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Item-Method Directed Forgetting: Effects at Retrieval?

Tracy L. Taylor, Laura Cutmore, & Lotta Pries

Department of Psychology and Neuroscience

Dalhousie University

1355 Oxford Street, PO 15000

Halifax NS, CANADA

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Abstract

In an item-method directed forgetting paradigm, words are presented one at a time, each followed by an instruction to Remember or Forget; a directed forgetting effect is measured as better subsequent memory for Remember words than Forget words. The dominant view is that the directed forgetting effect arises during encoding due to selective rehearsal of Remember over Forget items. In three experiments we attempted to falsify a strong view that directed forgetting effects in recognition are due *only* to encoding mechanisms when an item method is used. Across 3 experiments we tested for retrieval-based processes by colour-coding the recognition test items. Black colour provided no information; green colour cued a potential Remember item; and, red colour cued a potential Forget item. Recognition cues were mixed within-blocks in Experiment 1 and between-blocks in Experiments 2 and 3; Experiment 3 added explicit feedback on the accuracy of the recognition decision. Although overall recognition improved with cuing when explicit test performance feedback was added in Experiment 3, in no case was the magnitude of the directed forgetting effect influenced by recognition cueing. Our results argue against a role for retrieval-based strategies that limit recognition of Forget items at test and posit a role for encoding intentions only.

Item-Method Directed Forgetting: Effects at Retrieval?

Intentional forgetting occurs when participants successfully implement top-down control to limit unwanted encoding and/or unwanted retrieval (see Anderson & Hanslmayr, 2014 for a review). In the laboratory, an item-method directed forgetting paradigm is used to elicit intentional forgetting at encoding (see MacLeod, 1998 for a review). Participants are presented with items – most often words – one at a time, each followed by an instruction to Remember or Forget. If the instruction is to Remember, participants engage in elaborative rehearsal to commit the item to long-term memory. If the instruction is to Forget, participants engage frontal control mechanisms (Bastin, Feyers, Majerus, Balteau, Degueldre, Luxen, Maquet, Salmon, & Collette, 2012; Hauswald, Schulz, Iordanov, & Kissler, 2010; van Hooff & Ford, 2011; Wylie, Fox, & Taylor, 2008; Yang, Liu, Cui, Wei, Li, Qiu, & Zhang, 2013) to withdraw attentional resources from the Forget item representation (Fawcett & Taylor, 2010, 2012; Taylor, 2005; Taylor & Fawcett, 2011; Thompson, Hamm, & Taylor, 2014; see also Rizio & Dennis, 2013) and thereby limit further rehearsal (e.g., Hourihan & Taylor, 2006). Successful implementation of the memory instructions is inferred from a directed forgetting effect, which is defined as better subsequent memory for Remember items than Forget items.

Using an item-method paradigm, directed forgetting effects occur for explicit tests of memory but not for implicit tests (e.g., Basden, Basden, & Gargano, 1993; Paller, 1990) and occur for *remember* but not for *know* responses (Basden, 1996; Gardiner et al., 1994). While general information about the Forget items persists in memory, specific details are lost (Fawcett, Taylor, & Nadel, 2013a, 2013b). Indeed, Forget items that are accidentally remembered despite the intention to Forget are represented with less fidelity than items that are intentionally remembered (Fawcett, Lawrence, & Taylor, 2016), and with a seemingly weaker trace strength (Thompson, Fawcett, & Taylor, 2011). Together, these results are consistent with the dominant view that Remember and Forget items are attended and maintained in working memory until the memory instruction is presented (e.g., Gardiner, Gawlik, & Richardson-Klavehn, 1994; Hsieh, Hung, Tzeng, Lee, & Cheng, 2009; Paz-Caballero, Menor, Jiménez, 2004) but that an instruction to Forget prevents further elaboration of the unwanted trace. As a consequence, any long-term representation of an unwanted Forget item exists in a relatively weak and/or degraded state that makes its retrieval relatively more effortful than that of an intentionally encoded Remember item (e.g., Ullsperger, Mecklinger, Müller, 2000). Nevertheless, the fact that Forget items are represented at all argues that encoding control is not absolute (e.g., Gao, Cao, Zhang, Qi, Li, & Li, 2016; Lee, Lee, & Tsai, 2007).

