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Memorable objects are more susceptible to forgetting: Evidence for the inhibitory account of retrieval-induced forgetting

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RUNNING HEAD: Recognition-induced forgetting for memorable objects

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Abstract

Retrieval of target information can cause forgetting for related, but non-retrieved, information – retrieval-induced forgetting (RIF). The aim of the current studies was to examine a key prediction of the inhibitory account of RIF – interference dependence – whereby ‘strong’ non-retrieved items are more likely to interfere during retrieval and therefore, are more susceptible to RIF. Using visual objects allowed us to examine and contrast one index of item strength –object typicality, that is, how typical of its category an object is. Experiment 1 provided proof of concept for our variant of the recognition practice paradigm. Experiment 2 tested the prediction of the inhibitory account that the magnitude of RIF for natural visual objects would be dependent on item strength. Non-typical objects were more memorable overall than typical objects. We found that object memorability (as determined by typicality) influenced RIF with significant forgetting occurring for the memorable (non-typical), but not non-memorable (typical), objects. The current findings strongly support an inhibitory account of retrieval-induced forgetting.

In our everyday interactions with the world we are required to retrieve information from memory about stimuli that populate our world, such as faces or objects. Successes in remembering are always welcome but can come at the cost of interfering with other memories (e.g., Roediger, 1973; Tulving & Arbuckle, 1963). For instance, when shopping at the local grocery store we might try to remember which fruits were on our shopping list (which we forgot to bring). In a moment of intuition we remember oranges were on our list but when we go home with our bag of oranges we realize that we had forgotten to buy the apples that were also on our list - why? At least two decades of research on remembering and forgetting has shown that the act of remembering information can cause forgetting of related information (e.g., Anderson, Bjork & Bjork, 1994).

One paradigm used to examine the costs of remembering on related information is the *retrieval practice paradigm* introduced by Anderson et al. (1994). In a typical retrieval practice experiment, participants study categories of related items (e.g., Fruit – apple, banana, orange, strawberry; Vehicle – car, bicycle, airplane, bus). Participants then perform retrieval practice on half of the items from half of the categories (e.g., Fruit – ap___, Fruit – ba___), establishing three item types which differ in retrieval status: practiced items from the practiced category (Rp+ items; Fruit –apple, banana); unpracticed items from the practiced category (Rp- items; Fruit – orange, strawberry); and unpracticed items from the unpracticed category (Nrp items; all items from the Vehicle category). Memory for the three item types is then tested in a memory retrieval test. Typically, two findings occur. First, as might be expected, the practiced (Rp+ items, e.g., apple, banana) items are facilitated in comparison to the unpracticed items from the unpracticed categories (Nrp items, e.g., vehicles) – the *retrieval practice effect*. Secondly, and more surprisingly, recall of unpracticed items from the practiced categories (Rp- items, e.g., orange, strawberry) are impaired in comparison to the also unpracticed but unrelated Nrp items (i.e., Vehicle – car, bicycle, airplane, bus). This phenomenon is called the *retrieval-induced forgetting* (RIF) effect (see Murayama, Miyatsu, Buchli, & Storm, 2014 for a recent review).

One explanation of RIF posits an important role for inhibitory processes (e.g., Anderson et al., 1994; Anderson & Spellman, 1995), which may be acting either at the level of the item's semantic (e.g., Anderson & Spellman, 1995; Johnson & Anderson, 2004; also see Anderson, 2003, for review), or episodic (e.g., Racsmány & Conway, 2006) representation. According to this account, inhibitory processes suppress the representation of competing memories below baseline levels of activation and the suppression lingers beyond the original moment of competition (e.g., Anderson & Spellman, 1995; Anderson, Green & McCulloch, 2000), resulting in RIF on final memory tests. Specifically, during retrieval practice, attempts to retrieve the Rp+ item in response to the practice cue also leads to activation of related Rp- items and these latter items interfere with successful retrieval of Rp+ items. In order to resolve this unwanted interference, inhibitory processes act directly on the memory representations of Rp- items to suppress them (e.g., Anderson & Spellman, 1995; Levy & Anderson, 2002; see Storm & Levy, 2012, for a review).

In contrast, non-inhibitory accounts of RIF (e.g. associative blocking: J.R. Anderson, 1983; Butler, Williams, Zacks & Maki, 2001; encoding specificity: Perfect et al, 2004; competitor interference: e.g., Jakab & Raaijmakers, 2009; Raaijmakers & Jakab, 2013; Verde, 2013; and context-based accounts: Jonker, Seli & MacLeod, 2013) do not appeal to inhibitory mechanisms in order to explain RIF. Despite their diversity, a common theme among most non-inhibitory theories is that RIF is due to the strong practiced memories (i.e., Rp+ items) blocking or interfering with the retrieval of weaker non-practiced memories (i.e., Rp- items). As retrieval strengthens the association between a retrieval practice cue and the practiced item (e.g., Fruit – cherry), it simultaneously weakens the association between this cue and other related but non-practiced memories (e.g., Fruit – kiwi). As a result, RIF will occur whenever a strong practiced item blocks retrieval of weaker non-practiced items, such as when an Rp+ item is strengthened through retrieval practice.

