Memory, 2015
Vol. 23, No. 6, 901–927, http://dx.doi.org/10.1080/09658211.2014.937722

The kinds of information that support novel associative object priming and how these differ from those that support item priming

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(*Received 7 January 2014; accepted 18 June 2014*)

We investigated how the information that supports novel associative and item object priming differs under identical study/test conditions. In Experiments 1 and 2, participants rated the meaningfulness of sentences linking two object pictures at study. At test, they performed either a size judgement or an associative recognition memory task on intact, recombined and novel picture (Experiment 1) or word (Experiment 2) associations. Associative priming was modulated by subjective meaningfulness of the encoded links, and depended on study/test perceptual overlap. In contrast, item priming was neither affected by the meaningfulness of the sentences nor by study/test changes in the stimulus presentation format. Associative priming and recognition were behaviourally dissociated, and associative recognition was probably too slow to have seriously contaminated associative priming. In Experiment 3, participants performed a perceptually oriented task during both experimental phases, and both associative and item priming were observed. These results suggest that associative priming depends on stored associative semantic and perceptual information when the test task requires flexible retrieval of associative information. Under the same conditions, item priming may only require activation of items' semantic properties. When both study and test tasks stress perceptual processing, retrieval of perceptual information is sufficient to support both kinds of priming.

Keywords: Implicit memory; Priming; Novel associations; Recognition memory.

Research on priming—stimulus-specific memory that is indicated by the repeated stimulus being more efficiently processed (e.g., faster or more accurately) in a way that is independent of explicit memory—has mainly focused on priming of individual items (see Richardson-Klavehn & Bjork, 1988; Tulving & Schacter, 1990 for reviews). There has been, however, increasing interest in the characteristics of priming of associations (also known as novel associative priming), in particular for novel inter-item associations (e.g., between two unrelated words; e.g., Graf & Schacter, 1985, 1989; Mayes & Gooding, 1989; Schacter & Graf, 1986a, 1989; Shimamura & Squire, 1989; Verfaellie, Martin, Page, Parks, & Keane, 2006).

Typically, novel associative priming is assessed by having participants study unrelated item pairs (e.g., FORK-TELEPHONE, ELEPHANT-TABLE, SHIP-KEY), which are then either kept

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We thank Catherine Dibble and Katherine Jones for their assistance with data collection.
This work was supported by the Fundação para a Ciência e a Tecnologia [grant number SFRH/BD/41637/2007].

with their original associates (intact pairs, e.g., FORK-TELEPHONE), or rearranged with different studied associates (recombined pairs, e.g., ELEPHANT-KEY, SHIP-TABLE) during a subsequent test task. Better performance for intact relative to recombined associations is taken to indicate associative priming. It is believed that if the component items are appropriately linked together into an associative memory during encoding, reactivation of part or all of this memory at retrieval facilitates associative priming performance (e.g., Mayes, Montaldi, & Migo, 2007). In contrast, with this paradigm, better performance for recombined pairs than unstudied novel pairs (e.g., WINDOW-APPLE) is taken to indicate item priming.

Although enhanced associative priming performance has been found across several associative priming tasks including word-stem completion (e.g., Graf & Schacter, 1985; Micco & Masson, 1991; Reingold & Goshen-Gottstein, 1996a, 1996b; Schacter & Graf, 1986a, 1986b, 1989), reading (e.g., Moscovitch, Winocur, & McLachlan, 1986; Musen & Squire, 1993), lexical decision (e.g., Goshen-Gottstein, Moscovitch, & Melo, 2000; Goshen-Gottstein & Moscovitch, 1995a, 1995b), perceptual identification (e.g., Gabrieli, Keane, Zarella, & Poldrack, 1997; Yang et al., 2003) and category exemplar generation (e.g., Verfaellie et al., 2006) tasks, there remains much debate regarding the type of information that supports associative priming as well as what distinguishes it from item priming.

It has been argued that in order for novel associative priming to occur a high degree of semantic elaboration at encoding is necessary to mnemonically link previously unrelated items appropriately (e.g., Graf & Schacter, 1985; Schacter & Graf, 1986a, 1986b), whereas priming for single items can usually be obtained without the need to encode stimuli elaboratively (see Brown & Mitchell, 1994 for a review).

However, demonstrations of novel associative word priming in the absence of semantic elaboration at encoding have also been reported using study tasks that largely focused on the physical components of word associations (e.g., counting syllables) rather than their meaning (Goshen-Gottstein & Moscovitch, 1995a, e.g., 1995b; Micco & Masson, 1991; Reingold & Goshen-Gottstein, 1996a, 1996b). These studies suggest that study semantic elaboration is not critical for the emergence of association-specific priming provided that priming tasks emphasise analysis of the physical input.

One useful heuristic has been the division of memory tasks into perceptually and conceptually driven tasks. In perceptually driven tasks emphasis is put on the processing of the physical characteristics of stimuli whereas conceptually driven tasks require analysis of the stimulus meaning rather than their physical form. The characterisation of memory tasks into perceptual and conceptual is one of the central tenets of the processing framework proposed by Roediger and colleagues (e.g., Blaxton, 1989; Roediger, 1990) which postulates that it is the degree of processing overlap between study and test phases that dictates memory performance.

Processing accounts, however, do not make any clear predictions regarding the kinds of mnemonic information that differentially support associative and item priming when the same encoding/retrieval conditions are used. For instance, it is not clear why associative priming, but not item priming, would be affected by study/test manipulations of modality of presentation (e.g., Schacter & Graf, 1989), or different degrees of semantic processing (e.g., Schacter & Graf, 1986a, Experiment 4). These two findings, in particular, led Schacter and colleagues to conclude that, even though both types of priming were obtained under the same testing conditions, associative priming during the word-stem completion task depended on both meaningful semantic elaboration at encoding *and* preserved perceptually encoded information, whereas item priming did not. Thus, for associative, but not item, priming, elaborative encoding provided the "glue" with which the distinct perceptual constituents were integrated into a single representation during encoding.

However, some researchers have also suggested that the associative word-stem completion paradigm used by Schacter and colleagues may promote the use of explicit memory strategies (e.g., Gooding, Mayes, van Eijk, Meudell, & MacDonald, 1999; McKone & Slee, 1997; Reingold & Goshen-Gottstein, 1996b). This is because the associative word-stem completion priming effect depended on elaborative encoding, and it is known that explicit memory also benefits from semantic elaboration (e.g., Graf & Mandler, 1984; Jacoby & Dallas, 1981). In addition, only patients with mild cases of amnesia showed associative priming (e.g., Schacter & Graf, 1986b; Shimamura & Squire, 1989), as did only participants who were aware of the relationship between study and test tasks (e.g., Bowers & Schacter, 1990; McKone & Slee, 1997).

Although we concur that explicit remembering probably influenced priming during the associative word-stem completion task, the differential impact of semantic study elaboration on associative and item conceptual priming has not been systematically investigated with conceptual associative tasks that may be less prone to explicit memory contamination. Consequently, we reasoned that semantic study elaboration may still be a critical condition in conceptual priming tasks that require access to flexible associative conceptual representations, i.e., semantic study elaboration may promote the creation of associative conceptual links that could later be retrieved under a variety of study-test conditions (e.g., when study and test tasks differ). We also speculated that, under the same conditions, item priming should not depend on elaboration, even when the tasks differ between study and test phases (e.g., Challis & Brodbeck, 1992), provided that the test-relevant conceptual information of objects has been accessed during study (Vriezen, Moscovitch, & Bellos, 1995). Similarly, associative perceptual priming only occurred when items were physically analysed in relation to each other (e.g., Goshen-Gottstein & Moscovitch, 1995a) but not when they were analysed individually (e.g., Carroll & Kirsner, 1982), whereas item priming was found regardless of presentation format. This means that the memory information supporting associative and item priming, which are otherwise matched, should not be distinguished by whether the representation is perceptual or conceptual but rather by whether the encoded information links previously unrelated stimuli (associative priming) or not (item priming).

In sum, although study elaboration-dependent associative priming effects have been largely attributed to explicit memory contamination, performance on associative, but not item, priming tasks may still depend on semantic linking information driven by elaboration at study. This may be especially evident under testing conditions where learned information needs to be retrieved flexibly (e.g., different study and test tasks), since participants cannot rely on previous stimulus–response bindings (e.g., links between a specific key press or a decision at study and its associated physical stimulus; e.g., Dobbins, Schnyer, Verfaellie, & Schacter, 2004; Horner & Henson, 2008, 2009; Logan, 1990). Furthermore, although several studies have claimed that perceptual information alone is sufficient to support word association priming (e.g., Goshen-Gottstein & Moscovitch, 1995a), the same has to be convincingly shown using other types of stimuli (e.g., pictures of objects; but see Kan et al., 2011), as stimulus overlearning, automatic extraction of semantic meaning from word reading (Stroop, 1935), incidental elaboration and/or transformation of word pairs into compounded words with specific meanings (e.g., seeing the unrelated word pair sea-cube could still trigger the image of a cube holding sea water; Mayes et al., 2007) cannot be ruled out as possible contributors to "perceptual" associative word priming effects.

The present study

We conducted three experiments of which the main aim was to identify what kinds of stored information are processed in order to support novel associative object picture priming, as well as differences and similarities to object picture item priming (with respect to the information stored) under identical experimental conditions. The second aim was to assess whether explicit memory could have contributed to any associative priming effects obtained. A third minor aim was to determine whether multiple study trials are necessary for novel associative priming to occur.

More specifically, in order to explore the kinds of information that support novel associative and item picture priming we manipulated type of encoding, type of priming task and changes in stimulus format between study and test phases.

Kind of encoding and priming task differed between Experiment 1–2 and Experiment 3. Experiments 1 and 2 included an elaborative task at encoding (rating the meaningfulness of sentences linking two objects) and, at test, priming was measured through reaction times (RTs) on a size judgement task—a task that requires access to conceptual object properties. Experiment 3, in contrast, used an encoding task that required analysis of the physical properties of the pictures, and, therefore, should have reduced processing of the semantic aspects of the depicted objects; at test, we examined whether associative and item priming effects for object pictures could be obtained if processing indicative of priming mainly focused on the perceptual analysis of stimuli.

The impact of changes in the stimulus presentation format was manipulated between Experiments 1 and 2. In Experiment 1, object pictures were presented at both study and test phases, whereas, in Experiment 2, the words describing the objects were presented at test instead of their corresponding study pictures.

The second aim was to evaluate whether explicit memory could have been driving associative priming performance. For that reason, we administered a speeded associative recognition test to a separate group of participants in Experiments 1 and 2. Although speeded recognition tasks have been used in conjunction with previous associative priming paradigms, it is unclear how much relational processing actually occurred in these tasks. For instance, Goshen-Gottstein and Moscovitch (1995b) required participants to respond "old" if both words of a pair had been studied, regardless of whether together or not, whereas they were to respond "new" if at least one of the words had never been studied. Because participants had to compare each individual word to a memory representation to successfully make old/new decisions in this task, emphasis was likely to have been placed on item-based processing. Relatedly, it is not possible to obtain an accurate estimate of successful associative recognition, because an "old" response to intact pairs could have been the result of successful remembering of either associative or item information.