The fact that Forget items might exist in a weak and/or degraded state raises the possibility that there may be additional contributions to item-method directed forgetting from decision-making strategies that operate at retrieval. One such strategy might be to base recognition decisions on absolute signal strength and/or quality (e.g., recollective details). Such a strategy would tend to favour successful retrieval of Remember items compared to weakly encoded and/or poorly represented Forget items. Thus, even when items defy the intention to Forget at encoding and a long-term representation is formed, there may be processes – in addition to those that take place at encoding – that operate to limit their successful recognition. Indeed, a number of imaging studies indicate that Forget items are less accessible and require more effort to retrieve than Remember items (e.g., Nowicka, Jednoróg, Wypych, & Charchewka, 2009; Paz-Caballero & Menor, 1999; Ullsperger et al., 2004; Van Hooff, Whitaker, & Ford, 2009). These results tend to be explained by inhibitory processes operating to suppress the Forget item representation at encoding and/or retrieval; however, rather than positing a role for inhibition – which should be viewed with some skepticism (MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003) – we prefer the conclusion that Forget items are less accessible and relatively more difficult to retrieve *precisely* because imperfect encoding control leads to weak and/or degraded Forget item traces. And it is this weak or degraded state that – despite increased efforts at retrieval – might make Forget items particularly vulnerable to retrieval strategies that favour recognition of more robust representations.

To be clear: We do not presume that any such effects operating at retrieval are primarily responsible for item-method directed forgetting. We merely wonder whether such processes have a role in those instances when control over encoding is incomplete. If so, it should be possible to increase retrieval of Forget items by cueing participants with respect to the expected strength and/or quality of the trace. To wit, if participants know that a test item might have been a Forget word at study, they might be inclined to base their recognition decision on a weaker and/or poorer quality representation than they might have absent such a cue.

MacLeod (1975) reported the results of a study that could potentially speak to this hypothesis. He presented study trials in an item-method paradigm and then had participants return for testing after a 1- or 2-week retention interval. Testing consisted of a 3-alternative forced-choice recognition task for which participants were required to select a studied word from amongst two simultaneously presented unstudied foil words. A key manipulation was that on some of the recognition trials, a cue informed participants whether the word they were attempting to recognise had received a Remember or a Forget instruction at study. MacLeod (1975) found no significant effect of recognition cueing on the directed forgetting effect, countering our suggestion that a cue to potential signal strength/quality should assist recognition of weakly encoded Forget items. We would argue, however, that MacLeod's (1975) study might not have provided a strong enough test of the hypothesis. Even if normal (unintentional) forgetting over MacLeod's (1975) uncharacteristically long retention intervals left the relative strength and quality of memory traces intact, a forced-choice recognition test might be a less sensitive measure than a more typical yes-no recognition test. This is because decisions in choice recognition tasks are relative (i.e., is one of the test items *more* familiar than the other(s)?) rather than absolute (i.e., is the test item presented alone sufficient to drive a recognition response?).

With this in mind, we conducted three experiments that presented cues in a yes-no recognition task that followed immediately after the study phase of an item-method directed forgetting paradigm. At study, words were presented one at a time, each followed by an instruction to Remember or Forget. At test, we colour-coded these studied words and intermixed them with an equal number of similarly coloured unstudied foil words. When test words were coloured black, they provided no information about the memory instruction that had been presented at study; these trials were akin to how yes-no recognition is usually tested. In contrast, when test words were presented in green, they cued a potential Remember item; when presented in red, they cued a potential Forget item. Our goal was to determine whether the magnitude of the directed forgetting effect would be relatively reduced when decision-making at retrieval was aided by a colour-coded cue to potential signal strength/quality (i.e., because of facilitated retrieval of weak/degraded Forget item traces). The three experiments testing this hypothesis were identical except that in Experiment 1 we intermixed the presentation of uncued and cued yes-no recognition trials; in Experiments 2 and 3 we blocked their presentation; and, to Experiment 3, we added explicit feedback on the accuracy of the recognition response.

Experiment 1

To determine whether retrieval-based decision processes contribute to directed forgetting effects in a yes-no recognition task, Experiment 1 incorporated recognition cues into such a task. These cues were intended to inform participants of potential item strength/quality and thereby counter a potential over-reliance on strong/high-quality indicators of absolute recognition. The goal was to determine whether recognition cues reduce the magnitude of the directed forgetting effect that is otherwise obtained in a yes-no recognition test.

Methods

Participants

A total of 34 Dalhousie University students participated in exchange for psychology course credit. All participants were tested individually in a single experimental session that lasted approximately 1hr.

Stimuli and Apparatus

Psyscope X (http://psy.cns.sissa.it; cf. Cohen, MacWhinney, Flatt, & Provost, 1993) was used to present stimuli and collect responses using 24" iMac computers equipped with extended universal serial bus keyboards and mice. All text was displayed in black font on a uniform white background, except for cued items on the recognition test, which were coloured red or green. A fixation cross ("+") and written task instructions were presented in size 24 font; all other text was presented in size 12 font. The instruction to Remember consisted of a string of 6 "R"s (i.e., "RRRRRR"); the instruction to Forget consisted of a string of 6 "F"s (i.e., "FFFFFF").