Four specific predictions of the inhibitory account of RIF differentiate it from non-inhibitory accounts: cue independence, retrieval dependence, strength independence, and interference dependence (see Anderson, 2003, and Storm & Levy, 2012, for reviews). Cue independence predicts that RIF occurs regardless of whether the original cue (e.g., Fruit___), or a different cue (e.g., Blood___), is used to retrieve the Rp- item (e.g., cherry), as inhibition acts at the level of the item's memory representation (e.g., Anderson & Bell, 2001; Anderson & Spellman, 1995; Ciranni & Shimamura, 1999; Johnson & Anderson, 2004; Levy, McVeigh, Marful & Anderson, 2007; MacLeod & Saunders, 2005; Veling & van Knippenberg, 2004; but see also Perfect, Stark, Tree, Moulin, Ahmed & Hutter, 2004; Jonker, et al., 2013, for failures to replicate). Second, the retrieval dependence prediction is based on the assumption that RIF should only be observed when practice involves active retrieval; specifically, that it is the act of retrieval itself which is key to activating inhibitory processes rather than simply strengthening Rp+ items (e.g., Anderson, Bjork & Bjork, 2000; Saunders, Kosnes & Fernandes, 2009; but see Jakab & Raaijmakers, 2009). The *attempt* to retrieve appears to be the critical component for the emergence of RIF as opposed to successful retrieval (e.g., Storm, Bjork, Bjork & Nestojko, 2006). Third, according to the strength independence prediction, the presence, or size, of RIF is independent of how memorable the practiced (Rp+) items are (e.g., Anderson et al., 2000; Ciranni & Shimamura, 1999; but see Raaijmakers & Jakab, 2012), and further strengthening of practiced items has been found to have minimal effects on RIF (e.g., Macrae & MacLeod, 1999).

The fourth, and most pertinent, prediction for the current experiments is the *interference dependence* prediction. According to this prediction, items that create the greatest degree of interference (i.e., retrieval competition) during retrieval practice are the most likely to be inhibited and, therefore, show RIF on a delayed memory test. If an item has weak potential to interfere, there will be less or, indeed, no need at all for inhibition and, as a result, little or no RIF would emerge (e.g., Anderson et al., 1994). Therefore, the 'strength' of the Rp- items (and not the strength of the Rp+ items) can predict whether RIF emerges or not (e.g., Anderson et al., 1994).

Surprisingly, there is little work examining the interference dependence prediction. Such paucity is partly due to the difficulty in defining 'strength' of the competing (Rp-) items. One approach to testing the interference dependence prediction has been to use semantic manipulations of item strength, such as taxonomic frequency of words (e.g., Anderson et al., 1994; Williams & Zacks, 2001), and dominant vs. non-dominant word meanings (e.g., Shivde & Anderson, 2001). Such studies utilising manipulations of competitor strength have typically found evidence consistent with the inhibitory account; specifically, that semantically or taxonomically strong competitors (e.g., Fruit – orange) are more susceptible to RIF compared to taxonomically weak competitors (e.g., Fruit – tomato; Anderson et al., 1994; but see Williams & Zacks, 2001).

Other studies have manipulated item strength within the experimental episode (e.g., Jakab & Raaijmakers, 2009; Storm et al., 2007). For instance, using a directed forgetting manipulation prior to a retrieval practice phase, Storm and colleagues (2007) found that items in a list which participants were instructed to remember showed more RIF compared to list items which participants were instructed to forget. However, other studies have failed to detect differences between episodically strong and weak competitors (e.g., Jakab & Raaijmakers, 2009; Williams & Zacks, 2001). According to

Storm and Levy (2012), studies with negative evidence for the interference dependence prediction may have been confounded with alternative explanations (see Raaijmakers & Jakab, 2013, for further discussion). Meanwhile, in a meta-experimental review, Spitzer (2014) showed that baseline item strength (as opposed to the strengthening of Rp+ items) predicts the presence and magnitude of RIF in studies using a recognition task during the test phase.

A particularly fertile ground for examining strength effects in memory is object recognition. Visual objects are both perceptually and semantically rich stimuli with robust long-term memory representations (e.g., Brady, Konkle, Alvarez & Oliva, 2008) compared to verbal materials (e.g., Nelson, Reed & Walling, 1976). As study materials, objects offer the possibility to examine and contrast different types of strength effects in memory.

Effects of item strength are very common in object recognition. Some strength effects concern semantically represented object colour. For instance, object identification is often more efficient (i.e., faster and more accurate) for objects that appear in typical colours, such as yellow bananas or red strawberries, as opposed to purple bananas and orange strawberries (e.g., Tanaka & Presnell, 1999). Other strength effects in object recognition concern the shape typicality of objects. For instance, objects typical of their category, such as dining chairs, are identified faster and more accurately at the basic level (e.g., chair), than are non-typical objects, such as artistic forms of chairs (e.g., Jolicoeur, Gluck & Kosslyn, 1984; Murphy & Brownell, 1985; Rosch, Mervis, Gray, Johnson & Boyes-Braem, 1976; Tanaka & Taylor, 1991). Therefore, visual objects can be ‘strong’ study items if they are typical exemplars of their category. In this sense, item ‘strength’ for visual objects parallels the strength in terms of taxonomic frequency in words.

Meanwhile, visual objects that are non-typical of their category can also be strong study items – this time, not because of how well they represent their category (as in the case of words) – but because of their unique visual features, which make them more distinctive than objects that are more typical of their category (e.g., Rosch et al., 1976). In this sense, item 'strength' for visual objects, unlike what is possible with words, is related to purely visual characteristics. Thus, findings from object recognition suggest that, not only are strength effects possible with rich complex visual stimuli, but that using objects as stimuli provide one avenue for examining different types of 'strength' effects in memory: ones resulting from the category *typicality* of an object, and another resulting from the *memorability* of an object.