In our experiments, we asked participants to decide whether the two items have been studied together or not. By only changing the test instructions between priming and recognition memory tasks, we were able to ascertain whether associative priming and recognition processes would be differently affected by the encoding manipulations (i.e., meaningfulness and study/test overlap).

The third and minor aim was to investigate whether multiple presentations are necessary for the emergence of associative priming. Although priming for individual items has been commonly observed after a single study presentation, a few studies have failed to find reliable associative priming after a single study presentation (e.g., Dean & Young, 1996; Musen & Squire, 1993), which suggests that multiple trial learning may be necessary to strengthen the memory representation that binds the two items together.

EXPERIMENT 1A

In Experiment 1A, participants rated how meaningful a sentence linking two unrelated objects was at study, and each pair was presented either once or three times. At test, they indicated as accurately and as fast as possible which object represented by the picture pairs was larger. Old object pairs (intact and recombined pairs) were presented intermixed with a set of new, unstudied object pairs.

This experiment allowed us to determine whether semantic elaboration is necessary for the formation of associative links that could support subsequent association-specific conceptual priming. Specifically, if associative priming does not depend on semantic elaboration, then it should not be influenced by meaningfulness. In contrast, if semantic elaboration is a pre-requisite for the emergence of association-specific effects during the size-judgement task, then associative priming should not be obtained under conditions that do not promote successful object binding (i.e., when intact pairs are presented with meaningless sentences). Importantly, we predicted that item priming would be obtained regardless of whether objects were embedded in either meaningful or meaningless sentences.

Method

Participants. Fifty students of the University of Manchester were recruited whose native language was English. All participants gave written consent before the beginning of the experiment. All had normal or corrected-to-normal vision. This and following experiments were approved by the School of Psychological Sciences Research Ethics Committee of the University of Manchester.

Materials. One-hundred and sixty-two (144 for the study/test phases and 18 for practice trials) coloured high-resolution clip art images of objects were selected from an Internet clip art database (www.clipart.com). These pictures consisted of everyday objects from a range of different categories (animals, transports, food, musical instruments, tools, office and household objects) and presented on a white background. Shadows were removed from the images, and the resulting pictures scaled down to fit in a box of 400 by 400 pixels, essentially normalising all images so as not to create a response bias for larger images. The 144 study/test pictures were split into 18 groups, each containing 8 pictures. The pictures in each group were further divided into two subgroups of 4 pictures with the restriction that the pictures in a subgroup were unrelated to the pictures in the other subgroup. Two different word association norms (Moss, 1996; Nelson, McEvoy, & Schreiber, 2004) were used to ensure the absence of any pre-existing relationship between the objects. This was achieved by selecting pairs that, first, did not belong to the same semantic category and, second, were not produced together in the word association norms mentioned above. Once the selection process was finished the four pictures within a subgroup were randomly assigned to the 4 pictures in the other subgroup, giving a total of 4 associations per group and a total of 72 associations. For half of these associations the bigger object of a pair appeared on the right, whereas for the other half the bigger object was presented on the left; thus, at test, an equal number of right- and left-sided objects were judged as the bigger objects. Importantly, the relative size of the objects were maintained across experimental phases even if recombined with a different object. For example, if the pair cabbage-ant was presented at study and, at test, the cabbage was recombined with a different object, then this object would be approximately the size of an ant (e.g., ladybird). Thus, at both study and test the cabbage would be the bigger object whereas the ant/ladybird would be the smaller object. The position of the pictures on the screen remained constant between study and test phases. The pairs of objects were constructed so that not only could an unambiguous, and consistent, response to pairs be made, but, at the same time, a specific object size on its own could not be used to infer any size decision (during the critical priming task) regarding the pair. For example, an elephant is usually regarded as a relatively large animal; however, in this experiment, it could have been paired with a bigger object such as a train and, therefore, basing a decision solely on the size of the elephant would not be sufficient to accurately make a size judgement on the pair. This was done in order to encourage participants to associate the two objects at all times. Furthermore, in order to ensure that any detectable associative effects could only be due to the associative link between the items and not to difficulty-related artefacts that arise from the fact that intact pairs are easier to judge than recombined pairs, all objects in each subgroup had approximately the same size, so that once a pair was recombined the difficulty was held constant by recombining the items with similar-size items.

One-hundred and forty-four English sentences were also created in order to relate the two objects of a pair at study. Twelve sentences were constructed for each group of pictures, so that three different sentences varying in meaningfulness were assigned to each object pair. All sentences followed the same basic structure: the word "The" followed by the subject (e.g., train), followed by the action (e.g., transported), followed by the object (e.g., elephant). The sentences were standardised and pilot-tested to ensure consistency of ratings by asking three native English speakers to rate each sentence according to subjective meaningfulness (there was nearly perfect agreement so no further testing was deemed necessary). Examples of sentences used in this experiment are given in Table 1.

Pairs of pictures shown once at study were presented with a sentence that was either meaningful or meaningless whereas pairs shown three times at study were presented with three different sentences varying in meaningfulness.

Procedure. Participants sat approximately 50 cm in front of a PC monitor. At study, they were instructed that a series of picture pairs were going to be shown on the computer screen along with a sentence containing two sets of three dots (…) presented above each pair. Participants were instructed to read the sentence, give the names of the objects in the place of the dots (see Figure 1) and then judge how meaningful the sentence relating the two objects was. Participants used the keys 1–4 (meaningless to highly meaningful) on the keyboard. No reference to a test phase was made. Participants engaged in some practice trials in which the researcher presented pairs of objects and sentences with varying degrees of meaningfulness that helped

TABLE 1
Example sentences varying in meaningfulness for two object pairs used in Experiments 1 and 2

Meaningfulness	*Example sentences*
High	The *train* transported the *elephant*.
	The *cabbage* was eaten by the *ant*.
Medium	The *train* hit the *elephant*.
	The *cabbage* rolled over the *ant*.
Low	The *train* was eating with the *elephant*.
	The *cabbage* pushed the *ant*.

The words shown in italics were substituted by three dots during the study phase.

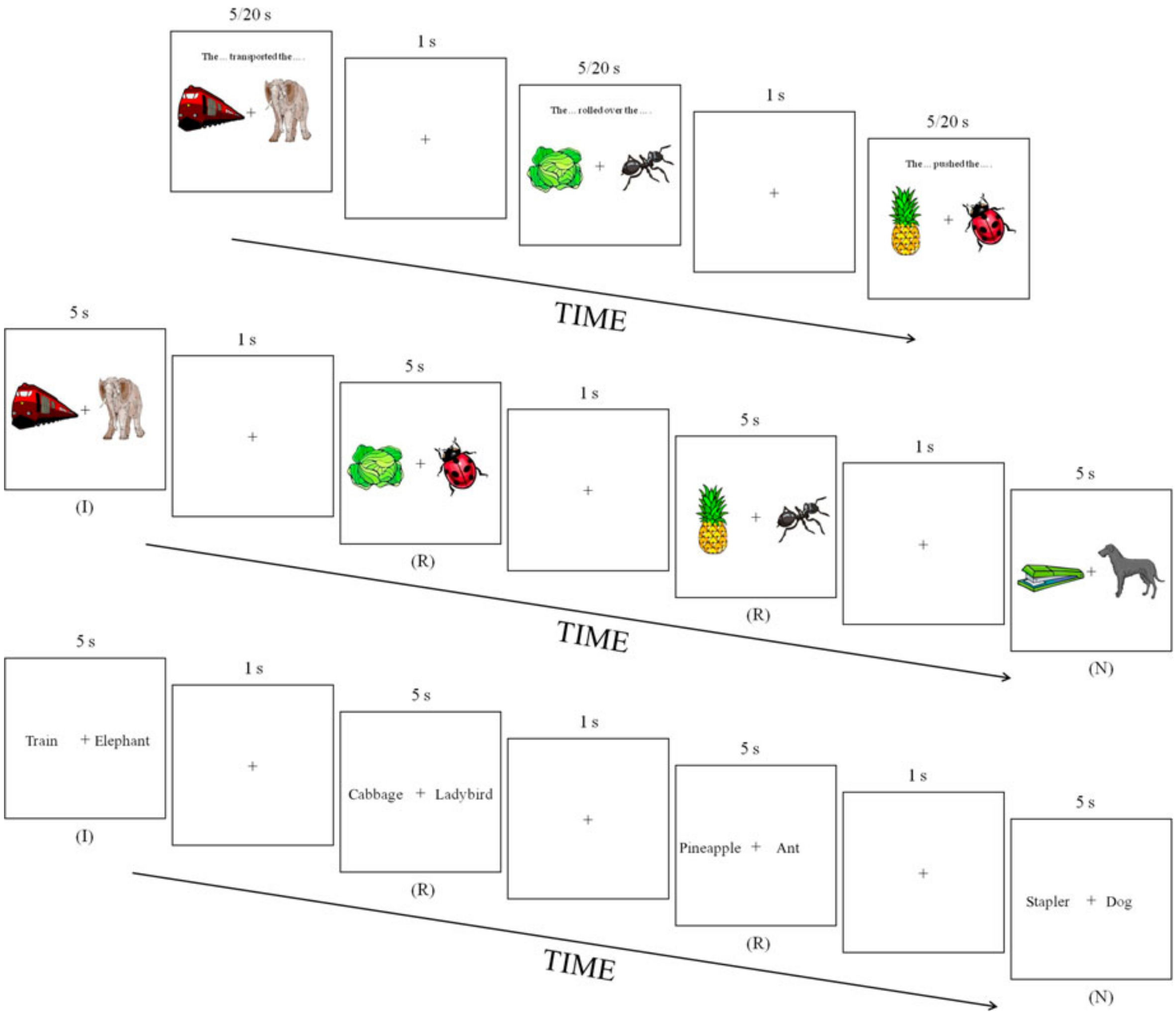

Figure 1. Experimental paradigm of Experiments 1 and 2. At study (top), participants rated the meaningfulness of sentences linking two object pictures. At test, they either made size judgements or associative recognition decisions on object picture (Experiment 1, middle) or word (Experiment 2, bottom) associations. The number above each event corresponds to the duration of that event in seconds. I = Intact pairs, R = Recombined pairs, N = New pairs.

participants understand the level at which each sentence should be rated. This was done in order to ensure that participants used the full range of four points appropriately. It was also emphasised that a sentence should only be rated highly meaningful (i.e., 4) if the sentence made sense and was likely to occur in a real life situation (e.g., "The train transported the elephant") whereas a meaningless rating (i.e., 1) should only be given for those sentences in which the event would be absurd in reality (e.g., "The train was eating with the elephant").

A fixation cross was displayed for 1000 ms at the beginning of each trial. Then, the pair of pictures and a sentence was presented for up to 5000 ms, and participants attempted to respond within that time. In case no response was made, the programme proceeded to the next trial. Half of the participants (selected at random) saw each pair only once (one-presentation condition), whereas the remaining half saw each pair three times (three-presentation condition). Each pair of pictures was shown with either one or three different sentences varying in meaningfulness (see Table 1 for some examples), depending on the group to which a participant belonged. A computer programme controlled the selection and order of presentation of the pairs, ensuring that each participant was presented with different pairs in each of the conditions. For those participants that saw each pair three times at study, a different presentation sequence was used for each run by randomly shuffling all pairs after the completion of a run.

