False memory for perceptually similar but conceptually distinct line drawings

Christoph Stahl¹, Laura Henze¹, Frederik Aust¹

¹ University of Cologne

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Author Note

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Correspondence concerning this article should be addressed to Christoph Stahl, Herbert-Lewin-Str. 2, D-50674 Cologne, Germany. E-mail: christoph.stahl@uni-koeln.de

Abstract

Whereas most false memory effects for pictorial material are thought to be based on semantic or conceptual similarity, some findings, based on novel visual material, have been attributed solely to perceptual similarity. However, alternative accounts of these perceptual effects in terms of associative and/or conceptual processes have been proposed. We report four experiments that address these points of criticism, using pairs of perceptually similar but conceptually distinct line drawings of objects (e.g., banana – crescent). Similar lures were judged old more often than unrelated items, and confidence for false alarms was greater for similar lures than for unrelated items. This perceptual false memory effect was not modulated by rotation of stimuli between study and test, was unaffected by retention interval (0 vs. 20 min), and was obtained regardless of response format (old/new and old/similar/new). These findings rule out the criticism of previous perceptual false memory effects and more conclusively demonstrate false memory on the basis of perceptual similarity.

Keywords: false memory, perceptual false memory

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We sometimes falsely believe that we have previously encountered persons, objects, or events—especially if they are similar to actually encountered stimuli. Research has found that people are more likely to falsely recognize novel stimuli as “old”—without having previously encountered them during the course of a study—if there is a similarity relation based on associative, thematic, or feature overlap between the novel *related lure* and previously encountered *target* stimuli (for an overview see Gallo, 2006). This *false memory* effect has been famously demonstrated for converging-associates word lists (Deese, 1959). For instance, after studying lists of words that were all associated with a single critical lure, these critical lures were falsely recognized as old at levels comparable to targets and with high confidence (Roediger & McDermott, 1995). Interitem associations, in this context, are typically operationalized as *backward associative strength* (BAS), that is the probability that the related lure is spontaneously generated as the first word that comes to mind in response to a list word. Although BAS is a strong predictor of false remembrance (e.g., Deese, 1959; Roediger, Watson, McDermott, & Gallo, 2001), false memories can be elicited in the absence of strong associations between target and lure. For example, studying word lists of category exemplars (e.g., *apple*, *pear*) increases false memory for unstudied exemplars (e.g., *banana*; Shiffrin, Huber, & Marinelli, 1995). These findings are typically explained by thematic or conceptual relations between target and lure, for instance, a shared semantic category: The presentation of several exemplars from a category activates the category representation; at test, this activation causes unstudied category exemplars to be falsely recognized as having been on the study list (e.g., Reyna & Brainerd, 1995). A second account holds that overlap of—conceptual or perceptual—features between studied items and related lures results in increased feelings of familiarity for those lures that are then used as the basis of recognition decisions (e.g., Arndt & Hirshman, 1998).

False memory is not restricted to verbal material; it has also been reported with non-verbal pictorial stimuli, such as pictures of objects and scenes (e.g., Koutstaal &

Schacter, 1997). In contrast to word material—where similarity is typically conceptual but not perceptual (e.g., *father* and *dad*)—there is both perceptual and conceptual similarity in pictorial material (i.e., photographs of waterfalls not only depict the same concept but also share many perceptual features). False memory for pictures (i.e., unstudied waterfall photographs) can therefore be attributed to both perceptual or conceptual similarity between target and lure. Several findings suggest that conceptual similarity is largely responsible for these findings, and it is unclear whether there is any independent contribution of perceptual similarity (Pidgeon & Morcom, 2014); it has even been argued that such a contribution is entirely absent (Weinstein & Shanks, 2008). In fact, perhaps because the majority of false memory research has employed material about which participants had pre-existing semantic knowledge, theoretical accounts of these effects have focused on semantic or conceptual similarity between studied items and related lures as the mediating construct. Much less is known about whether perceptual similarity alone is sufficient to cause false memory.

The best case for perceptual false memory is a false memory effect based on orthographic and phonological similarity (Brainerd, Reyna, & Kneer, 1995; Budson, Sullivan, Daffner, & Schacter, 2003; Ly, Murray, & Yassa, 2013; Schacter, Verfaellie, & Anes, 1997; Shiffrin et al., 1995): After studying a list of orthographically and phonologically similar words that are semantically and conceptually unrelated (e.g., *hate*, *mate*, *late*), participants showed false memory for nonstudied lures (e.g., *fate*). Because this effect is difficult to attribute to semantic or conceptual similarity, these findings support the notion that false memory may be solely driven by perceptual similarity, at least for certain materials. False-memory effects have also been reported for non-verbal pictorial material, but—as will be discussed next—the interpretation of these findings as perceptual in nature is still under debate. The present study aims at providing a compelling demonstration of perceptual false memory with non-verbal pictorial material.