Using recognition of objects to examine RIF requires a paradigm that is appropriate for pictorially rich stimuli. As visual objects do not easily lend themselves to memory *recall*, which is widely used with word stimuli, the current experiments utilised a *recognition practice* paradigm (e.g., Maxcey & Woodman, 2014) where old-new recognition is performed during both the practice and the test phases of the retrieval practice paradigm. Recognition practice with a subset of studied objects – as opposed to the typical cued-recall practice described earlier – has been found to successfully elicit significant *recognition-induced* forgetting or RIF[1] for unpracticed (Rp-) objects (e.g., Maxcey & Woodman, 2014). The present experiments utilise a recognition task during practice and test to induce and measure RIF for familiar visual objects. Experiment 1 was proof of concept for our variant of Maxcey and Woodman's recognition practice task. Experiment 2 used this variant to examine the interference dependence prediction of the inhibitory account for RIF.

[1] Although the acronym RIF refers to *retrieval-induced* forgetting, we use it here to also denote *recognition-induced* forgetting. Note that the acronym RIF has been used to describe the specific type of memory impairment described here, even in the absence of a retrieval task during practice (e.g., Raaijmakers & Jakab, 2012; Verde, 2013).

EXPERIMENT 1

Experiment 1 examined whether RIF would be obtained with object images as stimuli using recognition tasks at both practice and test. The paradigm we employed here was different from Maxcey and Woodman's recognition practice paradigm in 3 ways. First, we used incidental, as opposed to intentional, learning of each object during study, to better mimic conditions under which objects would normally be encountered (as opposed to words). Second, we used a yes/no recognition task in the practice phase, in order to force participants to rely on recollection as opposed to familiarity judgments (e.g., Holdstock, Mayes, et al., 2002). Finally, we used corrective feedback during the practice phase, to make the task non-trivial and competitive (e.g., Raaijmakers & Jakab, 2012). Provided that our version of the recognition practice task elicits competition between practiced and unpracticed items, a recognition task at practice was hypothesized to be sufficient to cause RIF.

Method

Participants and Design

Thirty Swansea University undergraduates (24 females, 6 males; *M* age = 20.1 years, *SD* = 2.5 years) were part of the Recognition Practice Group –henceforth referred to as the Practice group. A different group of thirty Swansea University undergraduates (25 females, 5 males) with a mean age of 21.4 (*SD* = 3.6) were part of the Control Group (no recognition practice). All participants reported normal or corrected-to-normal vision and reported being able to perceive colour normally.

The design for the Practice group was repeated-measures with Item Type as the within-participants factor, with three levels: Rp+, Rp-, and Nrp. The Rp+ items were objects that received recognition practice during the practice phase (e.g., the blue and the red armchairs; the green and the purple boxes; the yellow and the red cutlery sets; and the red and the grey towels –see Figure 1). The Rp- items were the unpracticed objects from the four practiced categories (e.g., the white and the black armchairs; the grey and the white boxes; the white and the red cutlery sets; and the black and the cream towels). Finally, Nrp items were objects from the four unpracticed categories (e.g., all the bookcases, chairs, hats, and tables).

For the Control group there was no recognition practice, making the terms Rp+, Rp- and Nrp irrelevant, but overall Control group participant performance served as an extra baseline for the assessment of RIF. Given that in the Control group all objects were unpracticed, Control group participants' recognition proportion was compared against the Practice group participants' Rp- items' recognition proportion, providing a between-participant calculation of RIF (see Results section).

The dependent measure in both the Practice and Control groups was accuracy in terms of *A'* scores, which was chosen as the most suitable measure of discriminability for this task, as it is not sensitive to very high scores (1) or very low scores (zero).

Apparatus and Materials

Stimulus presentation and recording of responses was controlled via E-Prime 2.0 (Psychology Software Tools) running on a Windows-based PC. All stimuli were presented against a white background on a 19-inch Mitsubishi LCD monitor. Stimuli were coloured photographs of everyday objects from eight object categories (armchair, bookcase, box, chair, cutlery set, hat, table, towel; Figure 1). In each category there were 8 objects, four of which were used as targets and four as distractors.

Apart from the 8 experimental object categories, there were 3 filler object categories (glass cups, cushions, and gift-bags), with 8 objects per category. Those filler objects were used as buffer items at the beginning and the end of the study phase, as well as randomly intermixed with experimental category objects in the recognition practice and test phases.

To create the objects in each category, a single object was chosen and was realistically surface-rendered using Adobe Photoshop in 8 different colours - four target and four distractor colours. In total 88 objects were created, 64 for the experimental object categories and 24 for the filler object categories.

FIGURE 1 ABOUT HERE

Procedure

There were three phases for the Practice group participants (study, recognition practice, and test) and two phases (study and test) for the Control group participants.

Study phase. During the study phase, Control and Practice group participants were asked to rate how attractive each object was on a 1 (not attractive) to 5 (very attractive) Likert scale. In order to avoid influences of primacy or recency on the items of interest (the objects from the eight main object categories), six of the twelve filler objects appeared at the beginning of the study phase and the other six appeared at the end of the study phase. Each object was shown in colour against a white background. The exact instructions were: “During this phase you will be shown a series of objects. You will be asked to rate how attractive you think they are on a scale of 1 to 5.” Therefore, learning of the objects was entirely incidental. Objects were presented one at a time at screen centre, until the participant responded. The order of presentation of the objects was randomised, with the condition that objects of the same category did not appear together in succession. Following the study phase, participants completed a two-minute word generation filler task.