Immediately after the study phase, the test phase was introduced. Participants were told that a series of pairs of pictures of common objects were going to be presented and that they needed to decide which object in the pair was bigger in real life. They were made aware that the two pictures were very similar in size on the computer screen, and therefore, in order to perform the task well, they needed to think of the real size of each object. They pressed the left control key if they thought the left object was bigger or the right control key if they thought the right object was bigger. They were asked to try to respond as quickly and accurately as possible. Participants engaged in some practice trials that allowed them to familiarise themselves with the test task. Each trial was initiated by presenting a fixation cross for 1000 ms followed by an association of one of the three possible types (intact, recombined or new) that remained on the screen for up to 5000 ms. Stimuli were presented and responses recorded using the Matlab (http://www.mathworks.com) toolbox Cogent (www.vislab.ucl.ac.uk).

Design. The experimental design consisted of Number of Presentations (one vs. three study trials) as a between-subject factor,[1] and Type of Association (intact, recombined and new) as a within-subjects factor. Accuracy and RT data were analysed using mixed repeated-measures analysis of variance (ANOVA) and *t*-tests. A Huynh–Feldt correction was applied to the degrees of freedom of those tests for which the assumption of sphericity was violated. The alpha level was set, for all statistical tests, at .05 and *t*-tests were two-tailed unless noted otherwise.

[1]The reason we used Number of Presentations as a between-subject factor was because we wished to minimise as much as possible semantic overlap across our pool of object pictures. For that reason, we were restricted with the amount of truly distinctive and easily nameable objects we could select. Considering that many of our statistical analyses required some kind of division (e.g., into meaningful and meaningless categories), and because associative priming experiments require double the stimuli of single priming experiments (i.e., each trial effectively comprises two pictures), there would not be sufficient trials within each condition to represent it accurately had we used Number of Presentations as a within-subject factor.

Results

Trials with RTs shorter than 300 ms or longer than 3000 ms were considered outliers and excluded from subsequent analyses. Incorrect trials or trials with an absence of a response were also excluded. This resulted in the elimination of approximately 5% of trials for all conditions and participants.

Table 2 shows the mean accuracy and mean RTs for each condition during the associative priming task.

Accuracy levels were submitted to a 2 (Number of Presentations: one, three) × 3 (Type of Association: intact, recombined, new) mixed repeated measures ANOVA, but this analysis did not reveal any significant effects, so the remaining analyses focused on RTs.

An initial analysis included all trials present in each condition. A 2 (Number of Presentations: one, three) × 3 (Type of Association: intact, recombined, new) mixed repeated measures ANOVA, revealed a significant main effect of Type of Association, $F(2, 96) = 20.131$, $MSE = 3667$, $p < .001$, indicating that participants were fastest judging intact pairs, followed by recombined pairs and then new pairs. The interaction between presentation and Type of Association was also significant $F(2, 96) = 4.140$, $MSE = 3667$, $p < .05$, indicating that the number of study presentations had an impact on the magnitude of priming effects. Pairwise comparisons indicated that whereas associative priming was only observed for the three-presentation condition (one-presentation: $t(24) = -0.662$, $p > .10$; three-presentation: $t(24) = -2.044$, $p = .05$), item priming was significant both in the one-presentation condition, $t(24) = -1.959$, $p < .05$ [one-tailed], and in the three-presentation condition, $t(24) = -3.113$, $p < .01$.

In order to assess the influence of meaningfulness on associative priming, we separated intact pairs that had been presented with highly meaningful sentences ($\text{Intact}_{\text{meaningful}}$) from intact pairs that had been shown with less meaningful sentences ($\text{Intact}_{\text{meaningless}}$). For the one-presentation condition, we divided intact pairs that had been associated with highly meaningful sentences (i.e., ratings of 4) from those pairs associated with meaningless sentences (i.e., ratings of 1). This was done in order to emphasise differences in meaningfulness. For the three-presentation condition we divided intact pairs that had at least one

TABLE 2
Mean accuracy levels (Acc) and RTs for intact, recombined and new associations during the associative size judgement task in Experiment 1A

	One presentation		*Three presentations*	
Type of association	*Acc*	*RTs*	*Acc*	*RTs*
Intact	0.94 (0.01)	930 (39)	0.95 (0.01)	943 (41)
Meaningful	0.93 (0.02)	882 (44)	0.96 (0.01)	913 (31)
Meaningless	0.98 (0.01)	934 (38)	0.96 (0.02)	975 (40)
Recombined	0.95 (0.01)	939 (38)	0.97 (0.01)	964 (34)
Meaningful	0.96 (0.03)	858 (70)	0.97 (0.01)	991 (41)
Meaningless	0.98 (0.01)	934 (38)	0.96 (0.01)	958 (40)
New	0.94 (0.01)	970 (41)	0.95 (0.01)	1031 (32)

The means for the overall intact and recombined conditions are not the average of meaningful and meaningless pairs because they are based on different observations – see Results section of Experiment 1A for a description. Standard error of the means within parentheses.

associated highly meaningful decision from those pairs with none. Throughout the article we will refer to the latter type as "low meaningful" (as opposed to "meaningless" as described for the one-presentation condition), since the three sentences could have effectively been given ratings of 2 or 3. Only participants who had a sufficient number of trials (equal or greater than four trials) in each condition were included in these analyses. We contrasted these two conditions with the overall recombined condition, because dividing recombinations in the same manner as intact pairs would have resulted in an insufficient number of participants in the one-presentation to accurately perform any statistical analysis on the data. A 2 (Number of Presentations) × 3 (Type of Association: $Intact_{meaningful}$, $Intact_{meaningless}$, Recombined) mixed repeated measures ANOVA yielded a main effect of Type of Association only, $F(2, 76) = 5.626$, $MSE = 6587$, $p < .01$. Paired *t*-tests revealed that whereas $Intact_{meaningful}$ pairs were judged faster than recombinations, $t(44) = -3.656$, $p < .001$, $Intact_{meaningless}$ pairs were not, $t(43) = -0.302$, $p > .10$.[2]

Although there was no interaction with the number of study presentations, one could still argue that this effect was mainly driven by the three-presentation condition and not by meaningfulness per se. For example, the fact that each pair was presented three times at study probably allowed for more opportunities to form associative links, and thus associative priming could directly relate to the number of presentations. Thus, given that in the one-presentation condition it is possible to restrict the analyses to only meaningful- or meaningless-studied pairs (i.e., some pairs were judged with only one meaningful sentence whereas others with only one meaningless sentence), we analysed the data from the one-presentation condition separately. Whereas intact pairs that had been encoded with meaningless sentences did not differ from recombined pairs, $t(23) = 0.451$, $p > .10$, intact pairs encoded with highly meaningful sentences were judged faster than recombinations, $t(20) = -2.732$, $p < .05$. These effects occurred despite the fact that participants took similar amounts of time rating meaningful than meaningless sentences, $t(24) = 0.800$, $p > .10$, indicating that the absence of an effect for intact pairs presented with meaningless sentences is not simply related to less encoding time given to those pairs.

As we pointed out above, we contrasted $Intact_{meaningful}$ pairs with the overall recombined pairs (i.e., including all trials), because if we had divided recombinations into meaningfully and meaninglessly encoded pairs, we would have only been able to analyse the data from three participants in the one-presentation condition. Although Table 2 seems to suggest that $Recombined_{meaningful}$ pairs were judged faster than

[2] We should point out that the difference in accuracy between $Intact_{meaningful}$ and $Intact_{meaningless}$ did reach significance for the one-presentation condition. However, we believe this to have been the result of a Type-I error for the following reasons. First, there were fewer trials in this calculation than in the overall means. Second, there were on average 3.2 more trials in the $Intact_{meaningless}$ than in the $Intact_{meaningful}$ condition, which could have reduced power in the latter condition. Third, no differences were found for the three-meaningful condition. Fourth, a 2 (Number of Presentations) × 3 (Type of Association: $Intact_{meaningful}$, $Intact_{meaningless}$, Recombined) mixed repeated measures ANOVA revealed neither a main effect of Type of Association nor an interaction (both $p > .10$).

$\text{Intact}_{\text{meaningful}}$ pairs in the one-presentation condition, this is, in fact, an artefact caused by both the low number of participants and the low number of trials in the $\text{Recombined}_{\text{meaningful}}$ condition. Indeed, when the analysis was performed using the three-presentation condition (in which 23 participants were included and an average of 15 trials per participant), $\text{Intact}_{\text{meaningful}}$ pairs (913 ms) were still judged faster than $\text{Recombined}_{\text{meaningful}}$ pairs (953 ms), $t(22) = -2.494$, $p < .01$. Furthermore, the difference between $\text{Intact}_{\text{meaningless}}$ (975 ms) and $\text{Recombined}_{\text{meaningless}}$ (969 ms) pairs failed to reach significance, $t(19) = -0.226$, $p > .10$, which is consistent with the results described above.

We also questioned whether item priming would be observed even if both objects comprising a recombination had been presented with meaningless sentences. For the one-presentation condition, we selected recombinations in which both recombined objects had been presented with either only a meaningful or only a meaningless sentence. For the three-presentation condition we divided recombinations in which both recombined objects had been encoded with at least one meaningful sentence from recombinations in which none of the recombined objects had been encoded with a meaningful sentence. A 2 (Number of Presentations) × 3 (Type of Association) mixed repeated measures ANOVA yielded a main effect of Type of Association only, $F(2, 42) = 4.366$, $MSE = 6877$, $p < .05$. Paired t-tests revealed that recombined objects that had been presented with meaningful sentences (942 ms) were judged faster than new pairs (1006 ms), $t(29) = -2.970$, $p < .01$, as were recombined pairs that had been presented with less meaningful sentences (955 ms; New = 1038 ms), $t(28) = -4.440$, $p < .001$.

Discussion

This experiment led to three important findings. First, novel associative priming for object picture pairs, defined as the difference in RTs between recombined and intact pairs, was observed in a size judgement task only when intact pairs had been encoded with highly meaningful sentences. Second, item priming was obtained in both presentation conditions and was not modulated by meaningfulness. Third, both associative and item priming were observed even after just one study trial.

Although a net associative priming effect (i.e., with all trials included) was obtained for the three-presentation condition, this overall effect was not present for the one-presentation condition. This may seem problematic considering the wealth of evidence of one-study trial associative priming (e.g., Dew & Giovanello, 2010a, 2010b; Goshen-Gottstein et al., 2000; Kan et al., 2011). However, note that intact pairs that had been associated with meaningless sentences had RTs close to those of recombinations, which potentially masked any RT advantage arising from $\text{Intact}_{\text{meaningful}}$ pairs. Thus, the fact that associative priming was observed for the one-presentation condition only when participants rated pairs embedded in highly meaningful sentences seems to indicate that not only is one study trial sufficient to produce novel associative priming but also that it may have been influenced by the greater amount of conceptual processing involved in rating meaningful sentences.

Although, a similar result has been reported by Schacter and Graf (1986a, Experiment 3), the associative word-stem completion task used by the authors may have encouraged participants to retrieve studied words (e.g., Bowers & Schacter, 1990; Gooding, Mayes, & van Eijk, 2000; McKone & Slee, 1997). In the present experiment, we measured associative priming through speeded decisions rather than accuracy judgements (the priming measured used by Schacter and Graf), and this measure is believed to be less prone to explicit memory contamination (e.g., Shiffrin & Schneider, 1977). Furthermore, we used different tasks at study and test phases such that retrieving study responses (i.e., ratings) would have not helped performance in our test task (i.e., size judgements).