Perceptual false memory for pictorial material

Several studies report findings of false memory for pictorial material that have been attributed solely to perceptual similarity. Similar to some research on verbal material (Zeelenberg, Boot, & Pecher, 2005), these studies attempted to eliminate the contribution of conceptual similarity by using novel material about which participants had no pre-existing semantic or conceptual knowledge. For instance, studying a series of similar random dot patterns induced false memory for unstudied patterns that were similar to the studied ones (Kolodny, 1994; Posner & Keele, 1970). Similarly, perceptual false recognition has been reported for exemplars of novel objects that were drawn from a category of similar objects: studying a series of similar pictures of novel objects increased false recognition of unstudied exemplars of these objects (Budson, Desikan, Daffner, & Schacter, 2001; Koutstaal, Schacter, Verfaellie, Brenner, & Jackson, 1999; Slotnick & Schacter, 2004). Stimuli were taken from categories defined by perceptual similarity. Categories were defined by a prototype dot pattern or figure, and sets of exemplars were created by applying different distortions to the prototype. Participants falsely recognized novel objects from studied categories more often than novel objects from non-studied categories. This false recognition of unstudied exemplars could be interpreted as due to “perceptual gist” (Koutstaal & Schacter, 1997; Koutstaal et al., 1999), that is, due to similarity between exemplars of perceptually defined categories. According to this line of argumentation, the false memory effect could not have been due to semantic or conceptual similarity because the objects and categories were unfamiliar and meaningless. In the words of the authors, the results demonstrate false memory in the absence of pre-existing semantic associations (Koutstaal et al., 1999), and therefore renders associative accounts of the false-recognition effect less likely (Gallo, 2006).

Alternative accounts in terms of non-perceptual processes

The absence of *pre-existing* conceptual knowledge does not exclude the possible contribution of conceptual information to the observed false-memory effects. Specifically,

participants may have acquired new conceptual knowledge when studying multiple exemplars from abstract categories during an experimental session. As argued by Pidgeon & Morcom (2014), when categories of (perceptually) similar items are learned (e.g., random dot patterns or abstract figures and objects), the acquired perceptual gist might be seen as a newly acquired conceptual representation. This can be seen by noting that, in the aforementioned experiments, the study phase was either explicitly a category learning task (Kolodny, 1994; Posner & Keele, 1970), or it closely resembled one (Koutstaal et al., 1999). In both cases, participants may have acquired new conceptual knowledge by studying novel unfamiliar stimuli and mentally clustering—possibly even verbally labeling—subsets of these stimuli based on their mutual similarity. By example of novel objects used by Koutstaal et al. (1999, Figure 1A), participants may have learned that there is a category consisting of orange-blue inverted parabola shapes. If participants indeed acquire conceptual knowledge during the study phase of a false-memory experiment, then the false memory effect may have been based on this abstracted conceptual similarity rather than on perceptual similarity (Pidgeon & Morcom, 2014). Indeed, the correspondence of the reported findings with those obtained with semantically related material underlines the plausibility of this alternative account of the findings. Moreover, under experimental conditions that render acquiring of new concepts difficult (i.e., when only 1-3 category exemplars are presented during study), there appears to be no false recognition in these paradigms (Koutstaal et al., 2003, 1999; Pidgeon & Morcom, 2014).

A related alternative explanation invokes—shared or idiosyncratic—semantic associations of novel objects with participants’ pre-existing knowledge (perhaps mediated by perceptual similarity): When studying a novel object, participants may retrieve semantic associations from memory, and the contents of these associations may be encoded as part of the study episode (this account is similar to the associative account of false memory of the DRM paradigm). These associations may be either retrieved spontaneously or actively searched for to serve as mnemonic cues. For example, an orange-blue inverted parabola shape

could resemble the letter *A*, while the color scheme and pattern could be associated with 80s Hawaiian shirts. Moreover, participants may generate verbal labels for the novel objects based on these associations as part of their encoding strategy (“Hawaiian A”, Koutstaal et al., 1999, Figure 1A). False memory may then be mediated by these (spontaneous or strategically generated) semantic associations rather than being due to perceptual similarity. Supporting this notion, participants were able to generate semantic labels for the set of abstract novel figures used in that line of research (Pidgeon & Morcom, 2014); moreover, these labels showed some consistency across participants, suggesting that the abstract figures were in fact (at least weakly) associated with pre-existing conceptual knowledge.

In sum, false memory has been reported for novel pictorial material about which there was no pre-existing conceptual knowledge, but it has been argued that these effects may nevertheless be due to conceptual or semantic representations: First, participants may have acquired new concepts during study, thereby attributing meaning to the perceptual similarity of the novel stimuli. Second, the effect may have been based on spontaneous or actively generated semantic associations with pre-existing knowledge. The interpretation of these false-memory effects as due to perceptual similarity is therefore questionable. The present research addresses these alternative accounts and demonstrates a clearly non-conceptual false memory effect for pairs of perceptually similar but *conceptually distinct* pictorial material.