Recognition practice phases. There were three recognition practice phases, and in each phase the same objects were shown in a different randomly assigned order. In each recognition practice phase eight target objects from the experimental categories appeared –two from four of the eight object categories, as well as their associated distractors. For instance, for some participants the Rp+ objects would be the blue and red armchairs; the green and the purple boxes; the yellow and the orange cutlery sets; and the red and the grey towels. Consequently, the Rp- objects would be the white and the black armchairs; the grey and the white boxes; the white and the red cutlery sets; and the black and the cream towels. Finally, the Nrp objects would be all the bookcases, chairs, hats, and tables. The categories that were practiced was counterbalanced across participants. Furthermore, four target objects from the filler categories appeared, two objects from two of the three filler categories, as well as their associated distractor objects.

Objects appeared one at a time at screen centre in a random order, with the condition that no two objects from the same category appeared in succession. In each trial, participants decided whether or not they had seen the object during the earlier attractiveness-rating (study) phase by pressing the ‘Q’ or the ‘P’ key on a standard keyboard (counterbalanced between participants to indicate ‘Yes or ‘No’ respectively). Feedback appeared on the screen for half a second after the response indicating ‘Correct’ or ‘Incorrect’ presented in Courier New 18 font. After each practice phase there was a two-minute word-generation filler task. Following the last recognition practice phase, a five-minute word-generation task intervened before the test phase.

Participants in the Control group completed a similar procedure to that of participants in the Practice group, with the only exception that instead of completing the recognition practice phases they were given a series of word-generation filler tasks for

15 minutes, as this was how long it took on average the participants in the Practice group to complete the recognition practice and filler tasks.

Test phase. During the test phase all the studied objects and their corresponding distractors appeared one at a time at screen centre and in a random order. The task was identical to the recognition practice phase: participants decided whether or not they had seen the object in the attractiveness-rating phase (responding ‘Yes’ or ‘No’ to each object followed by feedback).

Results

Only data from the eight experimental object categories were analysed, while data from the three filler object categories were not used. Recognition memory during the recognition practice phase was successful (*A'*: *M*=.79, *SD*=.11, B''_D: *M*=-.36, *SD*=.34).

Test phase mean hit and false alarm rates, as well as *A'* and B''_D scores per Item Type are shown in Table 1. Figure 2 presents *A'* scores again, for visualization purposes. Analyses were conducted on *A'* scores, but the pattern of results (and significance) was the same for hit rates, unless otherwise indicated (see Footnote 2 and 3).

RIF was significant both within- and between-participants. Within-participant RIF on *A'* scores was examined in pairwise comparisons between Rp- and Nrp objects. Rp- objects had lower *A'* scores than Nrp objects, t (29) = 2.57, p=.02, thus yielding significant within-participant RIF. Between-participant RIF was also significant, Rp- objects had lower *A'* scores than the Control Group, $t(58)$=4.15, p<.0001.

There was no evidence for within-participant facilitation in *A'* scores, $t(29)$=.57, p=.58[2]. Between-participant facilitation was assessed by comparing the Control group’s *A'* scores against the Practice group Rp+ items’ *A'* scores. There was no evidence for

[2] There was significant facilitation in hit rates for practiced items with higher hit rate for Rp+ items than for Nrp items, $t(29)$=5.29, p<.0001.

between-participant facilitation: in fact, Practice group Rp+ *A'* was lower (not higher, as would be expected) than the mean Control group *A'* scores, $t(58)=2.52$, $p=.01$[3]. The lack of facilitation in Experiment 1 is discussed in the Discussion section of Experiment 2.

TABLE 1 AND FIGURE 2 ABOUT HERE

Discussion

Experiment 1 examined whether RIF would be obtained with rich pictorially-based object stimuli using recognition tasks at both practice and test. Using our variant of the recognition practice procedure we found significant RIF for visual objects: unpracticed objects from the practiced categories (Rp- items) were recognised less accurately than unpracticed objects from unpracticed categories (Nrp items).

The results from Experiment 1 add to the limited previous evidence showing that RIF can be elicited by practice other than verbal cued-recall (see Maxcey & Woodman, 2014, and Verde 2013, for exceptions), and for everyday objects (i.e., Koutstaal, Schacter, Johnson & Galluccio, 1999; Maxcey & Woodman, 2014), despite our use of incidental learning and other procedural differences. In real life we often encounter, learn and encode objects unintentionally. The current study phase mimicked this unintentional learning, by having participants learn object incidentally – by making judgments about them.

However, without a recall-based practice task, how was competition induced in the current study? It has been previously suggested that the retrieval process mediating the *recollection* component of recognition tasks is similar, or identical to, that found in

[3] As with the *A'* scores, there was no difference in hit rates between the Practice group Rp+ condition and the Control Group hit rate, $t(58)=1.12$, $p=.26$.

recall tasks (e.g., Brown, 1976; Clark, 1999; Humphreys, 1978; Mandler, 1980). Experiment 1 encouraged recollection-based recognition in four different ways: (1) by using distractor (unstudied) items that were very similar to the target (studied) items, forcing participants to remember the target studied items, as opposed to relying on familiarity (e.g., Bodner & Richardson-Champion, 2007); (2) by utilising a yes/no recognition task during practice, which may rely more upon recollection as opposed to familiarity judgments (e.g., Holdstock, Mayes, et al., 2002); (3) by using a non-speeded recognition task, which has been previously used to encourage recollection (e.g., Verde & Perfect, 2011); and (4) by using corrective feedback during the practice phase, to make the task non-trivial and competitive (e.g., Raaijmakers & Jakab, 2012). Thus, the findings of Experiment 1, and that of others (e.g., Maxcey, 2016; Maxcey & Woodman, 2014), suggest that recognition practice of pictorial stimuli is analogous to that of the more commonly used verbal retrieval practice and can be used to create conditions under which competition between target and non-target items can occur and be manipulated. Thus, while the tasks differ, they both result in RIF via the creation of competition between target and non-target items in memory.