Another explanation for the lack of associative priming for intact pairs embedded in meaningless sentences could be advanced. One could argue that the encoding of meaningless sentences greatly reduced the relevant *perceptual* processing critical to later perform the test task or that participants quickly discarded the information presented in meaningless sentences resulting in a poorer encoding process. However, it is hard to reconcile this explanation with our finding that participants in the one-presentation condition spent similar amounts of time processing intact pairs presented with meaningful and meaningless sentences, suggesting that poorer perceptual encoding processes for meaninglessly than meaningfully studied intact pairs are not likely to be the cause for the lack of associative priming for the former.

It should also be noted that, although participants could, in principle, have created their own images or meaningful elaborations when reading meaningless sentences, we do not believe this to have been the case for two reasons. First, participants had very little time to engage in extra processing of the relationships between objects because each trial lasted only up to 5 seconds. The different stages participants had to go through to reach a decision (read each sentence, replacing the objects in the gaps, thinking about the meaning of the sentence, choosing an appropriate rating score and pressing the appropriate key), would hardly leave any time for additional relational processing, especially considering that the next pair would be shown after just one second. Second, had participants imagined meaningful scenarios, then we would have expected associative priming for both $\text{Intact}_{\text{meaningful}}$ and $\text{Intact}_{\text{meaningless}}$ pairs, but this was clearly not the case.

Another interesting finding was that item priming did not seem to be affected by meaningfulness, considering that when recombined pairs were selected such that each individual recombined object had previously been presented with a meaningless sentence, a priming effect was still observed. This result suggests different underlying processes mediating associative and item priming, although the nature of the processes that mediated this item priming effect are still unclear. One possibility could be that item priming performance was solely mediated by perceptual processes. Alternatively, conceptual information could still have been extracted even from meaningless sentences (e.g., object-level information) which subsequently supported item priming. Experiment 2A was designed to partly address this issue.

A final criticism could also be that the very small number of participants/trials in the $\text{Recombined}_{\text{meaningful}}$-one-presentation condition poses a threat to the reliability of the item priming effect observed. However, when the three-presentation condition was analysed separately, the data showed the same trend of results (i.e., item priming for both meaningfully and meaninglessly encoded objects). More importantly, item priming was observed when the overall Recombined condition (i.e., regardless of whether objects had been encoded with meaningless or meaningful sentences) was compared with the New condition. Had recombined objects only benefited from meaningful elaboration, we would have expected a pattern of results similar to that of associative priming. That is, the inclusion of trials consisting of previously meaninglessly encoded objects would have wiped out any performance advantage from trials consisting of previously meaningfully encoded objects (i.e., there would be no item priming).

EXPERIMENT 1B

One potential concern with the previous associative priming finding relates to the extent that associative recognition memory processes helped in the identification and subsequent processing of intact pairs during the size-judgement task. It is likely that participants realised at some point during the critical priming task that some pairs had been shown together before whereas others had not (indeed post-experimental debriefing confirmed this impression). Thus, it is possible that they could have used one of the objects of an intact pair (e.g., cabbage, in the pair cabbage-ant) as a cue to retrieve its studied associate (e.g., ant), which would, in turn, facilitate retrieval of other associative semantic information including size. According to this explicit recognition contamination account, recombined pairs (e.g., cabbage-ladybird) would be judged slower, because the cue object (e.g., cabbage) would result in the retrieval of its study associate (e.g., ant) but not the recombined object (e.g., ladybird), leading to a slight response inhibition for those pairs.

In this respect, the inclusion of an associative recognition test would be informative, as it would allow us to investigate whether the association-specific priming effect depended on this explicit retrieval of studied intact pairs. Thus, Experiment 1B was exactly the same as Experiment 1A with the exception that participants decided at test whether an object association consisted of either an intact or a recombined/new pair. Considering that only test instructions differed between the implicit and explicit tests, we could evaluate whether associative recognition task RTs were at least as short as those during priming. If this was indeed the case, explicit memory mechanisms could have supported priming performance. Alternatively, if priming RTs were faster than RTs during associative recognition, this possibility would be unlikely.

Method

Participants. Fifty students of the University of Manchester were recruited whose native language was English. All participants gave written consent before the beginning of the experiment. All had normal or corrected-to-normal vision.

Materials, procedure and design. The materials and design were the same as in the previous experiment. The procedure was also identical with the following exception: at test, participants were asked to decide as quickly as possible, without compromising accuracy, whether the two objects in an association had been presented together in the study phase. They gave their YES/NO responses by pressing either the left or right control key (counterbalanced across participants) on the keyboard.

Results

Trials with outlying RTs as well as incorrect trials or trials with an absence of a response were excluded from subsequent analyses (approximately 3% for all conditions and participants).

The recognition data scores are presented in Table 3. The corrected hit rate (PR) was computed by subtracting false alarm rate (i.e., "yes" decisions to recombined pairs) from intact hit rate (i.e., "yes" decisions to intact pairs) and an independent *t*-test was conducted using Number of Presentations as the between-subject factor. Despite a numerical difference in accuracy between the three- (0.41) and one-presentation (0.31) conditions, this difference did not approach significance, $t(48) = -1.532$, $p > .10$. Associative recognition scores were, however, above chance levels for both presentation conditions (one presentation: $t(24) = 8.605$, $p < .001$, three presentations: $t(24) = 7.631$, $p < .001$).

Next, we examined the effects of meaningfulness on successful associative recognition by subtracting recombined false alarms from both intact hits consisting of pairs presented with highly meaningful sentences ($PR_{meaningful}$) as well as intact hits consisting of pairs presented with less meaningful sentences ($PR_{meaningless}$). A 2 (Number of Presentations) × 2 (PR: $PR_{meaningful}$, $PR_{meaningless}$) mixed repeated measures ANOVA revealed a main effect of PR, $F(1, 48) = 15.355$, $MSE = 0.214$, $p < .001$, with better accuracy for $PR_{meaningful}$ (0.42) than $PR_{meaningless}$ (0.33), as well as a significant interaction, $F(1, 48) = 10.414$, $MSE = 0.145$, $p < .01$, due to a larger difference in accuracy between the two conditions in the one-presentation condition (0.17) than in the three-presentation condition (0.02). Analysis of the RT data did not yield any significant results (main effect of condition: $F(1, 38) = 2.943$, $MSE =$ 25,424; interaction: Type of Association × Number of Presentations: $F(1, 38) = 0.282$, $MSE =$ 25,424).

Analysing the one-presentation condition independently, a paired *t*-test revealed a significant effect, $t(24) = 4.264$, $p < .001$, indicating a higher associative recognition memory score for pairs that had been encoded with meaningful (0.42) rather than meaningless (0.25) sentences. This

TABLE 3
Proportion of responses (Pr) and mean RTs for intact hits, intact misses, recombined correct rejections and false alarms and new correct rejections and false alarms during the associative recognition task in Experiment 1B

	One presentation		*Three presentations*	
Category	*Pr*	*RTs*	*Pr*	*RTs*
Intact HIT	0.77 (0.03)	1441 (60)	0.91 (0.02)	1141 (37)
Meaningful	0.88 (0.03)	1366 (55)	0.93 (0.02)	1123 (35)
Meaningless	0.71 (0.05)	1434 (69)	0.91 (0.02)	1157 (72)
Intact MISS	0.23 (0.03)	1473 (97)	0.09 (0.02)	1291 (100)
Recombined CR	0.55 (0.04)	1565 (58)	0.50 (0.05)	1331 (45)
New CR	0.99 (0.005)	1131 (41)	0.99 (0.004)	951 (39)
Recombined FA	0.45 (0.04)	1564 (72)	0.50 (0.05)	1232 (46)
New FA	0.01 (0.005)	1554 (316)	0.01 (0.004)	989 (272)

The means for the overall intact and recombined conditions are not the average of meaningful and meaningless pairs because they are based on different observations – see Results section of Experiment 1A for a description. Standard error of the means within parentheses.

HIT, hits; MISS, misses; CR, correct rejections; FA, false alarms.

effect occurred despite the fact that recognition RTs to intact pairs encoded with meaningful sentences were not significantly different than RTs to pairs encoded with meaningless sentences, $t(19) = -1.692$, $p > .10$, indicating that greater accuracy for intact meaningful relative to meaningless pairs was not the result of a speed/accuracy trade-off. Also, study RTs were faster for meaningful than meaningless ratings, $t(19) = -3.656.$, $p < .01$, suggesting that poorer accuracy for intact meaningless pairs was not due to differential encoding time.

Finally, we evaluated whether explicit memory for the pairs could have driven associative priming performance during Experiment 1A. Two independent *t*-tests (one for the one-presentation condition and the other for the three-presentation condition) were conducted in which $\text{Intact}_{\text{meaningful}}$ RTs from the associative priming task were compared with RTs for $\text{Intact}_{\text{meaningful}}$ hits from the associative recognition task. For both tests, intact pairs during the priming task were judged faster than intact pairs during the recognition task (one-presentation: $t(41) = -6.826$, $p < .001$, three-presentation: $t(47) = -4.535$, $p < .001$), suggesting that the association-specific priming effects obtained here were unlikely to have been influenced by recall-like strategies.

Discussion

The main finding of the current experiment was the substantial increase in RTs when participants had to think back to the study phase in order to decide whether the two pictures had been paired together, which provides additional evidence that the associative priming effect observed in Experiment 1A was not due to contamination from associative recognition processes.

It should be noted, however, that our measure of associative recognition memory (hits for intact pairs minus false alarms for recombined pairs) was also influenced by meaningfulness, as indicated by better associative recognition performance for highly meaningful than for meaningless encoded pairs. Furthermore, both word-stem associative completion priming and associative cued-recall performance in Schacter and Graf's (1986a) experiment were also poorer for the anomalous sentences, and some authors have suggested that their priming measure may have reflected contamination from explicit memory retrieval processes (e.g., Gooding et al., 1999). It could then be argued that since both types of associative memory (i.e., priming and recognition) were modulated by meaningfulness, performance on the associative size judgement task in Experiment 1A could have also reflected the deliberate engagement of recollection-like memory strategies from the previous study phase. For instance, participants could have retrieved the responses associated with the individual items of the intact pairs presented in meaningful sentences, leading to faster priming RTs for only meaningfully studied intact pairs. We, however, consider this argument very implausible, as there would be absolutely no benefit in retrieving the response made at study (i.e., rating sentences) in order to aid the different kind of decision needed at test (i.e., size judgement). Furthermore, RTs did not differ between $\text{Intact}_{\text{meaningful}}$ hits and $\text{Intact}_{\text{meaningless}}$ hits during the associative recognition test, whereas they were shorter for $\text{Intact}_{\text{meaningful}}$ relative to $\text{Intact}_{\text{meaningless}}$ pairs during the priming test. To explain greater associative priming for meaningful- than meaningless-studied pairs based on an associative recognition account, one would expect successful associative recognition memory to have also arisen earlier for meaningful than meaningless pairs, which we did not observe.