A list of 320 words was drawn from the online MRC Psycholinguistics Database (http://websites.psychology.uwa.edu.au/school/MRCDatabase/uwa_mrc.htm). These words had an average concreteness rating of 578 (*R*=500-670), an average familiarity rating of 552 (*R*=501-646), and an average Kuçera-Francis word frequency rating of 52 (*R* =1-787), with an average length of 4.7 letters (*R* =3-7) and 1.3 syllables (*R* =1-3). Custom software was used to randomise and divide the 320-item word list into two lists of 160 study words and 160 foil words. The software further subdivided the study words into a list of 80 Remember words and 80 Forget words: 40 of the items on each of these lists were randomly selected to be coloured black at test; 20 were selected to be coloured green; and, 20 were selected to be coloured red. The 160 foil words were likewise randomly subdivided into a list of 80 words that were coloured black at test; 40 that were coloured green; and, 40 that were coloured red. This custom program was executed prior to collecting each data set.

Procedure

Participants provided written informed consent and were given a verbal overview of the experiment, which was reiterated on the computer monitor before they proceeded to the study trials. The instructions informed participants that they would be presented with a relatively long list of words, one word at a time, each followed by an instruction to Remember ("RRRRRRRR") or Forget ("FFFFFFFF"). They were told that when the instruction was to Remember, they should try to commit to memory the word that just disappeared; when the instruction was to Forget, they could forget the word that just disappeared. They were told that after all the words had been presented, they would be given a memory test, the instructions for which would follow. No mention was made of the fact that this memory test would query Forget items as well as Remember items. The experimenter remained in the room until the participant was ready to start the study trials.

There were a total of 160 study trials. Each trial began with an 800 msec presentation of the fixation cross in the centre of the computer monitor. This fixation stimulus was removed simultaneously with the presentation of the study word for 400 msec. Following a 1000 msec delay during which the monitor remained blank, the memory instruction appeared for 400 msec. On a random half of trials, this instruction was to Remember ("RRRRRR"); on the other half of the trials, this instruction was to Forget ("FFFFFF"). The memory instruction was followed by a 2700 msec inter-trial interval during which the computer monitor remained blank. The total trial duration was 6 s.

After completing the study trials, participants received an instruction to call the experimenter back into the room by activating a remote light switch. The experimenter returned to the room to provide verbal instructions for the yes-no recognition test. These instructions informed participants that they would be presented with a list of words, one at a time in the centre of the computer monitor, and that they were required to decide for each word whether it had been presented during the study trials or not – regardless of its associated memory instruction. They were instructed to press the "y" key (for "yes") if they recognised a study word and the "n" key (for "no") if they did not.

Participants were told that test words could appear in one of three colours: Black, green, red. Whereas the black colour provided no information, participants were informed that the green colour cued a potential Remember word and the red colour cued a potential Forget word. A "Do you recognise this word? (y/n)" prompt accompanied each test item and was prepended according to the cue condition: "This word MAY have been presented at study", "This word MAY have been presented with a REMEMBER instruction at study", "This word MAY have been presented with a FORGET instruction at study." A reminder of the task instructions and meaning of the colour coding remained visible at the top left of the computer monitor throughout the recognition test trials.

Data Analysis

The data were collated and analyzed using R Studio 1.0.143 running R 3.4.0 (R Core Team, 2017) and packages plyr (Wickham, 2011), dplyr (Wickham & Francois, 2016), tidyr (Wickham, 2017), stringr (Wickham, 2017), ggplot2 (Wickham, 2009), and ez (Lawrence, 2016). We used the output from ezANOVA to generate a Bayesian Information Criterion (BIC) approximation to Bayesian posterior probabilities according to the method described by Masson (2011).

Whereas traditional null hypothesis testing allows only for rejection of the null hypothesis with no ability to provide support for the null, a Bayesian approach evaluates the amount of evidence in favour of the null hypothesis versus in favour of the alternative (see Kruschke & Liddell, 2017). Where pH0 refers to the approximated posterior probability of the null hypothesis and pH1 refers to the approximated posterior probability of the alternative hypothesis of a non-zero effect, these values sum to 1 using Masson's method. Thus, values of $p\text{H0} = p\text{H1} = 0.50$ cannot be interpreted as support for either hypothesis. Increasing support for one hypothesis over the other occurs as the corresponding probability approaches 1 (and, conversely, as the other probability approaches 0).