EXPERIMENT 2

Having provided proof of concept for our version of the recognition practice task in Experiment 1, the current study used an identical procedure to examine the interference dependence prediction of the inhibitory account. The interference dependence prediction of the inhibitory account posits that RIF is observed when Rp- items compete and interfere with the retrieval of Rp+ items. Such competition has been found to be more likely to occur for strong as opposed to weak Rp- items (e.g., Anderson et al., 1994). Observations of competitor (Rp-) strength affecting RIF have been made both when the Rp- items are episodically strong, such as when they were part of the ‘to-be-remembered list’ in a directed forgetting paradigm (e.g., Storm et al., 2007), and when the Rp- items are semantically strong, such as when they have high taxonomic frequency, or they represent a dominant word meaning (e.g. Anderson et al., 1994; Shivde & Anderson, 2001).

The prediction that episodic item strength directly affects RIF magnitude has direct implications in distinguishing between inhibitory and non-inhibitory accounts. That is, although both the inhibitory account and the context-based account of RIF predict that the items most likely to be inhibited will be the semantically (or taxonomically) strongest competitors, episodic strength of competitor is a unique prediction of the inhibitory account.

Studies previously investigating effects of Rp- item memory strength have used verbal material (e.g., Anderson et al., 1994; Shivde & Anderson, 2001; with the exception of Sharman, 2011, who manipulated bizarreness of actions performed on everyday objects). In Experiment 2 we manipulated item strength in visual objects. When we move from word lists into the domain of visual objects there is an opportunity to manipulate item strength in novel ways.

In Experiment 2 we manipulated item strength through manipulating *object typicality*, by which we define as how typical an individual object is of its category as measured by its shape. We chose shape as our measure of typicality as shape is one of the most important features determining object categories (e.g., Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976), leading us to expect that a shape typicality manipulation would be sufficiently strong to influence recognition memory performance. Typicality was measured via independent ratings in a pilot experiment. Raters were instructed to rate objects on how typical their shape was for their category providing us with a value of shape typicality for a large database of objects to select from.

Object typicality may influence recognition in two ways. If strength in terms of typicality mattered most for the presence of RIF, then objects most typical of their category may be stronger competitors in memory because they are better exemplars of their category (e.g., Anderson et al., 1994; Jonker et al., 2013). In this case, RIF was predicted to be significant for typical, but not for non-typical, objects. However, non-typical objects tend not to share many physical shape features with other objects in the same category (e.g., penguin vs. bird; Rosch et al., 1976; Tanaka & Taylor, 1991), making them more distinctive in memory. Therefore, an alternative possibility is that strength in terms of memorability (that is, distinctiveness of the item in memory), as opposed to typicality, will determine the presence RIF. If this is the case, then non-typical objects may be stronger competitors in memory because they were more distinctive and therefore more memorable among the other objects from the same category in the studied set (e.g., Storm et al., 2007). Object memorability will be examined in a Control group (see Method section).

Method

Participants and Design

Thirty new Swansea University undergraduates (5 males), with a mean age of 21.0, (*SD*=1.82) were part of the Practice group (recognition practice). In the Control Group (no recognition practice) there were twenty participants (1 male), with mean age of 20.4 (*SD*=.64). Participants received course credits in exchange for completing the experiment. All participants reported normal or corrected-to-normal vision, and the ability to perceive colour normally.

The design for the Practice Group was repeated-measures manipulating object Typicality with two levels (typical versus non-typical) and Item Type with three levels

(Rp+, Rp-, and Nrp). The dependent measure for the Practice and Control Groups was *A'* scores.

Apparatus and Materials

The same computer apparatus as in Experiment 1 was used. Stimuli were grey-scale images of everyday objects from eight different experimental categories: chairs, clocks, cups, hats, knives, lamps, telephones and vases (Figure 3). There were also three filler categories (boxes, tables, and luggage), objects from which were used as buffer items at the beginning and end of the study phase, as well as randomly intermixed with experimental category objects in the recognition practice and test phases.

Object typicality for all objects was determined on the basis of shape from a pilot study of fifteen participants who did not take part in the main experiment. Typicality for each object category was determined by methods similar to those used previously (e.g., Bramão, Inácio, Faísca, Reis & Peterson, 2011; Rossion & Pourtois, 2004; Snodgrass & Vanderwart, 1980; Ventura, 2003). Pilot participants were given the following instructions: *"Please indicate how typical each object is for each object category* ***on the basis of its shape alone****, by assigning a number under each object in a descending order of typicality, with "1" for most typical, then "2" for the next most typical object, and so on. Please remember to make your decision on the basis of the shapes of objects and NOT textures or patterns".*

The four most typically shaped and the four least typically shaped objects – henceforth referred to as *typical* and *non-typical* objects respectively –were chosen for each category. For the eight experimental object categories, typical objects had a mean shape typicality rating of 5.4 (*SD*=1.88) and non-typical objects had a shape typicality mean rating of 15.0 (*SD*=2.46). An independent-samples t-test confirmed that this difference was significant, $t(62)=20.50$, $p<.0001$.

FIGURE 3 ABOUT HERE

Procedure

The general procedure was similar to Experiment 1, with the only difference being in the recognition practice phase. Half of the objects practiced during recognition practice were the typical objects of a category and the other half would be the non-typical objects of a different category. Thus, although every category contained typical and non-typical objects, for each participant, typical and non-typical objects during the recognition practice phase would come from different categories. For each category, whether typical or non-typical objects were practiced during the practice phase was counterbalanced. For instance, for participants who practiced the clock, hat, lamp, and vase categories, some participants would practice two typical clocks, two typical vases, two non-typical hats and two non-typical lamps, while other participants would practice two non-typical clocks, two non-typical vases, two typical hats, and two typical lamps (see Appendix 1 for details about how many participants saw each category). In each practice phase, targets appeared intermixed with distractor objects. All remaining aspects of the procedure (study phase, filler tasks, and test phase) remained the same as in Experiment 1.