Present studies

In analogy to phonologically similar yet conceptually distinct words, we used pairs of perceptually similar but conceptually distinct line drawings in which each element of a pair depicted a different object (Rouder, Ratcliff, & McKoon, 2000). Because the members of each pair are clearly distinct semantically and conceptually, a false memory effect (i.e., an increase in false “old” responses to the unstudied element of a pair after studying the other element) cannot be attributed to meaning-based similarity. To the contrary, retrieval of semantic information at test would help participants *reject* perceptually related lures as new,

and thereby reduce false memory effects. Furthermore, participants' unfamiliarity with the structure of the material, as well as the fact that they saw only a single presentation of a single item, reduces the potential of alternative process, such as the generation of verbal labels, that may subserve false memory. In a series of three studies, we established a robust perceptual false-memory effect for this material that was unaffected by stimulus rotation or retention interval, and was obtained on different dependent measures and across different presentation durations and response formats.

Experiment 1: Rotation

The first study aimed at establishing a false-memory effect due to perceptual similarity, using pairs of similar line drawings that depicted distinct objects, Figure 1. To assess whether an effect could be attributed to orientation-dependent low-level perceptual similarity versus rotation-invariant object-level representations, we manipulated the objects' orientation between study and test.

Method

Participants. $N = 60$ University of Cologne students of different major courses of study were recruited and participated in exchange for a small monetary compensation or partial course credit.

Material and design. We used the set of 30 pairs of line drawings taken from Rouder et al. (2000), Figure 1. The members of each pair were perceptually similar but depicted conceptually distinct objects (e.g., banana – crescent or pencil – needle). Previous research showed that the objects were correctly identified after being presented for approximately 700-800 ms (i.e., naming responses with mean RT of 1000 ms were 95% accurate; and duration of decision-unrelated response processes is typically estimated to be between 200 and 300 ms; Rouder et al., 2000). To avoid a ceiling effect, we aimed at increasing participants' uncertainty about the objects' identity by presenting them for a slightly shorter duration of 500 ms. We randomly selected (for each participant anew) 20 of

the 30 pairs for the study phase; the remaining 10 pairs were not studied and were used as new items during the recognition test. At test, the studied member of a studied pair was presented as a *target* probe, the nonstudied member was presented as a *related* lure, and a randomly selected member of a nonstudied pair was presented as an *unrelated* probe. We manipulated stimulus rotation between study and test: Items were studied at one of three possible orientation levels (rotated 90 degrees to the left, upright, rotated 90 degrees to the right). At test, they were either presented at the *same* orientation, or they were presented at a *different* orientation (i.e., one of the other two possible rotation levels).

Procedure. Participants were seated at a computer and instructed that the study investigated memory and that they would be viewing a series of pictures that they should memorize for a later test. In the study phase, participants viewed 20 line drawings (i.e., one item of each of 20 pairs randomly selected for each participant anew) which were presented for 500 ms each, with an inter-stimulus interval of 1000 ms. During a retention interval (20 min), participants completed unrelated questionnaires. In a final recognition test, participants were asked to indicate, for a series of pictures, whether a given picture had been presented during the study phase or not (regardless of same vs. different orientation). They were presented with 10 target probes (i.e., studied items of a studied pair), 10 related probes (i.e., perceptually similar but unstudied items of a studied pair), and 10 unrelated probes (i.e.; unstudied items from non-studied pairs); order of probes was randomized for each participant anew. During the recognition test, half of the target and related probes were rotated away from their presentation positions during study; orientation of unrelated probes was determined randomly. Participants indicated whether a probe image was old (by pressing “A”) or new (“N”), and (if they responded “old”) how confident they were that it was an old image, using a 6-point scale ranging from “very uncertain” (1) to “very certain” (6).

Data analysis. We performed ANOVA with Greenhouse-Geisser-corrected degrees of freedom to analyse our data with α set at .05. Whenever substantive hypothesis tests yielded non-significant results, we calculated the tests’ statistical sensitivity in units of

Cohen’s d given $\alpha = \beta = 0.05$ and no correction for nonsphericity ($\epsilon = 1$). We used the mean empirical correlation and 95% confidence limits as estimates of repeated measures correlations in the population yielding a point estimate and a 95% confidence interval for the tests’ statistical sensitivity. Experimental data were analysed using R (3.3.1, R Core Team, 2016) and the R-packages *afex* (0.16.1, Singmann, Bolker, Westfall, & Aust, 2016), *ggplot2* (2.1.0, Wickham, 2009), *papaja* (0.1.0.9076, Aust & Barth, 2016), and *TreeBUGS* (0.4.9, Heck, Arnold, & Arnold, 2016); Statistical sensitivities were estimated using G*Power (3.1.9.2, Faul, Erdfelder, Lang, & Buchner, 2007). Raw data and analysis scripts are available at <https://osf.io/jxm7z/>.