Finally, it could also be argued that the RT difference between associative priming and recognition is due to the engagement of different control processes, because the latter task is more difficult and requires more retrieval processes. Thus, partial recognition of objects could have resulted in much faster RTs, and our instructions to take into account whether both objects had been paired together, had the consequence of slowing RTs down. However, partial recognition (e.g., remembering that a specific object had been previously presented) would have been of no help in making an associative decision about a pair, which is at the core of associative priming. Consequently, only if participants remembered *associative* information specific to intact pairs could their performance have been aided by recall processes (e.g., by using one object to cue its studied associate). In fact, that was the reason why we opted for the associative recognition task as opposed to a simple old/new recognition task (e.g., Goshen-Gottstein & Moscovitch, 1995a), because the latter could be performed based solely on item information. As already mentioned, the RT data for the associative recognition memory task showed that the time it takes to accurately judge whether two objects had been paired together is much longer than the RTs during the priming task, which suggests that participants were not trying to recollect responses made to studied objects. Based on this evidence, it is unlikely that strategies based on explicit memory retrieval contributed to the association-specific priming effects obtained in Experiment 1A.

EXPERIMENT 2A

In Experiment 1A, it was shown that associative (but not item) priming benefited to a greater extent from pairs encoded with meaningful sentences, and this finding was interpreted as a reflection of participants engaging in more conceptual processing to link pairs embedded in meaningful sentences than for pairs embedded in meaningless sentences. However, it was also noted that a reliance on a pure conceptually driven explanation of this associative priming effect may be incomplete, since perceptual matching may still be required for associative priming to be observed.

It has been suggested that priming for individual items can survive a change in stimulus format of presentation (e.g., Weldon, Roediger, Beitel, & Johnston, 1995) or sensory modality (e.g., Graf, Shimamura, & Squire, 1985; Jacoby & Dallas, 1981; Schacter & Church, 1992; Schacter & Graf, 1989) between study and test, although the magnitude of priming is usually reduced. The idea is that if a sufficient degree of conceptual processing is allowed at encoding, then access to the same or related conceptual information at test leads to more efficient processing of repeated test items, regardless of stimulus type.

The effect of changing perceptual features between study and test on associative priming, however, is less clear. Early research using the word-stem completion paradigm suggested that association-specific priming depended on the preservation of perceptual information across experimental phases (Schacter & Graf, 1989). Consistent with this, Kan et al. (2011, Experiment 3) did not obtain reliable association-specific priming effects during a perceptual identification task when the format of presentation was changed (from pictures at study to words at test). However, Goshen-Gottstein and Moscovitch (1995b) did find that associative priming was insensitive to manipulation of sensory modality when a relatedness judgement task was administered at test. These studies have also produced conflicting results with respect to item-specific effects as measured in associative-like tasks. Kan et al. (2011) did not find item priming when the format of presentation was changed between study and test, whereas the other two aforementioned studies did find reliable item priming when modality was switched between experimental phases (Goshen-Gottstein & Moscovitch, 1995b; Schacter & Graf, 1989).

One way to resolve the discrepancies found among these studies would be to assume that the study conditions in Goshen-Gottstein and Moscovitch's and Schacter and Graf's studies (generating and rating sentences linking two words, respectively) promoted non-perceptual processing, which may have contributed to the observed cross-modal priming. In contrast, in Kan et al.'s study, participants were only required to name each object at encoding, and thus conceptual representations may not have been accessible or sufficiently strong to support cross-modal priming. However, this does not explain why associative priming was obtained in the relatedness judgement task but not in the word associative stem completion task, unless one assumes that the word-stem completion task is perceptual in nature, and thus modality-specific (but see Richardson-Klavehn and Gardiner (1996), for evidence that the word-stem completion task has a strong conceptual component).

Another possibility could be that whereas item priming does not depend on preserved perceptual information, provided that abstract (e.g., conceptual) representations can support this kind of priming during a conceptually driven test, associative priming may rely on perceptual information, acting as a cue to retrieve conceptual associative links (Graf & Schacter, 1989).

Given that the study task in Experiment 1 requires participants to evaluate the meaningfulness of each sentence linking the pair of objects and, at test, participants must retrieve information regarding semantic properties of objects (i.e., size), one could view this paradigm as an appropriate candidate to test whether associative and item priming could survive a cross-format manipulation. Thus, Experiment 2A was identical to Experiment 1A with the difference that, at test, the words describing the objects replaced the pictures of those same objects. If associative and item priming effects present in Experiment 1A were solely dependent on access to conceptual links formed at study, then priming should also be present after a format switch in the present experiment. Alternatively, if priming effects also rely on the reinstatement of the physical properties of stimuli, then the change in format of presentation should disrupt priming.

Method

Participants. Fifty students of the University of Manchester whose native language was English were recruited. All participants gave written consent before the beginning of the experiment. All had normal or corrected-to-normal vision.

Materials, design and procedure. The materials used in this experiment were similar to the ones used in the previous experiment, with the only differences being that all the objects included in this experiment had names that consisted of a single word (e.g., *ship* as opposed to *washing machine*). The selected objects were also chosen such that their names would evoke unambiguous objects with an obvious size. Furthermore, we took particular care in selecting each object belonging to a specific superordinate category (e.g., insects), such that they would be readily identifiable by their basic level (e.g., ladybird). To maximise word agreement between study and test phases and between participants, an independent group of three judges named each object to establish its appropriate name. Although these steps were performed to minimise inconsistencies in word agreement, participants could nevertheless use a word that would be inappropriate (e.g., they may say *boat* while seeing a *ship*). Thus, to account for this inter-variability in object naming, participants were asked to read each sentence aloud and, in case they used the incorrect word for an object, the experimenter corrected the participant by providing the appropriate name of the object and ask the participant to re-read the sentence using the word given by the experimenter. This was done in order to prevent inconsistencies between the named objects at study and the respective presentation of their words at test, as it has been shown that in tasks for which word agreement between study and test is critical, priming is affected by the degree of dissimilarity in name agreement (e.g., Park & Gabrieli, 1995). The average number of interventions was approximately 10% of the trials. The names of the objects consisted of words between 3 and 11 letters in length with word frequencies ranging between 0 and 352 occurrences per million (M = 23, SD = 54; Kučera & Francis, 1967). Also, minor modifications had to be made to the sentences from Experiment 1A in order to accommodate the new objects.

The experimental design and the procedure in the present experiment were identical to those in Experiment 1A with the following exception to the procedure. At study, participants were required to read each sentence out loud to the experimenter. Each object pair with its associated sentence was presented for up to 20 seconds, in order to ensure that there was enough time for the participant to use the appropriate word in case the experimenter was required to intervene. At test, the names of the objects were presented instead of their corresponding pictures and participants decided which corresponding object was bigger in real life.

Results

Trials with outlying RTs as well as incorrect trials or trials with an absence of a response were excluded from subsequent analyses (approximately 3% for all conditions and participants).

Table 4 shows the mean accuracy and RTs during the size-classification task for each presentation condition. As in Experiment 1A, no effects of accuracy were observed (all Fs < 1), and therefore subsequent analyses focused on the RTs.

A glance at Table 4 shows that with a change in presentation format between study and test phases, intact pairs were not judged more quickly than recombined pairs, although facilitation was detected for recombined pairs when compared with new pairs. A 2 (Number of Presentations: one, three) × 3 (Type of Association: intact, recombined, new) mixed repeated measures ANOVA indicated a significant main effect of Type of Association, $F(2, 96) = 13.142$, MSE = 5071, $p < .001$. The interaction, however, failed to reach significance, $F(2, 96) = 1.014$, MSE = 5071, $p > .10$, and, therefore, the data were collapsed across number of presentations. Pairwise comparisons corroborated the observations made earlier by revealing an item-specific, $t(49) = -4.567$, $p < .001$, but not an association-specific, $t(49) = 1.186$, $p > .10$, effect.

When intact pairs were divided into a meaningful and a meaningless condition and contrasted with recombined pairs, a 2 (Number of Presentations) × 3 (Type of Association) mixed repeated

TABLE 4
Mean accuracy levels (Acc) and RTs for intact, recombined and new associations during the associative size judgement task in Experiment 2A

	One presentation		*Three presentations*	
Type of association	*Acc*	*RTs*	*Acc*	*RTs*
Intact	0.97 (0.01)	1310 (43)	0.98 (0.01)	1242 (54)
Meaningful	0.98 (0.01)	1356 (77)	0.98 (0.01)	1246 (52)
Meaningless	0.97 (0.01)	1308 (38)	0.96 (0.02)	1196 (77)
Recombined	0.96 (0.01)	1275 (35)	0.98 (0.01)	1246 (49)
Meaningful	0.97 (0.03)	1112 (63)	0.98 (0.01)	1239 (49)
Meaningless	1.00 (0.00)	1286 (119)	0.97 (0.01)	1286 (61)
New	0.96 (0.01)	1385 (46)	0.97 (0.01)	1312 (55)

The means for the overall intact and recombined conditions are not the average of meaningful and meaningless pairs because they are based on different observations – see Results section of Experiment 1A for a description. Standard error of the means within parentheses.

measures ANOVA yielded no main effect of Type of Association or interaction (both Fs < 1).

For recombinations, a 2 (Number of Presentations) × 3 (Type of Association) mixed repeated measures ANOVA yielded a main effect of Type of Association only, $F(2, 38) = 4.191$, $MSE = 8459$, $p < .05$. Recombined objects that had been presented with meaningful sentences (1210 ms) were judged faster than new pairs, $t(26) = -3.783$, $p < .05$, as were recombined objects that had been presented with less meaningful sentences (1286 ms), $t(26) = -1.729$, $p < .05$ [one-tailed].

As with Experiment 1A, the critical one-presentation condition was divided into two categories (meaningful and meaningless pairs) and analysed separately, but no significant differences were found between those categories when intact and recombined pairs were contrasted (both $p > .10$). Importantly, item priming approached significance when both recombined objects had been judged with either a highly meaningful or meaningless sentence, $t(4) = -1.943$, $p = .06$ and $t(7) = -1.873$, $p = .055$ [one-tailed], respectively.

Inter-experimental analysis (Experiments 1A and 2A). In order to determine whether the lack of associative priming in the present experiment could have been the result of a Type II error, priming scores were calculated separately for associative (recombined minus intact pairs) and item (new minus recombined pairs) priming, and the data submitted to a 2 (Experiment: Experiment 1A, Experiment 2A) × 2 (Number of Presentations) × 2 (Type of Priming: associative, item) mixed repeated measures ANOVA.[3] The only reliable effects were the main effect of Type of Priming, $F(1, 87) = 9.239$, $MSE = 17{,}791$, $p < .01$, indicating more item (67 ms) than associative priming (6 ms), and the interaction between Experiment and Type of Priming, $F(1, 87) = 6.630$, $MSE = 17{,}791$, $p < .05$, indicating that priming scores differed across experiments. Collapsed across number of presentations, two independent t-tests, using Experiment as the grouping variable, showed that whereas item priming effects did not differ across experiments, $t(98) = -0.817$, $p > .10$, associative priming was present in Experiment 1A (53 ms) but not in Experiment 2A (−31 ms), $t(68.018) = 2.854$, $p < .01$.