Results

The data from three Practice group participants were excluded from the analysis because their ‘Yes’ responses were significantly greater than 3 standard deviations from the mean amount of ‘Yes’ responses in the group (suggesting that they were not following task instructions). Only data from the eight experimental object categories were analysed, while data from the three filler categories were discarded.

The primary goal of Experiment 2 was to examine the effect of Rp- item strength on RIF using an object typicality manipulation. Two different analyses allowed us to test how well the item strength manipulation worked. One was the analysis of the Control group (no recognition practice) data and the other was the analysis of the Practice group recognition practice phase data. Both analyses estimated whether the typical objects were remembered significantly more (or less) than non-typical objects.

Analyses were conducted on *A'* scores, but the pattern of results (and significance) was the same for hit rates, unless otherwise indicated (see Footnote 4).

Control Group: Test phase analysis

Mean recognition performance measures (hit and false alarm rate, as well as *A'* and B''_D scores) per Typicality condition for the Control Group appear in Table 3. Planned comparisons showed that non-typical objects yielded significantly higher *A'* scores compared to typical objects, $t(19)=5.80$, $p<.0001$. Therefore, the results from the Control Group showed that objects that were rated as non-typical of their category were more memorable than those rated as typical of their category.

Practice Group: Study Phase analysis

During the study phase participants rated objects on how attractive they appear to be on a 1-5 Likert scale. Non-typical objects were rated as overall more attractive (M=2.59, SD =.50) than typical objects (M=2.38, SD=.52), t (26)=3.17, p=.004.

Practice Group: Recognition practice analysis

Table 2 shows a summary of hits, false alarms, *A'* and B''_D scores per cell mean for the Practice group's recognition practice data. A paired-samples t-test showed that non-typical objects had significantly higher *A'* scores than typical objects, *t*(26)= 4.73, *p*<.0001, suggesting that non-typical objects were more memorable than typical objects.

TABLE 2 ABOUT HERE

Practice Group: Test phase analysis

Table 3 shows the mean hit rates, false alarm rates, and *A'* and B''_D scores for the test phase data of the Experimental and Control groups. Figure 4 presents *A'* scores only.

TABLE 3 AND FIGURE 4 ABOUT HERE

Comparisons between Practice group recognition performance on unpracticed (Nrp) items and unpracticed Control Group items (all items), showed that they were not significantly different on *A'* scores, *t*(45)=.35, *p*=.73. Therefore, RIF and facilitation are reported for within-participants' comparisons only (Nrp item's accuracy minus Rp- items' accuracy). However, the pattern of RIF and facilitation using the Control Group baseline produced an identical outcome.

A 2 (Typicality: typical vs. non-typical) x 3 (Item Type: Rp+, Rp-, Nrp) repeated-measures ANOVA on *A'* scores showed a significant main effect of Typicality, *F*(1, 26)=30.21, *MSE*=.590, *p*<.0001, with non-typical items being significantly more discriminable than typical items. The main effect of Item Type was not significant, *F*(2, 52)=1.11, *MSE*=.024, *p*=.34, but it was qualified in a significant interaction with Typicality, *F*(2, 52)=4.94, *MSE*=.085, *p*=.01.

Planned comparisons showed significant RIF for non-typical objects: non-typical Rp- items yielded significantly lower *A'* than non-typical Nrp items, $t(26)=2.25$, $p=.03$. However, there was no significant RIF for typical objects [typical Rp- versus typical Nrp: $t(26)=1.28$, $p=.25$]. A comparison of the RIF effect (Nrp minus Rp-) for typical ($M=-.05$, $SD=.19$) and non-typical objects ($M=.06$, $SD=.14$), showed a significant difference, $t(26)=2.38$, $p=.03$. Therefore, RIF was significant for non-typical but not for typical objects.

Planned comparisons examining facilitation following recognition practice, showed that neither typical nor non-typical Rp+ items were more discriminable than Nrp items [$t(26)=.47$, $p=.61$, and $t(26)=1.40$, $p=.17$, respectively][4].

Discussion

Firstly, the most important finding in Experiment 2 was that item strength, as indexed by object memorability, influenced RIF. The finding that the magnitude of RIF was influenced by object memorability, as opposed to object typicality, provides novel support for the interference dependence prediction of the inhibitory account which predicts that ‘strong’ memorial representations are more likely to create competition, and interfere, during retrieval of target memories, than ‘weak memorial representations, resulting in suppression of ‘strong’ memories – as gauged by RIF. Secondly, the findings provide the first support for interference dependence in RIF using pictorial – as opposed to word stimuli (e.g., Anderson et al., 1994; Shivde & Anderson, 2001; e.g., Storm et al., 2007; see Storm & Levy, 2012 for recent review). This finding extends support for the interference dependence prediction beyond word stimuli and opens up this often previously overlooked prediction of the inhibitory account of RIF for future

[4] Rp+ items yielded significantly higher hit rates compared to Nrp items both for typical [$t(26)=3.35$, $p=.003$], and for non-typical objects [$t(26)=4.52$, $p<.0001$].

investigation using a much wider range of stimulus material. Furthermore, the current finding strengthens the generalisability of this prediction for explaining why we forget seemingly 'strong' information within our everyday lives.