Results and Discussion

As shown in Figure 2, participants’ “old” responses varied as a function of probe type, $F(1.88, 110.9) = 312.28$, $MSE = 0.03$, $p < .001$, $\eta_G^2 = .776$, but were unaffected by the rotation of memory probes relative to studied items, $F(1, 59) = 3.26$, $MSE = 0.03$, $p = .076$, $\eta_G^2 = .011$, or the two-way interaction, $F(1, 59) = 0.47$, $MSE = 0.03$, $p = .496$, $\eta_G^2 = .001$. Crucially, “old” responses were more frequent for related compared to unrelated probes, $M_d = 0.17$, 95% CI [0.12, 0.22], $t(59) = 6.55$, $p < .001$, showing that perceptually similar but non-studied members of a pair were falsely remembered as having been previously encountered.

We computed recognition sensitivity by relating the proportion of “old” responses to targets and related lures to the false-alarm rate for unrelated lures, using the nonparametric statistic A’ (with corrections for zero counts; see Snodgrass & Corwin, 1988). Sensitivity was greater for old than for related probes, $F(1, 59) = 186.01$, $MSE = 0.01$, $p < .001$, $\eta_G^2 = .336$. It was not affected by rotation, $F(1, 59) = 2.54$, $MSE = 0.01$, $p = .116$, $\eta_G^2 = .005$, nor the probe type by rotation interaction, $F(1, 59) = 0.49$, $MSE = 0.01$, $p = .485$, $\eta_G^2 = .001$. Importantly (as revealed by a positive intercept after subtracting the .50 chance level), sensitivity for related probes was greater than chance, $F(1, 59) = 59.28$, $MSE = 0.04$,

$p < .001$, $\eta_G^2 = .433$, reflecting a false memory effect.

For a parallel analysis of confidence ratings, we subtracted confidence ratings for unrelated probes from those of the other probe types (note that this step eliminated 27 subjects, i.e., those without false alarms to unrelated probes¹). Confidence was greater for old than for related probes, $F(1, 32) = 42.09$, $MSE = 1.21$, $p < .001$, $\eta_G^2 = .182$ (see Figure 2). It was not affected by rotation, $F(1, 32) = 0.15$, $MSE = 1.08$, $p = .703$, $\eta_G^2 = .001$, nor by the two-way interaction, $F(1, 32) = 1.42$, $MSE = 0.76$, $p = .242$, $\eta_G^2 = .005$. Confidence for related probes was, however, not significantly greater than for unrelated probes, $F(1, 32) = 0.76$, $MSE = 3.36$, $p = .389$, $\eta_G^2 = .017$.

In sum, Experiment 1 demonstrated a perceptual false-memory effect: Participants falsely claimed to have seen an unstudied object (e.g., a banana) if they had studied a perceptually similar but conceptually distinct object (e.g., a crescent). Confidence in false recognition of perceptually similar and distinct objects, however, did not differ; our study had a power of 95% to detect effects larger than $d = 0.57$, 95% CI [0.45, 0.65]. Importantly, we found that a change in orientation of the objects between study and test phases has at best a small effect on the rate of false recognition; our study had a power of 95% to detect effects larger than $d = 0.45$, 95% CI [0.38, 0.47] and $d = 0.31$, 95% CI [0.25, 0.38] for the proportion of “old” responses and recognition sensitivity, respectively. Thus, our findings suggest that the observed false memory effect is based on orientation-independent perceptual representations.

Experiment 2: Retention interval

Experiment 2 aimed at replicating the basic effect, and to address a potential artifact: Given that study duration was brief (i.e, 500 ms), it is possible that participants failed to correctly identify the objects in a substantial proportion of cases during study. In particular, they might have mistaken the studied member of the pair (e.g., crescent) for the nonstudied

¹An exploratory analysis revealed no differences in the reported false memory effects on any dependent variable between the included and excluded participants.

member (e.g., banana). In this case, the effect might have been based on semantic codes instead of perceptual similarity. To address this possibility, and to exclude the possibility of false memory due to misidentification, we increased presentation duration to 1000 ms in Experiment 2. Previous research has shown that this would be more than sufficient to ensure that participants could identify the objects with high accuracy (Rouder et al., 2000).

If the findings are due to perceptual similarity, the lack of an effect of rotation suggests that the underlying representation was not a low-level orientation-dependent perceptual representation. Low-level perceptual information decays relatively quickly (Laming & Scheiwiller, 1985), so that one might expect to see an even greater false-memory effect at a shorter retention interval. To address this notion, and to explore the temporal characteristics of the perceptual false-memory effect, we manipulated retention interval in Experiment 2 by adding an immediate-test condition.