Discussion

The results from the present experiment shed additional light on the arguments used in the Discussion of Experiment 1A. First, a change in stimulus format between study and test phases eliminated the associative priming effect that had been observed in Experiment 1A without such change. Second, and contrary to what had been observed in Experiment 1A, intact pairs encoded with meaningful sentences in the one-presentation condition did not show an RT advantage over recombined pairs; thus, no associative priming

[3] Because associative (but not item) priming was modulated by meaningfulness, associative priming was defined as the difference between Recombined and $\text{Intact}_{\text{meaningful}}$ pairs in this analysis.

was observed in the present experiment. Third, item priming occurred with the same change of presentation format, regardless of number of presentations and was not modulated by meaningfulness.

The elimination of novel associative priming due to changes in the format of presentation suggests that perceptual matching between study and test phases is essential for this kind of priming to occur. This finding indicates that retrieval of associative conceptual links alone is not the sole source of the association-specific effect observed in Experiment 1A; rather, both conceptual and perceptual links seem to act in concert to support novel associative priming. Thus, even if conceptual processing is maximised at study and test (as in this and previous experiments), preservation of structural information seems to be critical in order to obtain association-specific effects. Although this is consistent with previous findings that also reported format/modality-specific associative effects (Kan et al., 2011; Schacter & Graf, 1989), at least one study (Goshen-Gottstein & Moscovitch, 1995a, Experiment 3) did find reliable associative priming after a modality switch. It should be noted, however, that Goshen-Gottstein and Moscovitch measured priming as a response inhibition for intact pairs relative to recombined pairs (i.e., negative associative priming), and, for that reason, some caution must be exercised when comparing across different measures of priming. Interestingly, when collapsed across number of presentations, we also observed a negative priming effect for the comparison between Intact and Recombined (–22 ms) as well as for the comparison between $\text{Intact}_{\text{meaningful}}$ and Recombined (–31 ms), although these effects failed to reach significance. This negative trend was unexpected and even though we are presently unable to provide an explanation as to why changing format of presentation would lead to negative associative priming, it is, nevertheless, consistent with Goshen-Gottstein and Moscovitch's finding.

In contrast, item priming was observed despite the same changes in stimulus format, consistent with several single-item studies investigating conceptual priming after a change in the visual features of stimuli, such as in cross-modality studies (e.g., Graf et al., 1985; Jacoby & Dallas, 1981; Srinivas & Roediger, 1990). Furthermore, there was some evidence that meaningfulness did not modulate the magnitude of this effect. Thus, it appears that the type of conceptual information that supports item priming is qualitatively different from the one that supports associative priming (see General Discussion).

EXPERIMENT 2B

As with Experiment 1B, we decided to measure associative recognition memory under the same testing circumstances as in the previous experiment, in order to determine whether associative recognition would also be sensitive to changes in stimulus format. If, as with associative priming in the previous experiment, associative recognition was at least reduced after a format switch, this would indirectly suggest that associative priming may be influenced by associative recognition. If, in contrast, associative recognition in the present experiment was insensitive to changes in presentation format between study and test phases, it would provide additional evidence that associative priming in Experiment 1A was not contaminated by explicit memory processes.[4]

Method

Participants. Fifty students of the University of Manchester were recruited whose native language was English. All participants gave written consent before the beginning of the experiment. All had normal or corrected-to-normal vision.

Materials, procedure and design. The materials, procedure and design were the same as in Experiment 2A, with the exception that an associative recognition memory task similar to that in Experiment 1B was administered at test.

Results

Trials with outlying RTs as well as incorrect trials or trials with an absence of a response were excluded from subsequent analyses (approximately 10% for all conditions and participants).

The recognition data scores are presented in Table 5. The corrected hit rate (PR) was computed by subtracting false alarm rate (i.e., "yes" responses to recombined items) from intact hit rate (i.e., "yes" decisions to intact pairs), and an

[4] It should be noted however that such single dissociations could result simply due to differences in task sensitivity (see Berry, Shanks, Speekenbrink, & Henson, 2012, for a review).

TABLE 5
Proportion of responses (Pr) and mean RTs for intact hits, intact misses, recombined correct rejections and false alarms and new correct rejections and false alarms during the associative recognition task in Experiment 2b

	One presentation		*Three presentations*	
Category	*Pr*	*RTs*	*Pr*	*RTs*
Intact HIT	0.79 (0.03)	1687 (38)	0.91 (0.02)	1577 (59)
Meaningful	0.82 (0.03)	1666 (51)	0.91 (0.02)	1553 (60)
Meaningless	0.75 (0.05)	1669 (57)	0.92 (0.03)	1613 (106)
Intact MISS	0.21 (0.03)	1599 (82)	0.09 (0.02)	1678 (166)
Recombined CR	0.48 (0.04)	1861 (50)	0.64 (0.04)	1843 (62)
New CR	0.99 (0.01)	1408 (38)	0.99 (0.005)	1323 (60)
Recombined FA	0.51 (0.04)	1898 (62)	0.36 (0.04)	1785 (71)
New FA	0.01 (0.01)	1466 (165)	0.01 (0.005)	1875 (601)

The means for the overall intact and recombined conditions are not the average of meaningful and meaningless pairs because they are based on different observations – see Results section of Experiment 1A for a description. Standard error of the means within parentheses.

HIT, hits; MISS, misses; CR, correct rejections; FA, false alarms.

independent *t*-test was conducted using Number of Presentations as the between-subject factor. Accuracy was higher for three-presentation condition (0.55) relative to the one-presentation condition (0.28). Nevertheless, associative recognition scores were above chance levels for both presentation conditions (one-presentation: $t(24) = 6.024$, $p < .001$, three-presentations: $t(24) = 11.294$, $p < .001$).

As with Experiment 1B, we also examined the effects of meaningfulness on successful recognition memory by subtracting recombined false alarms from both intact hits consisting of pairs presented with highly meaningful sentences ($PR_{meaningful}$) as well as intact hits consisting of pairs presented with less meaningful sentences ($PR_{meaningless}$). A 2 (Number of Presentations) × 2 (PR) mixed repeated measures ANOVA did not reveal either a main effect or an interaction (all *F*s <1.2).

Similar to what was done in Experiment 1B, we analysed the one-presentation condition separately as these data provide a cleaner indication of the effects of meaningfulness on accuracy (i.e., each pair was presented with *only* a highly meaningful or meaningless sentence). Although the comparison between $PR_{meaningful}$ and $PR_{meaningless}$ hits did not approach significance, $t(24) = 1.204$, $p > .10$, there was still a numerical trend for better accuracy for pairs that had been encoded with meaningful (0.30) than meaningless (0.24) sentences. This modest advantage occurred despite the fact that recognition RTs for pairs encoded with meaningful sentences (1643 ms) were not significantly different than those for pairs encoded with meaningless sentences (1665 ms), $t(20)= -0.365$, $p > .10$, indicating that greater accuracy was not the result of a speed-accuracy trade-off.

Inter-experimental analysis (Experiments 1B and 2B). In order to determine whether associative recognition memory scores differed between Experiments 1B and 2B we conducted a 2 (Experiment) × 2 (Number of Presentations) × 2 (PR: $PR_{meaningful}$, $PR_{meaningless}$) mixed repeated measures ANOVA. This analysis only yielded a main effect of PR, $F(1, 93) = 9.891$, $MSE = 0.179$, $p < .01$, with greater associative recognition performance for $PR_{meaningful}$ (0.43) than $PR_{meaningless}$ (0.37) and an interaction between PR and Number of Presentations, $F(1, 93) = 8.142$, $MSE = 0.147$, $p < .01$, resulting from a larger difference between $PR_{meaningful}$ and $PR_{meaningless}$ in the one-presentation (0.11) relative to three-presentation condition (0.006). Importantly, none of the interactions involving the Experiment factor approached significance. Thus, the fact that associative scores were similar across Experiments 1B and 2B whereas associative priming was eliminated in Experiment 2B but present in Experiment 2A further excludes the possibility of explicit memory contamination in associative priming.

Finally, we also conducted an ANOVA on RT data for the one-presentation condition using Type of Association ($Intact_{meaningful}$ and $Intact_{meaningless}$ hits) and Experiment (Experiments 1B and 2B) as factors. Only the main effect of Type of Association, $F(1, 71) = 4.513$, $MSE = 27{,}500$, $p < .05$, reached significance, with slightly shorter RTs for $\text{Intact}_{\text{meaningful}}$ relative to $\text{Intact}_{\text{meaningless}}$ hits.

Discussion

The main finding of the present experiment was the observation of two behavioural dissociations between associative priming and recognition. Although Experiment 2 was similar to Experiment 1 with the only difference being that the names of the objects replaced their corresponding pictures at test, the data showed that despite *similar* levels of associative recognition memory and RTs between Experiments 1B and 2B, associative priming was found in Experiment 1A but eliminated in Experiment 2A. The presence of these behavioural dissociations between associative priming and recognition is indicative that association-specific priming effects observed here were uncontaminated by explicit memory, and therefore represent a genuine form of unconscious memory (although see Footnote 4).

It is also interesting to note that, if anything, RTs for $\text{Intact}_{\text{meaningful}}$ hits were shorter than those for $\text{Intact}_{\text{meaningless}}$ hits in Experiment 2B. In Experiment 2A, RTs for $\text{Intact}_{\text{meaningful}}$ pairs were, in fact, numerically larger than RTs for either $\text{Intact}_{\text{meaningless}}$ or recombined pairs. Although this negative associative priming effect clearly warrants further investigation, it, nevertheless, provides support for our conclusion that associative priming and recognition were functionally independent.

EXPERIMENT 3

The results from the previous two experiments suggest that a combination of both perceptual and conceptual processes contributed to the associative priming observed in Experiment 1A. Item priming, on the other hand, was insensitive to manipulations of items' perceptual features between study and test, thus demonstrating reliable cross-format priming. However, in these experiments, the study task involved a high degree of elaboration (embedding objects within sentences) and several studies have shown that elaboration is not a pre-requisite for novel associative priming to occur in tests that emphasise processing of the stimulus form (e.g., Goshen-Gottstein & Moscovitch, 1995a; Kan et al., 2011; Musen & Squire, 1993; Reingold & Goshen-Gottstein, 1996a). However, most of these studies employed word stimuli associations, so it is possible that other factors such as stimulus overlearning, semantic processing, incidental elaboration and/or treatment of word pairs as compound words may have contributed to the overall priming effect. An exception to this was Kan et al.'s (2011) study that showed novel associative priming for object pictures in a perceptual identification test. However, the effects were rather small (e.g., 7% in one of the comparisons) and the contribution of explicit memory to this effect cannot be completely ruled out (e.g., because their priming measure was based on accuracy, participants would have time to engage in explicit retrieval strategies). Furthermore, the study task used in their experiment (object naming) is believed to involve a strong conceptual component (e.g., Bruce & Humphreys, 1994). To the extent that participants engaged in semantic encoding, it is possible that the effects obtained during the priming test were the result of partially retrieved conceptual links, casting doubt on the priming effects in their experiment being the result of re-engaging in mainly perceptual processing. Although they observed that associative priming was eliminated when the pictures at study were replaced by their corresponding names at test (which was used as evidence that associative priming was perceptually based), this finding on its own is not sufficient to argue in favour of a mainly perceptually based associative priming effect, since, even with more conceptually oriented tasks that tap conceptual priming, associative priming can still be completely disrupted by manipulations of the format of presentation between study and test phases (e.g., Schacter & Graf, 1989; see also Experiment 2A of the present report).

