do not confuse remember/know instructions with confidence instructions (Rotello et al., 1995; Yonelinas 2001, Yonelains & Parks, 2007). The only other change relative to the previous experiment is that participants were given an extra second for each recognition judgment (i.e., 2,500 ms), with a 500 ms fixation cross between words.

Experiment 1b Results

Recollection was estimated as the probability of a remember response to an old item minus the probability of a remember response to a new item. Familiarity was estimated separately for old item and new items as the probability of a 'familiar' response given the item was not remembered (i.e. 'familiar'/(1-'remember')). Familiarity discriminability was measured as d′ given the familiarity estimates for old and new items (see Yonelinas & Jacoby, 1995). Again, similar to the previous experiment, we compared mean recollection (*M* = .47; *SD* = .15) and familiarity (*M* = .98, *SD* = .45) to average measure of free association priming (*M* = .08, *SD* = .05), given that the correlations across the different priming conditions did not differ.

First, overall recognition discriminability (as measured by *d′*; *M* = 1.52, *SD* = .49) was positively correlated with conceptual priming (r(22) = .58, p < .005). Moreover, consistent with Experiment 1a, priming was positively correlated with familiarity (r(22) = .55, p < .01), but not recollection (r(22) = .31, p =.14). These two correlations, however, were not significantly different (t(21) = 1.05, p = .15).

Unlike Experiment 1a, where recollection and familiarity were negatively correlated, in the current experiment they were unrelated, (r(22) = .22, p = .30), thus there was no concern that the observed correlation between familiarity and priming was an artifact produced by the negative familiarity-recollection correlation. To be thorough, however, we conducted partial correlation and regression analyses to examine any potential mediation, suppression, or multicollinearity effects. Consistent with the zero-order correlations, conceptual priming was not correlated with recollection when controlling for familiarity (r(21) = .23, p = .30), whereas it was significantly correlated with familiarity when controlling for recollection (r(21) = .55, p < .01). Additionally, the mean-centered regression (R^2 = .37, R^2_{adj} = .31, F(2,21) = 6.07, p < .01) indicated that familiarity significantly predicted priming (β = .54, t(21) = 3.00, *p* < .01), while recollection did not (β = .19, t(21) = 1.06, *p* = .30), and, that measures of multicollinearity were within acceptable ranges (VIF = 1.05, κ = 7.85).

Experiment 1 Discussion

The results of Experiments 1a-b indicated that conceptual implicit memory was positively correlated with familiarity, but not recollection. This pattern was observed in the correlation and regression analyses, and was observed when recollection and familiarity were measured using the confidence-base ROC method as well as with the remember/know method.

One concern with Experiment 1a was that there was a negative correlation between recollection and familiarity estimates across subjects. Although subsequent analyses suggested that this did not greatly impact the main findings, Experiment 1b showed that the same pattern of results was observed under conditions in which there was no negative correlation between recollection and familiarity. Thus, the results indicate that the relationship between familiarity and conceptual implicit memory is quite general and is not likely due to artifacts related to collinearity or the particular method used to estimate recollection and familiarity.

None the less, we had one further concern about the initial results which was that we were concerned that the lack of a correlation between recollection and implicit memory might arise because the familiarity parameter in the ROC and remember/know experiments may generally be a better measure of memory and thus, it may always be more strongly related to other measures of memory than will recollection. To test this possibility, we conducted Experiment 2 wherein the implicit free association task was replaced with an explicit associative cued recall task. Under these conditions, we expected to see a correlation between the recollection parameter and the recall measure, on the basis that explicit cued recall should rely more on recollection than an implicit task (Mandler, 1980). In contrast, if the null relationship between recollection and priming seen in Experiments 1a-b reflected the fact that our recollection estimate was less related to other measures of memory relative to familiarity, then recollection should not be correlated with explicit associative cued recall performance.

A secondary question that the experiment allowed us to address was how familiarity was related to explicit cued recall. One prior study that examined this issue found that recollection, but not familiarity, correlated with free recall performance (Quamme, Yonelinas, Widaman, Kroll, & Sauve, 2004). However, there is evidence that associative cued recall performance is related to ‘feelings of knowing’ (Gruneberg & Monks, 1974), that cued recall can be influenced by both controlled recollective processes and automatic familiarity processes (McCabe, Roediger, & Karpicke, 2011). Moreover, both recollection and familiarity are correlated with associative recognition, a form of recognition thought to depend more on recollection (Starns & Ratcliff, 2008). To the extent that the processing of a word leads to activation of its associates, one might expect that this could increase associative cued recall performance. Thus, one might expect familiarity to also be related to associative cued recall, though to a lesser extent than recollection.