Given that *p*H0 and *p*H1 sum to 1, we will report only the larger of the two probabilities. However, for consistency, we will interpret the larger probability with respect to the hypothesis of a non-zero effect. In this way values of *p*H1>0.50 will be described as evidence *for* effect, whereas values of *p*H0>0.50 will be described as evidence *against* an effect. The relative strength of this evidence will be described as suggested by Raftery (1995), with probabilities 0.50-0.75 interpreted as "weak" evidence; probabilities 0.75-0.95 interpreted as "positive" evidence; probabilities 0.95-0.99 interpreted as "strong" evidence; and, probabilities >0.99 interpreted as "very strong" evidence.

Results and Discussion

Hits were defined as "y" responses to studied Remember and Forget words; false alarms were defined as "y" responses to unstudied foils. Before proceeding with the full analysis, we averaged, on a subject-by-subject basis, the recognition false alarm rates across recognition cueing condition. One participant was identified as having an average false alarm rate that exceeded the mean of all participants by more than 2 standard deviations. Data obtained from this participant were removed from all subsequent analyses. The mean "yes" responses for the remaining 33 datasets are shown in Table 1.

[Table 1 about here]

To accommodate the varying foil false alarm rates that occurred as a function of whether and what type of recognition cue was presented (see Table 1), hit rates were corrected on a subject-by-subject basis. This was accomplished by subtracting the foil false alarm rate from the corresponding hit rate, such that: The proportion of "y" responses to black foil words were subtracted from the proportion of "y" responses to black Remember and black Forget words; the proportion of "y" responses to green foil words were subtracted from the proportion of "y" responses to green Remember words; and, the proportion of "y" responses to red foil words were subtracted from the proportion of "y" responses to red Forget words. The resulting data are shown in Figure 1 as a function of word type (Remember, Forget) and recognition cueing (No Recognition Cues = black, Recognition Cues = green/red). An analysis of these data provided very strong evidence *for* an effect of word type, pH1>0.99. This reflects an overall directed forgetting effect, with better recognition of Remember words than Forget words. There was positive evidence *against* an effect of recognition cueing, pH0=0.85, and positive evidence *against* a two-way interaction of word type and recognition cueing, pH0=0.79. Thus, recognition cues aided recognition of neither Remember nor Forget words. The only factor that had an identifiable impact on subsequent recognition was whether participants formed an intention to Remember or Forget during the study trials.

[Figure 1 about here]

Experiment 2

The results of Experiment 1 provided evidence that recognition cues have no discernable effect on the magnitude of the directed forgetting effect. To ensure that the effectiveness of the cues was not compromised by their mixed presentation, Experiment 2 replicated Experiment 1 using a blocked presentation.

Methods

Participants

Initially, 36 students at Dalhousie University were recruited for participation. Two of these participants were subsequently replaced due to technical difficulties that compromised stimulus presentation; an additional two participants were replaced due to concerns over their reported levels of concentration and alertness. The 4 replacement participants were recruited before any analyses had been conducted.

Stimuli and Apparatus

The stimuli and apparatus were identical to Experiment 1.

Procedure

The procedure was identical to Experiment 1 except that the test trials were blocked by recognition cue colour. The verbal and written instructions presented to participants in advance of the recognition test were altered to inform participants of the blocked design. Participants received one block of 160 trials on which all recognition test items were coloured black (40 Remember words, 40 Forget words, 80 unstudied foils); one block of 80 trials on which all recognition test items were coloured green (40 Remember words, 40 foils); and, one block of 80 trials on which all recognition test items were coloured red (40 Forget words, 40 foils). Our sample size in Experiment 2 was slightly larger than in Experiment 1 to ensure that we could fully counterbalance test block order across participants; our final dataset comprised 6 participants in each of the 6 possible test block orders.

Results and Discussion

Hits were defined as "y" responses to studied Remember and Forget words; false alarms were defined as "y" responses to unstudied foils. Before proceeding with the full analysis, we averaged, on a subject-by-subject basis, the recognition false alarm rates across recognition cueing condition. One participant was identified as having an average false alarm rate that exceeded the mean of all participants by more than 2 standard deviations. Data obtained from this participant were removed from all subsequent analyses. Proportion recognition "yes" responses are shown in Table 2 for the remaining 35 participants.