Method

Experiment 2 replicated Experiment 1, but with a between-participant manipulation of retention interval (0 vs. 20 min); rotation was not manipulated. In contrast to Experiment 1, study duration was doubled (i.e., 1000 ms instead of 500 ms). This ensured that participants were able to identify the depicted objects during study (see Rouder et al., 2000).

Participants. A new sample of $N = 61$ University of Cologne students of different majors participated in this study in exchange for partial course credit. Data for an additional participant was partially lost due to a programming error and excluded from the analysis.

Material and procedure. Experiment 2 differed from that of Experiment 1 as follows: First, we used 10 additional line drawings that were presented as primacy and recency buffers (5 each), so that participants studied 30 a total of items. Second, orientation was held constant across study and test. Third, 32 participants performed the recognition test immediately after study, whereas the other 29 participants completed a series of unrelated questionnaires for 20 minutes before working on the recognition test.

Results and Discussion

As shown in Figure 3, probe type again affected the rate of “old” responses, $F(1.52, 89.48) = 444.14$, $MSE = 0.03$, $p < .001$, $\eta_G^2 = .832$. The false memory effect obtained in Experiment 1 was replicated, with more false alarms to related than to unrelated lures, $F(1, 59) = 84.19$, $MSE = 0.02$, $p < .001$, $\eta_G^2 = .342$. Importantly, retention interval length did not affect memory, $F(1, 59) = 3.35$, $MSE = 0.03$, $p = .072$, $\eta_G^2 = .019$, nor did the two-way interaction, $F(1.52, 89.48) = 0.99$, $MSE = 0.03$, $p = .355$, $\eta_G^2 = .011$.

As in Experiment 1, we computed recognition sensitivity using the nonparametric statistic A' with corrections for zero counts. Sensitivity was greater for old than for related probes, $F(1, 59) = 174.19$, $MSE = 0.01$, $p < .001$, $\eta_G^2 = .590$. It was not affected by the length of the retention interval, $F(1, 59) = 2.38$, $MSE = 0.01$, $p = .128$, $\eta_G^2 = .020$, nor the probe type by retention interval interaction, $F(1, 59) = 0.67$, $MSE = 0.01$, $p = .418$, $\eta_G^2 = .005$. Again, sensitivity for related probes was greater than chance, $F(1, 59) = 147.49$, $MSE = 0.02$, $p < .001$, $\eta_G^2 = .714$, reflecting a false memory effect.

We subtracted confidence ratings for unrelated probes from those of the other probe types (this step eliminated 17 and 19 subjects from the 0 and 20 min condition, respectively²). Confidence ratings showed a clear effect of probe type, $F(1, 23) = 35.65$, $MSE = 0.60$, $p < .001$, $\eta_G^2 = .319$, but there was no indication of an effect of retention interval, $F(1, 23) = 3.84$, $MSE = 1.37$, $p = .062$, $\eta_G^2 = .104$, or the interaction, $F(1, 23) = 0.40$, $MSE = 0.60$, $p = .531$, $\eta_G^2 = .005$. Importantly, confidence in false alarms was significantly greater for related than for unrelated lures, $F(1, 23) = 42.80$, $MSE = 0.84$, $p < .001$, $\eta_G^2 = .650$.

To conclude, Experiment 2 replicated the false memory effect found in Experiment 1 and extended it to confidence ratings. The longer study duration did not eliminate the false memory effect, as predicted if it was due to semantic confusion. In contrast, the increase in

²An exploratory analysis revealed no differences in the reported false memory effects on any dependent variable between the included and excluded participants.

presentation duration increased false recognition in both sensitivity ($\eta_G^2 = .433$ vs. $\eta_G^2 = .714$) and confidence ($\eta_G^2 = .017$ vs. $\eta_G^2 = .650$). This rules out a misidentification account, and therefore, a semantic basis of the present false-memory effect. In addition, the increased retention interval did not affect false recognition in any of our dependent variables, although our study had 95% power to detect differences larger than $d = 0.57$, 95% CI [0.48, 0.59], $d = 0.65$, 95% CI [0.56, 0.66], and $d = 0.49$, 95% CI [0.35, 0.64] for the proportion of “old” responses, recognition sensitivity, and confidence, respectively. The lack of decay across the retention interval suggests that intermediate-level (i.e., in between low-level perceptual and semantic) representations are likely to mediate the effect.

Experiment 3A & 3B: Ternary response format

Experiments 3A & 3B addresses another alternative account of the previous findings. Specifically, participants may have misinterpreted the instructions of the recognition test: They might have classified perceptually similar pictures as “old” despite being aware that they were not identical to studied items (e.g., upon being presented with a related lure at test, participants may have retrieved the corresponding studied pair member from memory; noticing the similarity between the two, they may have been unsure about whether the task was to reject or to accept the similar lure, and may have interpreted the similar lures as sufficiently similar to be called “old”).