Experiment 2 Methods

Participants & Materials

Thirty-eight undergraduate participants (mean age = 19.16, *SD* = 1.87; mean education = 12.97, *SD* = 1.48; 26 female) were recruited from the University of California, Davis psychology participant pool. Two participants were excluded from the data analyses: one for not being a native English speaker, and the other for chance recognition performance. The materials were identical to those of Experiments 1a–b.

Design & Procedure

The procedure for Experiment 2 was identical to that of Experiment 1a, except that the free association instructions were replaced with explicit associative cued recall instructions. Rather than instructing participants to respond with the first related word that came to mind for a given cue, they were told to think back to the previous encoding and recognition phases and to respond only with a previously studied target word that was associated with the given cue.

Experiment 2 Results

The ROCs were examined as in Experiment 1, and the average ROC is presented in Figure 1b. Mean estimates of recollection (*M* = .40, *SD* = .24) and familiarity (*M* = .85, *SD* = .50) were derived from the DPSD model for each individual participant. Cued recall was measured as the proportion of unstudied target words recalled (i.e., false recall) subtracted from the proportion of studied targets generated from each condition (EncRec, Enc, and Rec). This yielded three measures of cued recall (EncRecR, EncR, RecR) as well as average cued recall (Table 2). As in Experiment 1, the correlations between recognition and the three measures of recall were similar so we focus here on the correlations with average recall.

Overall recognition discriminability (as measured by d′; *M* = 1.47, *SD* = .51) was significantly correlated with cued recall ($r(34) = .62$, $p < .001$; Figure 3a). In contrast to the results of Experiment 1, cued recall was significantly correlated with recollection ($r(34) = .45$, $p < .01$; Figure 3b), but not familiarity ($r(34) = .23$, $p = .18$; Figure 3c). These two correlations, however, were not significantly different ($t(33) = .85$).

As in Experiment 1a, recollection and familiarity were negatively correlated ($r(34) = -.40$, $p < .05$). An examination of partial correlations indicated cued recall was correlated with both recollection when controlling for familiarity ($r(33) = .62$, $p < .001$) and familiarity when controlling for recollection ($r(33) = .52$, $p < .005$). Moreover, a mean-centered regression ($R^2 = .41$, $R^2_{adj} = .37$, $F(2,33) = 11.53$, $p < .001$) indicated that, consistent with the partial correlations, cued recall performance was predicted by both recollection ($\beta = .65$, $t(33) = 4.49$), $p < .001$) and familiarity ($\beta = .50$, $t(33) = 3.43$), $p < .005$), and measures of multicollinearity were within acceptable ranges (VIF = 1.19, $\kappa = 6.57$).

Experiment 2 Discussion

The results from both the correlation and regression analyses demonstrate that recollection was closely related to cued recall. This finding indicates that the ROC-derived measure of recollection is a sensitive measure that is highly correlated with certain forms of memory. This reassures us that the correlation between conceptual priming and familiarity, but not recollection, in Experiments 1a-b could not be explained by the notion that only the familiarity parameter is a sensitive measure of memory. Moreover, given that recollection and familiarity were negatively correlated in Experiments 1a and 2, the finding of a significant relationship between recollection and cued recall is inconsistent with the notion that the null relationship in Experiment 1 between recollection and conceptual priming is an artifact that was produced by collinearity between the recognition parameters. Finally, while the results of Experiment 2 suggest that recollection was strongly related to explicit cued recall, the relationship between cued recall and familiarity was less clear. The zero-order correlation did not show a significant correlation between familiarity and associative cued recall, but the subsequent partial correlation and regression analyses suggested that familiarity was significantly related to recall. Potential accounts of this latter finding are discussed below.

General Discussion

The current study assessed the relationship between estimates of recollection and familiarity, derived from ROC and remember/know analyses, against measures of conceptual implicit memory. Results from Experiment 1a demonstrated that conceptual priming correlated with ROC-based estimates of familiarity, but not recollection. The correlations were observed even when we removed subjects claiming to have used explicit retrieval strategies, and regardless of whether words were encoded in an incidental judgment task (i.e., abstract/ concrete judgment) and/or during a recognition task. Moreover, additional analysis suggested that the results could not be explained by mediation, suppression or collinearity effects. Finally, Experiment 1b replicated this finding using estimates of recollection and familiarity derived from the remember/know procedure, showing that the effects generalized across two different measurement methods.