There was no evidence of facilitation in Experiments 1 and 2 – that is, there was no difference between practiced (Rp+) and unpracticed (Nrp) objects. One possible reason for this was that the same distractor objects were used for both the practice and the test phase. This may have led to participants 'learning' the new objects, and subsequently during the test phase, the false alarm rate for those new objects was increased. The high false alarm rate for practiced objects' lures led to lower discriminability for Rp+ items than would otherwise be expected. Indeed, an inspection of the hit rates confirms that practiced objects had significantly higher hit rates than unpracticed objects, which fits the expected pattern of recognition performance (higher accuracy for practiced compared to unpracticed items).

The alternative method would have been to present different practice distractors in the practice phase and in the test phase, as employed by Maxcey & Woodman (2014). However, this would have required increasing *either* the category size of the typical objects *or* the non-typical objects in each object category - depending on whether typical or non-typical were practiced from that category - but, critically, it would not be feasible to increase both category sizes together. We set our reasoning here to explain this methodological issue in more detail. Although category size may not influence the magnitude of RIF (e.g., Maxcey, 2016), in the current experiments we decided against increasing the category set size – by using different distractors in the practice and the test phases –because the critical manipulation relied on having equal number of items for the typical and non-typical objects per category. For example, if two typical chairs were practiced 3 times, each time requiring a novel distractor chair with an additional constraint that they must also be typical – which would be necessary in order to make the recognition task sufficiently difficult and, therefore, reliant on recollection, as opposed to, familiarity. This would amount to a category of chair with 10 typical and 4 non-typical objects for that participant. Any observation of RIF for non-typical objects would not be confidently distinguished from simple forgetting of those non-typical items because of increased set size of the typical objects. Lack of RIF would be equally difficult to interpret because the increased set size of typical objects may have made the non-typical objects more discriminable in memory. Therefore, the decision was made to sacrifice the observation of facilitation in *A'* scores – which is not necessary for observing and interpreting RIF effects (see Gómez-Ariza, Fernandez & Bajo, 2012; Gómez-Ariza et al., 2005; Storm et al., 2006) –in favour of keeping category set-size the same for typical and non-typical objects.

General Discussion

The current experiments used the recognition practice procedure to examine the interference dependence prediction of the inhibitory account of RIF: does item strength influence the presence of RIF? Experiment 1 showed that our version of the recognition practice procedure was successful in eliciting significant RIF. Experiment 2 used the same procedure to test the interference dependence prediction of the inhibitory account that RIF magnitude would be dependent on item strength. Experiment 2 supported this prediction, by showing that memorable unpracticed items showed significant RIF while non-memorable items failed to show any RIF.

The significant RIF for complex visual object stimuli observed here adds to existing evidence from studies on visual objects (e.g., Maxcey, 2016; Maxcey & Woodman, 2014), eyewitness memories (e.g., Shaw, Bjork, & Handal, 1995), actions and motor sequences (e.g., Koutstaal et al., 1999; Reppa et al., 2013; Sharman, 2011; Tempel & Friggs, 2013; 2015), and simple shapes (e.g., Ciranni & Shimamura, 1999) to show that RIF is a general memory phenomenon. But, how was competition between object representations achieved with the current paradigm? The design and procedure of the current study make a novel departure from the prototypical retrieval practice procedure. Competition was encouraged in the current studies by using a recollection-based recognition task, considered to be a search-like competitive memory process (e.g., Brown, 1976; Clark, 1999; Humphreys, 1978; Mandler, 1980). In the typical paradigm where category-exemplar pairs are used, e.g., Fruit —banana, Fruit —orange, any presumed response competition during retrieval of Fruit —banana potentially leads to RIF for unpracticed exemplars, e.g., Fruit —orange. In this example, the category cue is explicit, in the sense that it is explicitly linked to each item, and the experimenter explicitly uses it to probe the participant's memory of those items. In the current study exemplars were implicitly associated with a cue. In Experiment 1 the common cue linking exemplars was category and shape (e.g., identical bookcases, each in a different colour), and in Experiment 2 the common cue was category alone (e.g., differently shaped vases). Therefore, competition between practiced and related but unpracticed items in the current studies arose from sharing an implicit category cue.

Theoretical Implications

Two aspects of the current findings provide support for the inhibitory account of RIF: first, the finding of RIF using a recognition task in the test phase to gauge RIF, and second, the modulation of RIF by Rp- item strength. These are discussed in turn.

RIF was obtained with a recognition task in the test phase

Obtaining RIF with a recognition task in the test phase was predicted by the inhibitory account of RIF, according to which items competing for retrieval are inhibited in order to prevent them from interfering with retrieval of the wanted memory. As the item representation is inhibited during practice, then this inhibition should be subsequently evident in any test that probes the memory for that item. The significant

RIF in the current study complements findings of RIF using item recognition tests (e.g., Anderson et al., 1997; Gomez-Ariga et al., 2005; Hicks & Starns, 2004; Spitzer & Baüml, 2007; Starns & Hicks, 2004; Veling & van Knippenberg, 2004; Verde, 2004a, 2004b), and for the first time extends the application of recognition tests to produce RIF with pictorial stimuli. Empirically, this finding contradicts previous evidence showing that presenting item-specific information at test overrides RIF (e.g., Butler et al., 2001; Camp, Pecher, & Schmidt, 2007; Koutstaal et al., 1999).

Finding RIF using a recognition task at test is relevant to the question of whether the inhibited representations are semantic or episodic (e.g., Anderson, 2003). Combined with the finding of RIF for episodically stronger items (non-typical objects in Experiment 2), finding RIF with a recognition task at test, suggests that in the current study RIF was sensitive to episodic representations of objects (e.g., specific chair exemplars). This finding is consistent with previous reports of episodic inhibition with word stimuli (e.g., Racsmány & Conway, 2006), and simple geometric shapes (e.g., Ciranni & Shimamura, 1999).