Therefore, the aim of the present experiment was to investigate whether we could produce reliable association- and item-specific priming effects that mainly depended on perceptual processing. We used a very shallow encoding task that directed participants' attention to the perceptual form of pictures (deciding which picture is bigger on the computer screen) in order to minimise semantic processing of stimuli at encoding. At test, they performed a speeded object-decision task, a task also believed to engage extensive perceptual processing (e.g., Srinivas, 1995). Two opposing views about the roles of perceptual and conceptual processing in associative and item priming seem possible. First, perceptual encoding may allow for a new associative perceptual priming-supporting memory representation to be created in memory that will adequately support priming during a perceptual test task, resulting in reliable association-specific effects. Second, and in contrast, novel associative priming may always depend on some degree of conceptual processing at study and test no matter how perceptually loaded the priming task and, therefore, when encoding is largely perceptual, association-specific effects will not be obtained. In any case, we predicted item priming under these study/test conditions because a considerable amount of research has shown reliable item specific priming effects that were mainly perceptually based (e.g., Blaxton, 1989; Rajaram & Roediger, 1993; Roediger, 1990). As with the previous two experiments, each pair was studied either once or three times in order to determine whether multiple study presentations are necessary for perceptual priming for novel associations, as it has been suggested elsewhere (e.g., Musen & Squire, 1993).

Method

Participants. Forty-four students of the University of Manchester were recruited. All participants gave written consent before the beginning of the experiment. All had normal or corrected-to-normal vision.

Materials. Stimuli comprised 190 (10 for practice) black-and-white clipart pictures of common objects, largely taken from the previous experiments. The pictures were cleaned from shadows and other external features. In addition, a different set of 40 pictures (4 for practice) depicting different objects were altered to create non-objects used in the test task (see Figure 2). These non-objects were included in the experiment only to allow for object decisions. To create the non-objects, a 3 × 3 grid was superimposed on top of the image and the resulting nine cells were rearranged into a new image configuration. This procedure ensured that the resulting images (1) resembled real objects, thus, making the test task more challenging, (2) contained, on average, the same luminosity and spatial frequency, and (3) were as visually complex as real objects (e.g., equivalent number of image lines).

Eighteen groups of pictures, each containing 10 pictures, were formed. Each group was further divided into two subgroups, each of these containing five pictures of common objects. As with the previous experiments, the objects of one of the subgroups were unrelated to the objects of the other subgroup using the same relatedness checks performed for Experiment 1A.

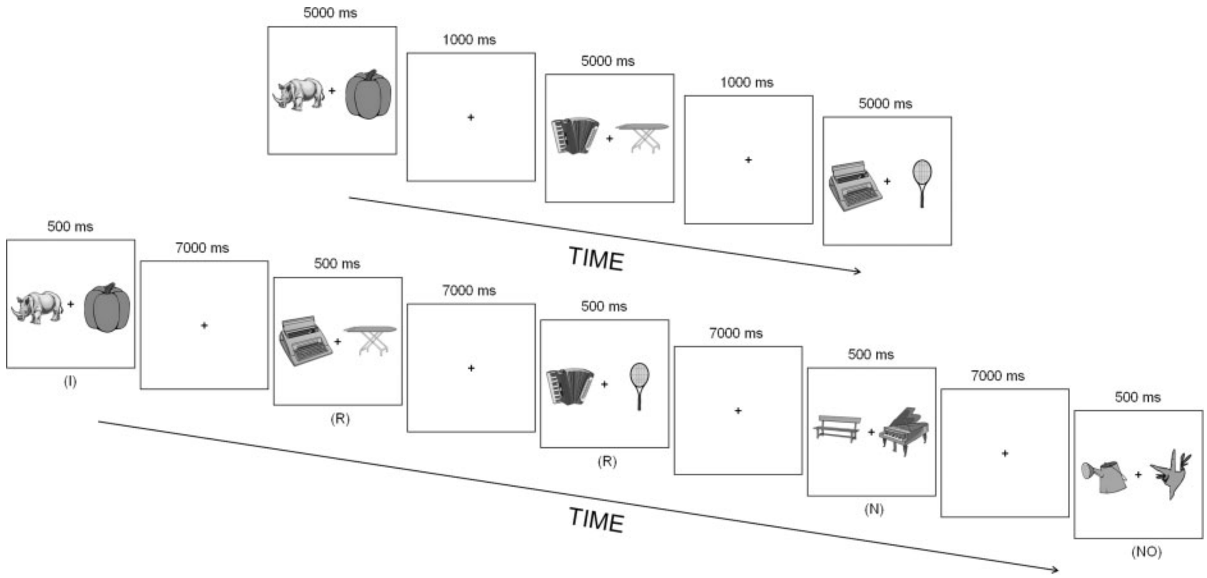

Figure 2. Experimental paradigm of Experiment 3. At study (top), participants decided which picture was bigger on the screen, whereas at test (bottom) they engaged in an object decision task.
The number above each event corresponds to the duration of that event in milliseconds. I = Intact pairs, R = Recombined pairs, N = New pairs, NO = Non-object−Object pairs.

Within each group, the pictures from one of the subgroups were randomly paired with the pictures from the other subgroup. Study pairs were formed by randomly selecting twelve groups from the pool of 18 groups, making up 60 pairs to be presented at study. The remaining six groups were used to form the new pairs. In half of the study trials, the bigger picture was on the right side, whereas, in the other half, the bigger picture was on the left side. There were an approximately equal number of size-congruent pairs (i.e., the bigger picture on the screen was also the bigger object in real life) and size-incongruent pairs (i.e., the bigger picture on the screen was not the bigger object in real life).

For the object-decision task, one pair of each group was randomly selected in order to re-pair their pictures with the 36 pictures of non-objects, comprising 36 object–non-object trials. For the object–object trials, two pairs were randomly chosen from each study group to form the intact pairs. The pictures of the remaining two pairs of each study group were re-arranged such that one of the pictures of a subgroup was recombined with the picture of the other subgroup.

In order to prevent participants from basing their decisions considering solely one of the objects (i.e., if non-object associations consisted of two non-objects and real object associations of two real objects, then participants could classify associations as either real or unreal based on only one of the pictures), a non-object association consisted of a real object and a non-object. An additional precaution was taken to discourage participants from automatically judging an association as real because of their involuntary retrieval of a given picture (i.e., if participants recognised that a picture of an elephant had been shown at study, they may have assumed that the association was real since only real associations had been shown during the study phase). For that goal, 24 pictures that had been shown at study were recombined with non-objects to form object–non-object associations. An additional 12 new pictures were also recombined with pictures of non-objects to create the total number of 36 object–non-object associations.

In sum, there were 72 pairs of object–object pictures, of which 24 consisted of intact pairs, 24 recombined pairs and 24 new pairs. In addition, 36 pairs of object–non-object pictures were created by repairing 24 pictures from the study phase plus 12 novel pictures with the 36 pictures of non-objects.

Procedure. Participants were told they were going to see a series of pairs of pictures of common objects in black-and-white and were instructed to decide which picture had a bigger size on the computer screen. They were also told that they should mentally superimpose the two pictures, so that the decisions were based on overall size rather than a specific geometrical measurement (e.g., length). It was further emphasised that the real size of the objects that the pictures represent was irrelevant to the experiment, and that they should only consider the size of the pictures on the screen (see Figure 2). After a few practice trials, participants started the experimental study phase. A fixation cross appeared for 1000 ms followed by a pair of pictures for 5000 ms. Participants responded using the left and right control keys on the computer keyboard depending on which picture was bigger (left or right). A group of 24 participants saw each pair once, whereas a second group of 24 participants saw each pair three times (with a different sequence for each run). Immediately after the study phase, each group of participants engaged in an object-decision task. They were told that they should decide as quickly and accurately as possible whether an object pair comprised two real objects. After a few practice trials to ensure participants could perform the task correctly, the test task was initiated. Each trial began with the presentation of a fixation cross for 2000 ms followed by an association in one of the conditions (intact, recombined, new, non-object) for 500 ms. A fixation cross was then displayed for 5000 ms to indicate to participants that they should respond. Participants pressed either the left or right control keys (counterbalanced across participants) to judge whether the two pictures represented real or real/unreal objects.

Design. The experimental design was identical to that of Experiment 1A

Results

Trials with outlying RTs as well as incorrect trials or trials with an absence of a response were excluded from subsequent analyses (approximately 4% for all conditions and participants).

Table 6 shows the mean accuracy and RTs for intact, recombined, new and non-object pairs for each presentation condition.

TABLE 6
Mean accuracy levels (Acc) and RTs for intact, recombined, new and non-object associations in Experiment 3

	One presentation		*Three presentations*	
Type of association	*Acc*	*RTs*	*Acc*	*RTs*
Intact	0.97 (0.01)	819 (40)	0.98 (0.005)	752 (30)
Recombined	0.97 (0.01)	840 (38)	0.99 (0.005)	773 (36)
New	0.97 (0.01)	871 (40)	0.95 (0.01)	831 (33)
Non-object	0.93 (0.02)	874 (38)	0.94 (0.01)	815 (26)

Standard error of the mean within parentheses.

Regarding accuracy scores, a 2 (Number of Presentation) × 3 (Type of Association) mixed repeated measures ANOVA was conducted. This only revealed a trend for a significant interaction, $F(2, 92) = 2.872$, $MSE = 0.001$, $p = .062$, as a consequence of greater accuracy for intact and recombined pairs than new pairs in the three-presentation, but not the one-presentation, condition (see Table 6).

The ANOVA on the RT data, on the other hand, only showed a significant main effect of condition, $F(1.767, 81.304) = 25.814$, $MSE = 2069.30$, $p < .001$, with intact pairs (786 ms) judged more quickly than recombined pairs (806 ms), as well as quicker RTs for recombined relative to new pairs (851 ms). Separate *t*-tests for one- and three-presentation conditions revealed that item priming was significant in both presentation conditions (one-presentation: $t(23) = -2.649$, $p < .05$, three-presentation: $t(23) = -5.708$, $p < .001$). Associative priming was also reliable after three study presentations ($t(23) = -2.151$, $p < .05$), although after a single presentation the *t*-test only approached significance ($t(23) = -1.425$, $p = .08$ [one-tailed]). Nevertheless, the interaction failed to reach significance, $F(1.767, 81.304) = 1.355$, $MSE = 2069.30$, $p > .10$, suggesting that the magnitude of these priming effects was similar between the two presentation conditions.

Discussion

The main finding of the current experiment was the observation of an associative priming effect, measured by RTs during an object decision task, without the need to encode pairs elaboratively (participants needed only to decide which picture was physically bigger on the screen). Furthermore, associative priming did not benefit from increased repetition at study, which suggests that one study presentation is sufficient to allow the formation of an adequate perceptual associative representation that supports perceptual associative priming. Indeed, this result fits well with existing evidence of reliable novel associative priming in various perceptual test tasks (e.g., Goshen-Gottstein et al., 2000; Light, Kennison, Prull, LaVoie, & Zuellig, 1996), including one study using pictorial stimuli (Kan et al., 2011).