These results support the hypothesis that familiarity and conceptual implicit memory rely on a common underlying process (Wagner & Gabrieli, 1998; Wang et al. 2010, Yonelinas, 2002). These conclusions converge with prior studies indicating that tconceptual fluency influences familiarity judgments (Rajaram & Geraci, 2000; Verfaellie & Cermak, 1999) and that conceptual processing improves subsequent familiarity-based recognition (Ngo, Brown, Sargent, & Dopkins, 2010). The results are also consistent with neuroimaging data and patient lesion data suggestingthat the perirhinal cortex is involved in both familiarity (Diana et al., 2007; Eichenbaum et al., 2007; Yonelinas et al., 2010) and conceptual priming (O'Kane et al., 2005; Voss et al., 2009; Wang et al., 2010). In light of this convergent evidence, it is likely that the cognitive process that supports familiarity judgments also supports conceptual implicit memory.

It is important to point out that the current results do not imply that there are no differences between familiarity and conceptual implicit memory. Familiarity accounted for 22% of the variance in conceptual implicit memory in Experiment 1a, while an examination of the zero-order correlations between our three measures of conceptual priming was between 42–53%. This put an effective ceiling on the amount of variance that the familiarity measure could account for (i.e., approximately half of the variability in priming). This is a substantial portion, but it leaves open the possibility that other processes may also contribute to conceptual implicit memory. For example, the decision processes involved in explicit recognition are quite different from those involved in conceptual implicit tasks, and so it should not be surprising if the tasks engage different processes. The claim that familiarity and conceptual implicit memory are influenced by task-specific processes is supported by imaging studies suggesting important differences in the patterns of activity associated with these two types of tasks (e.g., Donaldson et al., 2001; Voss, Reber, Mesulam, Parrish, & Paller, 2008).

In Experiment 2, recollection significantly predicted associative cued recall. This result demonstrates that the ROC-based estimate of recollection is not inherently less powerful or reliable than the estimate of familiarity. Rather, this is consistent with the idea that recollection and recall rely on a common underlying process (Quamme et al., 2004, Yonelinas, 2002). There also appeared to be a relationship between familiarity and associative cued recall. The zero-order correlation between familiarity and cued recall was positive, but it failed to reach statistical significance, but the partial correlation and regression analyses indicated that familiarity and cued recall were significantly related. Taken together the results suggest that familiarity also contributes to associative cued recall. Thus, the results are consistent with prior results showing cued recall tasks can be supported at least in part by familiarity (Gruneberg & Monks, 1974; Starns & Ratcliff, 2008; McCabe et al., 2011).

One potential concern with the results from Experiment 1a was that the negative relationship between recollection and familiarity estimates may have biased the correlation analysis (i.e., the null relationship between recollection and conceptual priming may have masked a true positive correlation). The negative correlation between recollection and familiarity is not inherent in the ROC method, but can occur when the number of trials in each subject-condition is low, as in the current design. However, subsequent analyses suggested that the dissociation was not due to suppression or collinearity. In addition, Experiment 1b replicated the findings of Experiment 1a with remember/know estimates of recollection and familiarity that were not correlated, thus further demonstrating that the positive correlation between conceptual priming and familiarity-based and the null correlation between conceptual priming and recollection is not due to colinearity. Additionally, if it is the case that the negative relationship between ROC-based estimates of recollection and familiarity had masked the true correlation between implicit memory and recollection in some way, then we would be less likely to find the predicted relationship between recollection and cued recall in Experiment 2. However, consistent with our a priori hypothesis, we found a significant relationship between recollection and recall in Experiment 2, which was consistent across the correlation and regression analyses.

To what extent are the current conclusions based on the specific manner in which the ROC and remember/know results were analyzed? At the broadest level, the current results are unambiguous in showing that there is a direct relationship between overall recognition memory and conceptual priming. This was shown to be the case in both the ROC and remember/know experiments where overall recognition was examined prior to examining the levels of confidence or reports of remembering and knowing. Thus, there is no question that the results are in good agreement with models that assume that a common process contributes to implicit and explicit memory.