To address this possibility, we used a ternary response format that asked participants, after they were instructed about the three possible probe types, to classify each probe as either a studied target, a related but unstudied lure, or an unrelated probe. To the extent that participants could indeed discriminate between targets and related lures, they should be able to classify them accordingly. Additionally, the ternary response format serves to replicate an important finding from research in the DRM paradigm: False memory may be attenuated but not eliminated by warning participants about critical lures before the recognition test (e.g., Gallo, Roediger, & McDermott, 2001; Neuschatz, Payne, Lampinen, &

Toglia, 2001).

Method

Participants. New samples of $N = 30$ and $N = 33$ University of Cologne students participated in Experiments 3A and 3B, respectively, and received partial course credit.

Materials and procedure. Experiment 3A was a replication of the 20 min retention interval condition of Experiment 2, with the following modifications: First, study duration was 750 ms for each item. Second, we used a different response format in the recognition test. Specifically, participants were instructed about the three types of probes, and they were asked to classify each probe as either studied/old, unstudied/similar, and unstudied/new. To ensure that participants interpreted the instruction correctly we presented examples for each response category and instructed them that “similar” probes had not been shown but looked like previously studied items, whereas “new” probes had not been shown and did *not* look like previously studied items. Experiment 3B was a replication of Experiment 3A with minor procedural differences.³

Results and Discussion

Figure 4A shows the distribution of responses across probe types. Most importantly, there was again a robust false memory effect: The proportion of “old” responses was affected by probe type, $F(1.35, 39.05) = 212.56$, $MSE = 0.03$, $p < .001$, $\eta_G^2 = .820$, and it was greater for related than for unrelated lures, $M_d = 0.11$, 95% CI [0.06, 0.16], $t(29) = 4.56$, $p < .001$, indicating robust false alarms to related lures.

³Another group of $N = 32$ students participated in that study after consuming an alcoholic beverage. Although alcohol did not affect the pattern of findings, data from this group are excluded from the present analyses. The procedure differed from Experiment 3A in that participants answered a questionnaire about alcohol consumption, consumed a control beverage, and watched an emotionally neutral video clip before the study phase. A set of 28 items was presented, each for 750 ms; a retention interval of 25 minutes was realized during which participants completed a test of fluid intelligence (CFT 20-R). Finally, participants did not provide confidence ratings during the test phase.

In addition, participants were able to correctly classify the probe types. For instance, an analysis of “similar” responses showed that they were partly able to detect and reject related lures: The proportion of “similar” responses was affected by probe type, $F(1.94, 56.4) = 8.50$, $MSE = 0.02$, $p = .001$, $\eta_G^2 = .141$, and related lures were more likely to be called “similar” than unrelated lures, $M_d = 0.12$, 95% CI [0.03, 0.21], $t(26) = 2.71$, $p = .012$. Also, as shown in Figure 4A, participants classified unrelated probes as “new” more often than related probes, $M_d = 0.22$, 95% CI [0.13, 0.31], $t(29) = 5.18$, $p < .001$.

As a complimentary approach, we applied a simplified version of the *Conjoint Recognition* model (Brainerd, Reyna, & Mojardin, 1999; Brainerd, Stein, & Reyna, 1998; Stahl & Klauer, 2008, 2009) to the data that allows for a quantitative estimation of the following processes: (a) an all-or-nothing detection of either the probe’s identity with a studied item (resulting in an *old* judgement), or its distinctiveness from a studied item (resulting in a *similar* judgement); (b) a (process detecting) gradual similarity between the probe and the items presented in the study phase that does not allow distinction of whether the probe is a target or a related lure; in this case, participants are assumed to guess *old* with probability a , and *similar* with probability $(1 - a)$; (c) a guessing process that selects a *new* judgment with probability b , and (with probability $1 - b$) proceeds to select among the *old* and *similar* judgments as above. In this model, if there is false memory for related lures, this should be reflected in non-zero estimates of the similarity process for these probes (i.e., $S_{related} > 0$). We tested this prediction by comparing an unrestricted model with one that restricts the similarity process for related lures to zero ($S_{related} = 0$). First, the unrestricted model accounted for the data well, and the results of parameter estimation showed evidence for false memory, $S_{related} = .22$, 95% CI [.12, .32]). Second, restricting parameter $S_{related}$ to zero significantly harmed the model’s goodness-of-fit, $\Delta\chi^2_{df=1} = 17.82$, $p < .001$. The model-based analyses thus confirm the above conclusion of robust false memory with the ternary response format.⁴ We did not analyse confidence ratings because only 6 participants

⁴Although simpler to compute and communicate, the classical strategy of modeling aggregated data may

gave “old” responses to unrelated probes.