It could be argued, however, that since novel associative priming depended on conceptual and perceptual processes in Experiment 1A, participants engaged in conceptual processing either before or during the primed response in the present experiment. If that was the case, then, as with Experiment 1A, the association-specific effect observed in the present experiment would reflect a contribution of both perceptual and conceptual processes. Although we cannot completely dismiss this possibility, it should be noted that the encoding task used in the present experiment was relatively low level and participants' attention was directed to the form of the pictures rather than to their meaning. In fact, the majority of the encoding tasks used in previous novel associative perceptual priming studies required participants to direct their attention to the stimulus identity (e.g., reading words or naming objects), whereas in the present experiment, such object identification was likely to have been incidental to the task aims. In addition, information at the perceptual level was likely to be particularly relevant during the object-decision priming task, especially considered the rapid presentation rate with which object pairs were shown (500 ms) as well as the speed-stress instructions. Thus, we believe that the highly perceptually loaded encoding and test tasks included in the current experiment make it very plausible that the priming effects observed mainly depended on perceptual information, with minimal contribution from conceptual information.

GENERAL DISCUSSION

Three experiments were conducted with the purpose of investigating the conditions under which novel associative priming (a kind of unconscious memory for associations between pre-experimentally unrelated items) for pictorial stimuli can occur, as well as to examine differences between this kind of priming and item object priming. To that aim, we manipulated the type of encoding, study/test changes in presentation format, type of test task and number of study presentations. Our results showed that associative priming was affected by manipulations of meaningful elaboration (Experiment 1A) and study/test perceptual overlap (Experiment 2A) when the two objects had been previously linked in memory. Analysis of RT data as well as the observation of two dissociations between associative priming and recognition performance indicated that association-specific effects were not contaminated by recollection-based strategies (Experiment 1 and 2). Contrary to associative priming, item priming was neither influenced by meaningfulness nor by study/test changes, indicating that this kind of priming was supported by different kinds of information. Experiment 3 showed that both kinds of priming were observed when study/test demands mainly focused on perceptual analysis of the object pairs, suggesting that both association- and item-specific effects can be obtained despite the absence of elaborative encoding. Finally, one study presentation was sufficient to produce reliable associative (Experiments 1A and 3) and item priming (Experiments 1A, 2A and 3), with no apparent benefit from multiple trial learning. In the next paragraphs we examine these findings in greater detail.

In Experiment 1A, participants rated, at study, the meaningfulness of sentences linking two unrelated object pictures, and, at test, intact (object pairs previously studied together), recombined (objects previously studied in separate pairs) and new associations (objects not presented at study) were presented and participants decided which corresponding object of an association was bigger in real life. Novel associative priming (indicated by faster RTs for intact relative to recombined pairs) was only obtained after intact pairs had been related in a meaningful way, which indicates that reinstatement of perceptual information alone was insufficient to produce associative priming in this task, and that retrieval of meaningful associative conceptual links (i.e., sensible semantic relations between objects) was an important aspect for this kind of priming to emerge. However, the fact that associative priming was eliminated in Experiment 2A after the format of presentation was changed from study to test suggests that this kind of priming does not depend solely on the establishment of meaningful conceptual links, but also hinges on the preservation of perceptual information, even when test demands require analysis of semantic information. This result is inconsistent with interpreting priming effects in terms of processing accounts (e.g., Roediger, 1990), which would predict cross-format associative priming in Experiment 2A. This is because conceptual processing should have been emphasised in both experimental phases of Experiment 2A and conceptual priming is believed to survive study/test changes in the presentation format of stimuli.

Associative priming's dependence on perceptual information agrees, however, with views which propose that the specific perceptual arrangement of pairs may act as a trigger to recover conceptual links (e.g., Graf & Schacter, 1989; Schacter & Graf, 1989), and changes in the format of presentation prevent access to such information. Thus, it may be reasonable to assume that if changing the presentation format of stimuli between study and test phases disrupts associative priming, then subtler alterations in the physical appearance of intact pairs should also diminish, although probably not eliminate, associative priming. Despite the non-inclusion of such a condition in the current experiments, some studies have indeed observed a slow-down in reading speed when intact word pairs changed the left–right configuration from study to test (e.g., Moscovitch et al., 1986; Poldrack & Cohen, 1997). Together, these results support the idea of "configural representations" underlying priming for new associations (Gooding et al., 2000); that is, in order for novel associative priming to occur the different components of an association need to be established in an integrated representation and processed/retrieved as a perceptual unit, even when study/test demands require the retrieval of conceptual associative links. This important contribution of perceptual integration to priming for novel associations suggests that the representations supporting associative long-term priming are at least relatively inflexible (i.e., tied to study-specific information such as modality of presentation). Perceptual integration of a multicomponent stimulus means that these components must be bound together in a strong fashion, but not necessarily that they have been unitised into a single item (see Mayes et al., 2007). Future studies employing designs with varying degrees of perceptual representational dissimilarity between study and test phases will be needed to confirm the suggested role of perceptual integration.

Interestingly, item priming was insensitive to manipulations of format of presentation, suggesting that it was heavily mediated by conceptual processes in Experiments 1A and 2A. However, the nature of the conceptual processes that supported item priming appear to be distinct from those that supported associative priming in Experiment 1A, since meaningfulness did not apparently influence item priming. One possibility could be that meaningless sentences may still provide useful object-related semantic information at the object level that can support item priming. For example, in order to judge a sentence such as “The train was eating with the elephant” as meaningless, one must consider whether the action of the sentence (i.e., to eat) is adequately applied to the subject/object of the same sentence (i.e., *train* and *elephant*, respectively). In order to do this one must extract functional knowledge of the train and the elephant from semantic memory (Tulving, 1972). Therefore, repeated access to pre-existing conceptual representations of each individual object likely mediated item priming performance during the size judgement task. Information retrieved in this manner is, nevertheless, insufficient to support associative priming because this type of retrieval emphasises individual meaning of objects rather than associative aspects. In this respect, meaningful study elaboration may have allowed the creation of an associative representation that contained information linking the two previously unrelated objects. This mnemonic linking was especially effective for pairs associated at study by meaningful sentences because these sentences possess several attributes that make possible a successful interpretation combining both items of a pair into a single associative memory (Graf & Schacter, 1989).

When study elaboration is absent, however, other, more direct forms of retrieval of associative conceptual memories may prevail (i.e., encoding specificity). For instance, Dew and Giovanello (2010b) showed that when participants performed a size-classification task (which object is more likely to be found *inside* the house?) at both study and test, associative priming was observed. However, when the cue was reversed at test (which object is more likely to be found *outside* the house?), associative priming was eliminated. These results fit well with theories that explain priming as the result of particular responses/decisions being associated with a particular stimulus (e.g., Dennis & Schmidt, 2003; Dobbins et al., 2004; Horner & Henson, 2008, 2009; Logan, 1990). Specifically, intact pairs could have been bound to specific decisions at study, and, once a pair was repeated at test, its associated decision was obligatory retrieved. In the case where the study and test task remained the same, the retrieved test decision was appropriate, leading to faster RTs to intact pairs. However, when the task was reversed at test, a recomputation of an appropriate decision was required, leading to a slow-down in RTs, and, consequently, a disruption in associative priming.

It follows that elaboration may provide several potential retrieval routes for associative conceptual memories that are not limited to, but can act concurrently with, the retrieval of previously learned responses. For example, in judging the sentence “The train transported the elephant”, participants need to consider whether the train could be adequately used to transport an elephant, which, indirectly, contains associative information regarding size (e.g., since the train is bigger than the elephant, it can transport the elephant). This idea is reminiscent of the encoding variability hypothesis, which states that after a number of different encodings a memory representation is associated with multiple retrieval routes and it can later be accessed via any of these routes (e.g., Cuddy & Jacoby, 1982; Glenberg, 1979; McDaniel & Masson, 1985). To the extent that semantic elaboration leads to an agglomeration of distinct but interconnected interpretations of a single input (Anderson & Reder, 1979), our findings indicate that elaboration may support associative priming by incidentally augmenting the number of retrieval routes available, such that associations among various object attributes (e.g., size) may be incidentally encoded, with the potential to be later retrieved in a different context than that of the study episode (i.e., when study and test task requirements differ). On this account, we have no reason to suspect that associative priming would not be obtained if the test task required participants to decide which object of a pair was smaller (i.e., the opposite question to the one used in Experiments 1A and 2A). In fact, future experiments could make use of different test tasks, with varying levels of demand, in order to evaluate the extent to which elaboration may still provide a valid route to access associative memories.

Interestingly, in Experiment 3, both associative and item priming effects were present in an object-decision task, regardless of the number of study presentations. Importantly, strong conceptual links were unlikely to have been formed at encoding, considering that the study task was relatively low level (deciding which of two pictures was bigger on the screen). Note that we are not arguing that participants were completely unaware of what the objects represented. In fact, considering the automaticity of object recognition (e.g., Carr, McCauley, Sperber, & Parmelee, 1982; Tipper, 1985), we acknowledge that even during this task some form of object identification was likely to have occurred and this may have contributed to the priming effects obtained here. We do maintain, however, that given the different ways we directed participants' attention away from conceptual analysis of the stimuli, the contribution of higher-level conceptual representations was likely to have been very small. Furthermore, participants were encouraged to relate the two figures at study by mentally imagining the two pictures of objects superimposed on each other. These encoding conditions may have fostered the establishment of a representation that integrated the distinct constituents of a pair into a single perceptual entity. The perceptual nature of the object-decision task (e.g., Srinivas, 1995) in conjunction with the emphasis placed on surface encoding and, consequently, the overlap in perceptual processes between study and test, may have been sufficient to produce novel associative and item priming in this experiment.

Although the object-decision task is not relational in nature, it has been argued that such relational processing is not a pre-requisite for retrieval of associative perceptual links (Goshen-Gottstein & Moscovitch, 1995a) so long as the binding of items has been established at encoding. One possibility could be that once both objects have been integrated, identification of one of the objects at test can cue identification of its studied associate. Given that this associative link is specific to intact pairs, recombinations would be processed slightly slower, resulting in associative priming. Nevertheless, item priming was still observed, presumably because identification of each recombined object was facilitated by previous identification of those same objects, consistent with the perceptual/conceptual processing framework. An interesting question for future research would be whether the same perceptual input modules that support item priming also represent perceptual associative information.

CONCLUSION

Three experiments were conducted which explored the cognitive bases of novel associative priming and their relation with item priming. Conceptual association-specific priming effects were obtained when intact pairs were related meaningfully, and this effect occurred even after a single study presentation. Preservation of the perceptual features of stimuli between study and test, however, was crucial for the occurrence of associative, but not item, priming, which was also not influenced by the meaningfulness of the sentences. It was also shown that elaboration is not a pre-requisite to obtain either associative or item priming, provided that study/test task demands focus on the perceptual characteristics of the stimuli. The possibility that recollection-based strategies contaminated associative-specific performance was ruled out, as reflected by (1) an RT difference between how long it took to make an explicit (associative recognition memory) and an implicit (associative priming) memory judgement, and (2) dissociations between the associative priming and recognition performance.

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