Apart from its theoretical implications, the use of item recognition tests to examine RIF has methodological advantages to the typically used cued-recall tasks (Fruit___). One such advantage is that item recognition tests help to mitigate the effects of *output interference* (e.g., Roediger, 1973; Tulving & Arbuckle, 1963), a powerful phenomenon in memory retrieval. If participants were allowed to recall the items themselves, as is the case in cued recall tests, then they would be more likely to recall the practiced items first, thus potentially interfering or blocking the recall of the remaining items. It would then be difficult to determine whether the observed RIF was caused by the suppression of the competing items during practice, as predicted by inhibitory accounts, or by the blocking of the memory of the unpracticed items during the test phase, as predicted by some non-inhibitory accounts, such as associative blocking accounts. The use of item recognition negates the issue of output interference because the order the objects appeared in was random –that is, in some cases Rp- objects would be recalled first, while in others Rp+ or Nrp items would be recalled first. Regardless of the random presentation of items, significant RIF was observed in the current experiments.

RIF was influenced by competitor strength

The finding that RIF was influenced by the memory strength of Rp- items provides converging support to the inhibitory account of RIF –and in particular the interference dependence prediction. Previous studies examining the effect of competitor strength on RIF using word stimuli have provided mixed support for the interference dependence prediction. Some studies have shown that strong competitors are more susceptible to RIF compared to weak competitors (e.g., Anderson et al., 1994; Shivde & Anderson, 2001; Storm et al., 2007), while others have not found such differences (e.g., Garcia-Bajos, Migueles, & Anderson, 2009; Jakab & Raaijmakers, 2009; Williams & Zacks, 2001). It has been noted, however, that both failures to find evidence for interference dependence (Jakab & Raaijmakers, 2009; and Williams & Zacks, 2001) used a category cued-recall test in the final test and did not control for output interference, which may have accounted for the lack of difference in RIF between weak and strong competitors (see review by Storm & Levy, 2012; but see Raaijmakers & Jakab, 2013 for counter-argument).

To our knowledge, the only previous attempt to examine the influence of competitor strength on RIF magnitude using non-verbal materials was by Sharman (2011). In that study, competitor strength was manipulated in terms of the bizarreness of object-related actions. Participants studied bizarre and non-bizarre object-related actions (e.g., put the flower on its petals or put the flower in a vase, respectively), and after cued-recall of a subset of actions were asked to recall all studied actions. Sharman found significant RIF regardless of action bizarreness, thus failing to support the interference dependence prediction. Of course, memory for actions may not always obey the same laws as other types of memory. Sharman's finding indicates that if one wants to address the issue of item strength with real life stimuli, then strength needs to be assessed and defined accordingly. Strength in a word list or in pictures may be different than strength in stimuli with motor representations.

Although our findings overall lend support to the inhibitory account of RIF, they are not incompatible with the recently formalized context-based account of RIF (Jonker et al., 2013). More specifically, our studies conform to the two tenets proposed by the context-based account as the necessary pre-requisites to obtain RIF: (1) the study and practice phases differed in context (as set by task requirements: attractiveness rating in study phase and item recognition in the test phase), and (2) the practice and test phases had the same context (both phases required item recognition). According to the context-based account, viewing Nrp items during the test phase re-instates the study context (the only context that Nrp items were encountered), while viewing Rp- items re-instates the most recent and relevant context of the practice phase (because the Rp- items' category belonged in the practice context). When the practice context is re-instated during the test phase (e.g., same stimuli and same task), Rp+ items benefit from context re-instatement and are remembered better then the baseline (Nrp) items. However, Rp- items, which are tied only to the study and not to the practice context, are deprived of the benefit of re-instatement of the practice phase and are remembered more poorly than baseline Nrp items.

Although the presence of RIF in our study could be predicted by the context-based account, the critical finding of RIF modulation by item memorability may be more difficult to fully reconcile with this account. For instance, the context-based account might predict that items with strong category cue-exemplar associations (e.g., Fruit—

apple) would suffer more from context change than those with weaker associations (e.g., Sahakyan & Goodmon, 2010; see also Jonker et al, 2013 for discussion). However, we found RIF for the opposite condition than the context-based account might predict: RIF was present for non-typical objects, which have weaker associations with their category than typical objects. At the moment it is not clear what the context-based account of RIF would predict regarding items with high memorability, while the inhibition account makes the direct prediction that such items would suffer more RIF – as shown in Experiment 2 (see also Storm et al., 2007). Overall, although a context-based account of our findings cannot be precluded, our findings are directly in line with the predictions of the inhibitory account of RIF.

In conclusion, the current findings corroborate previous findings showing that competitor strength influences the presence of RIF: strong items suffer from practice (cued-recall or recognition) more than weaker items (e.g., Anderson et al., 1994; Storm et al., 2007; see Spitzer, 2014 for review of RIF effects using recognition tests). The observation of competitor strength effects using objects suggests that it may not be as spurious a finding as previously thought (e.g., Jonker et al., 2013). Finally, studies like ours and others (e.g., Maxcey & Woodman, 2014; Maxcey, 2016) show that recognition practice can be used to induce RIF for visual objects. The use of recognition practice lends much greater flexibility and diversity in the use of the retrieval-induced paradigm to examine questions regarding not only mechanisms mediating the RIF effect (e.g., inhibitory vs. non-inhibitory), but also as a tool to examine questions regarding object representations. For instance, we are currently using RIF to examine the relative contribution of shape and surface information in object representations.

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