We replicated these finding in Experiment 3B (see Figure 4B): The proportion of “old” responses was affected by probe type, $F(1.91, 61.04) = 411.64$, $MSE = 0.01$, $p < .001$, $\eta_G^2 = .872$, and it was greater for related than for unrelated lures, $M_d = 0.10$, 95% CI [0.05, 0.15], $t(32) = 4.00$, $p < .001$, indicating robust false alarms to related lures. In addition, participants were able to correctly classify the probe types. For instance, an analysis of “similar” responses showed that they were partly able to detect and reject related lures: The proportion of “similar” responses was affected by probe type, $F(1.94, 62.02) = 26.89$, $MSE = 0.02$, $p < .001$, $\eta_G^2 = .331$, and related lures were more likely to be called “similar” than unrelated lures, $M_d = 0.18$, 95% CI [0.10, 0.26], $t(32) = 4.81$, $p < .001$. Also, participants classified unrelated probes as “new” more often than related probes, $M_d = 0.29$, 95% CI [0.21, 0.36], $t(32) = 7.76$, $p < .001$.

Model-based results also replicated: The unrestricted model accounted for the data well, and the results of parameter estimation were consistent with false memory, $S_r = .33$, 95% CI [.26, .40]. Restricting the parameter S_r to zero again significantly harmed the model’s goodness-of-fit, $\Delta\chi^2_{df=1} = 73.32$, $p < .001$. These findings indicate that, over and above guessing or response tendencies, a process of similarity between studied items and related lures is necessary to account for the present false-memory effect.⁵

distort results if substantial heterogeneity is present (Klauer, 2006, 2010; Stahl & Klauer, 2007). To account for heterogeneity across participants, we applied a hierarchical latent-trait version of the model; results obtained with this model supported the above conclusions. First, posterior predictive checks revealed that an unrestricted model was well able to account for the means, $T_{1,observed} = .30$, $T_{1,predicted} = .19$, $p = .218$, as well as covariances $T_{2,observed} = 7.63$, $T_{2,predicted} = 7.07$, $p = .395$; it estimated the similarity parameter for related lures at $S_r = .25$, 95% HDI [.15, .34]. Second, a restricted model with $S_r = 0$ did not achieve an acceptable fit, as it failed to adequately account for the pattern of mean category frequencies, $T_{1,observed} = .90$, $T_{1,predicted} = .18$, $p < .001$ (although it adequately accounted for the pattern of covariances, $T_{2,observed} = 10.89$, $T_{2,predicted} = 7.12$, $p = .20$).

⁵Results of a hierarchical latent-trait version of the model supported these conclusions: First, an unrestricted model was well able to account for the data, as revealed by posterior predictive checks, $T_{1,observed} =$

Taken together, Experiments 3A and 3B eliminated the possibility that participants somehow misunderstood their task during the recognition phase: Participants were explicitly instructed about the three types of probes, were given examples of each probe type, and instructed about the responses required for each probe type. Nevertheless, they falsely classified a substantial proportion of related probes as “old”, and did so significantly more often than for unrelated probes.

General Discussion

Across three experiments, using different study durations (500, 750, and 1000 ms) and different dependent variables (old/new, old/similar/new, confidence), we found reliable false memory for perceptually similar but conceptually distinct lures. This effect was not affected by rotating the memory probe relative to the studied item (Experiment 1) or by the length of the retention interval (Experiment 2). Most importantly, these findings cannot be explained by conceptual or semantic similarity because targets and lures were only perceptually similar but belonged to different semantic categories (e.g., banana – crescent; pencil – needle). Neither can our results be attributed to conceptual knowledge acquired during the study phase. In contrast to previous studies, in which participants studied multiple exemplars from each list, we presented only one exemplar from each distinct pair. Taken together, in our study, semantic or conceptual information is unlikely to account for the observed false recognition effects. In the absence of semantic associations and without the opportunity to form new conceptual representations of the stimuli, the observed false memory effects appear to be best explained by perceptual similarity. Notably, perceptual false memory was robust, that is, studying a single similar stimulus was sufficient to produce the effect, even when

.11, $T_{1,predicted} = .09$, $p = .312$, and $T_{2,observed} = 3.46$, $T_{2,predicted} = 3.43$, $p = .468$; it estimated the similarity parameter for related lures at $S_r = .29$, 95% HDI [.19, .37]. Second, a restricted model with $S_r = 0$ did not achieve an acceptable fit to the data, as it failed to adequately account for the pattern of mean category frequencies, $T_{1,observed} = .70$, $T_{1,predicted} = .09$, $p < .001$. (although it adequately accounted for the pattern of covariances, $T_{2,observed} = 6.39$, $T_{2,predicted} = 5.84$, $p = .36$).

participants were warned about related lures before the recognition test (Experiment 3).

Limitations and open questions

The effect may be due to object misidentification at study. Objects were identified correctly at high accuracy, but participants might have misidentified the studied pair member (e.g., crescent) as the unstudied member (e.g., banana) on some trials, and may have included this self-generated semantic misinformation in the study episode along with the line drawing (Henkel & Franklin, 1998). At test, upon being presented with the drawing depicting a banana, there would again be both perceptual as well as conceptual similarity to drive the false-memory effect. More critically, perceptual traces may have decayed entirely, and the semantic overlap with the study phase alone might have been sufficient to produce false memory.