The additional finding that conceptual implicit memory was related to familiarity but not recollection, does rely critically on the assumptions used to analyze the confidence and remember/know results. Although there is a growing literature validating those estimation procedures (e.g., Yonelinas et al., 2010; but see wixted, XX), and the convergence of results across the two different methods attests to the robustness of those conclusions, it is useful to examine the results in light of alternative approaches. For example, if one wished to adopt a single component signal detection model of memory one would end up with largely the same conclusions. That is, in experiment 1a, the correlation between d′ measured at the mid-point on the confidence scale was quite large (.47???), however, if d′ was measured for the high confidence responses then the correlation with priming drops to .29, which is significantly smaller than the correlation between the midpoint d′ and priming (.44???; $t(42)= 1.85$; $p= 0.04$, one-tailed). Similarly, in experiment 1b, the correlation between overall recognition and priming was also quite large (.55), but if d′ was measured for the remember responses the correlation with priming drops to .??, which is significantly smaller than the correlation with overall recognition (t….). In contrast, the relationship between recognition and cued recall (i.e. experiment 2) remained constant when one examines overall recognition (.64) with high confidence recognition (.62). Thus, even if one adopts a simple signal detection account of the results high confidence recognition responses (i.e, recollection) are not correlated with conceptual implicit memory whereas lower confidence responses (i.e., familiarity) are. Note that the results can also be examined using a signal detection model with two functionally independent memory components (i.e., the unequal variance signal detection model) and the results of that approach also converge in suggesting that the familiarity strength parameter (i.e., d′) is correlated with conceptual priming (for details of those calculations see Appendix).

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Appendix

To test the generalizability of the current conclusions, we also assessed the ROC-based recognition results using an alternative measurement model: the unequal variance signal detection (UVSD) model (for a review, see Yonelinas & Parks, 2007). The model is sometimes referred to as a single process strength model, but it does require two functionally independent memory parameters in order to account for recognition ROC results of the type seen in the current study (Ratcliff et al., 1992; Yonelinas & Parks, 2007). Fitting this model to recognition ROCs produces estimates of d'(strength) and old/new variance ratio (variance). The analysis showed that, in Experiment 1a, conceptual priming did not correlate significantly with variance ($r(46) = -.21$, $p = .15$) or d'($r(46) = .06$, $p = .69$). However, item variance and memory strength were positively correlated to one another ($r(46) = .71$ $p < .05$), so, we analyzed the partial correlations, which indicated that variance was negatively correlated with conceptual priming when controlling for d'($r(45) = -.35$, $p < .05$) whereas d' was positively correlated with priming when controlling for variance ($r(45) = .29$, $p < .05$). The mean-centered multiple regression ($R^2 = .13$, $R^2_{adj} = .09$, $F(2,45) = 3.24$, $p < .05$) also indicated that variance negatively predicted priming ($\beta = -.50$, $t(45) = -2.51$, $p < .05$) whereas d'positively predicted priming ($\beta = .41$, $t(45) = 2.06$, $p < .05$). Measures of collinearity were within acceptable ranges (VIF = 2.00, $\kappa = 7.46$). Thus, these results indicate that familiarity strength was positively related to conceptual implicit .

In Experiment 2, cued recall was found to be correlated with both variance ($r(34) = .43$, $p < .01$) and strength ($r(34) = .58$, $p < .001$). However, because variance and strength are also positively correlated in this experiment ($r(34) = .83$, $p < .05$), we again analyzed both the partial correlations and regression, which indicated that variance was not correlated with cued recall when controlling for d'($r(33) = -.12$, $p = .50$) whereas $d'$was significantly correlated with recall when controlling for variance (r(33) = .45), $p < .05$). The mean-centered multiple regression ($R^2 = .35$, $R^2_{adj} = .31$, F(2,33) = 8.76, $p < .001$) also suggested that strength significantly predicted recall (β = .73, t(33) = 2.86, $p < .01$), whereas variance did not (β = −.18, t(33) = −.69). Again, measures of collinearity were within acceptable ranges (V = 3.27, κ = 10.80). The pattern of results produced by the UVSD model is complex, but in general it appears that *d′*, a measure of memory strength, is positively related to both conceptual implicit memory and associative cued recall. To the extent that strength in this model (i.e., *d′*) is similar to familiarity, the results of the UVSD-based analysis converge with the finding that familiarity is correlated with conceptual priming and cued recall. However, the behavior of the variance parameter in the model was less clear. The partial correlations suggested that it was negatively related to conceptual priming, but not related to recall. Within the framework of the signal detection model it is not clear why this parameter would track implicit memory but not explicit memory. However, given that the parameter correlations and collinearity measures are numerically greater in the UVSD analysis relative to the DPSD analysis, these results should be interpreted with caution.

In summary, we assessed how the processes of recollection and familiarity were related to conceptual implicit memory and associative cued recall. Results demonstrated that conceptual priming is related to familiarity, but not recollection, whereas cued recall is related to both familiarity and recollection. These results support previous research that suggests that familiarity and conceptual priming rely on a similar underlying process (Yonelinas, 2002), and argue against models that postulate that explicit and implicit memory reflect fundamentally separate processes (e.g., Squire, 2004). In addition, the cued recall results are consistent with research demonstrating that both recollection and familiarity support associative recall (McCabe et al., 2011).