If this was the case, firm conclusions about the perceptual nature of the effect would not be warranted. We believe that this explanation is unlikely to apply to the present findings for two reasons: First, misidentification at study (i.e., approximately 5% after a processing duration of about 800 ms; Rouder et al., 2000) was much less likely than false recognition at test (approximately 10-20% in the present studies). Second, doubling study duration between Experiment 1 and Experiment 2 did not eliminate or even reduce false memory (as would have been predicted by the misidentification account), but instead it *increased* the false memory effect. Nevertheless, future research should further address this possibility, for instance by asking participants to name the stimulus during study and relating misidentifications to subsequent false memory on an item basis.

The effect may be due to similarity of outlines and/or structural representations. The present pattern of results largely excludes a purely conceptual or semantic explanation, but the exact nature of the underlying perceptual representations is less clear. One interpretation of the present findings is that the effect arises at an intermediate level of representation located in between low-level perceptual and high-level

object-level semantic representations. This is because (1) the effect was orientation-invariant, a phenomenon attributed to processing stages beyond those of low-level visual features such as contrast and orientation (Biederman & Cooper, 1991; Biederman & Gerhardstein, 1993); and (2), contrary to what would be expected for low-level visual information (Laming & Scheiwiller, 1985), the effect was not affected by a 20 min retention interval. Finally, because it consisted in confusing two distinct objects, the effect must arise below the object-identification level. This analysis suggests that the effect may be due to overlap in outlines or intermediate *structural representations* as suggested by Biederman & Cooper (1991; see also Schacter, Cooper, & Delaney, 1990). Additional research that addresses this question more directly is clearly needed.

The effect may be due to implicit memory. A final limitation does not question the perceptual nature of the effect but characterizes it as an implicit instead of explicit memory effect: In this account, instead of a false belief of having previously seen a lure, its perceptual similarity to a studied item induced a feeling of familiarity that then led to an “old” response. Put simply, it has been argued that perceptual false memory effects may in fact be due to perceptual priming (Doss, Bluestone, & Gallo, 2016; Ly et al., 2013). Previous research has used perceptual implicit-memory measures to determine whether false memory is due to perceptual or conceptual representations. For instance, McKone (2004) used a lexical-decision task and found that false memory in a DRM paradigm was not accompanied by priming of critical lures. Relatedly, in a perceptual-identification task, Weinstein & Shanks (2008) found that perceived but not imagined pictures were identified faster than novel pictures. Both studies found that true but not false memory was associated with priming. Future research should address this issue in the context of the present paradigm.

Conclusions

The present study addressed two criticisms of previous findings of perceptual false memory for pictorial material: First, false memory effects obtained with novel figures may

have been due to associations with pre-existing semantic knowledge, such that, during study, a novel figure may have been associated with a label, and the retrieval of this semantic association during test may have driven false memory effects (Pidgeon & Morcom, 2014). A semantic-associates account does not apply to the present findings because the material depicted pre-existing objects that were correctly identified by participants, such that the correct semantic label would be stored at study, and would—if retrieved at test—oppose, rather than promote, false memory. Second, false memory effects for random dot patterns or novel abstract figures might have reflected conceptual gist activation: after being presented with several exemplars of a (perceptually defined novel) similar category, participants may have acquired or generated a new concept of this category; the similarity of related lures with this conceptual gist may have driven false-memory effects. A conceptual-learning account does not apply to the present findings because only a single object was studied from each perceptually defined category, and because conceptual knowledge was already present for the depicted objects. Most importantly, the present false-memory effect was obtained despite conceptual distinctiveness of target and lure. Taken together, the present findings address the above criticisms and more compellingly demonstrate false memory on the basis of perceptual similarity.

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Figure 1. Examples of stimulus material used in our Experiments (Rouder et al., 2000). The banana and crescent are perceptually similar but conceptually distinct. The pan is perceptually and conceptually distinct from banana and crescent.

Figure 2. Proportion of “old” responses (A) and confidence ratings (B) as a function of probe type (*Target*, *Related*, or *Unrelated*) and probe rotation (*Same* or *Different*) in Experiment 1. Error bars represent 95% within-subject confidence intervals.

Figure 3. Proportion of “old” responses (A) and confidence ratings (B) as a function of probe type (*Target*, *Related*, or *Unrelated*) and retention interval (0 or 20 minutes) in Experiment 2. Error bars represent 95% between-subject confidence intervals.

Figure 4. Proportion of the three possible responses (*Old*, *Similar*, or *New*) as a function of probe type (*Target*, *Related*, or *Unrelated*) in Experiment 3A (A) and 3B (B). Error bars represent 95% within-subject confidence intervals.