[Table 2 about here]

Hit rates were corrected by subtracting the foil false alarm rate from the corresponding hit rate, as described for Experiment 1. The resulting data are shown in Figure 2 as a function of word type (Remember, Forget) and recognition cueing (No Recognition Cues = black, Recognition Cues = green/red). An analysis of these data provided very strong evidence *for* an effect of word type, $p\text{H1}>0.99$, reflecting an overall directed forgetting effect. There was positive evidence *against* an effect of recognition cueing, $p\text{H0}=0.85$, and positive evidence *against* a two-way interaction of word type and recognition cueing, pH0=0.79. This pattern is exactly the same as for Experiment 1 – including the probability values when rounded to two decimal places. Thus, as was true for Experiment 1, recognition cues aided recognition of neither Remember nor Forget words. Whether recognition cues are intermixed (Experiment 1) or blocked (Experiment 2), the only factor that has an identifiable impact on subsequent recognition is whether participants formed an intention to Remember or Forget during the study trials.

[Figure 2 about here]

Experiment 3

The results of Experiment 2 confirmed no influence of recognition cues on the magnitude of the directed forgetting effect, even in a blocked design that was intended to emphasise the meaning of the recognition colour cues. Experiment 3 replicated the methods of Experiment 2, except that we added additional instructions to further clarify the meaning of the recognition cues. We also added explicit feedback on the accuracy of the recognition response.

Our decision to add explicit feedback was informed by a study reported by Verde and Rotello (2007; see also Estes & Maddox, 1995; Rhodes & Jacoby, 2007). They were interested in understanding whether item strength affects the placement of the decision criterion during recognition. Whereas our manipulation of strength comes from the presentation of instructions to Remember or Forget, their manipulation came from varying study item duration or number of repetitions. When they tested subsequent recognition by blocking the presentation of strong and weak items, they found an effect of strength on overall recognition (with greater recognition of strong items than weak items) and on initial criterion placement, but no evidence for a dynamic shift in criterion due to variations in item strength across blocks. This changed, however, when explicit feedback was given on recognition accuracy. On this basis, the authors argued that participants do not normally utilise strength cues in their decision-making but can be motivated to do so when prompted by explicit performance feedback. Our question was thus whether explicit feedback can likewise motivate a change in decision-making for Remember and Forget items.

Methods

Participants

A total of 36 students at Dalhousie University were recruited for participation, in exchange for psychology course credit.

Stimuli and Apparatus

The stimuli and apparatus were identical to Experiment 2.

Procedure

The procedure was identical to Experiment 2 except for the following details. Although we had been very careful in Experiment 2 to ensure that our participants understood the meaning of the coloured recognition cues and we were confident that they did, in Experiment 3 we further increased awareness of the recognition cueing procedure by adding additional instructions. After recalling the experimenter to the room to explain the recognition task, this task was reiterated again on the computer monitor. These instructions explained that a search of memory might be aided by knowledge of what one is searching for and that we would assist in this matter by using colour cues to indicate whether we were testing memory for *all* study words (black font), only Remember words (green font), or only Forget words (red font). Then, before each test block, we presented a detailed description of the cueing condition. Participants were instructed that words presented in black were a test of both Remember and Forget items, with 50% of the test items drawn from the study phase and 50% new items; words presented in green were a test of Remember items *only*, with 50% of the test items drawn from those that participants were instructed to Remember and 50% new items; and, words presented in red were a test of Forget items *only*, with 50% of test items drawn from those words that participants were instructed to Forget and 50% new items. In each case, participants cleared the instructions by depressing the space bar. On the recognition test, we displayed abbreviated instructions in the top left of the computer monitor and prompted "Do you recognise this word? (y/n)".

The recognition response triggered immediate feedback. If participants pressed "y" to a studied item or "n" to a foil item, the test word and prompt cleared to display the word "CORRECT" for 1,500 msec; if they pressed "n" to a study word or "y" to a foil item, the test word and prompt cleared to display the word "INCORRECT" for 1,500 msec.

Results and Discussion

Hits were defined as "y" responses to studied Remember and Forget words; false alarms were defined as "y" responses to unstudied foils. Before proceeding with the full analysis, we averaged, on a subject-by-subject basis, the recognition false alarm rates across recognition cueing condition. No participant's average false alarm rate exceeded the mean of all participants by more than 2 standard deviations; all data were retained for analysis. Proportion recognition "yes" responses are shown in Table 3.

[Table 3 about here]

Hit rates were corrected by subtracting the foil false alarm rate from the corresponding hit rate, as described for Experiments 1 and 2. The resulting data are shown in Figure 3 as a function of word type (Remember, Forget) and recognition cueing (No Recognition Cues = black, Recognition Cues = green/red). An analysis of these data provided very strong evidence *for* an effect of word type, $p\text{H1}>.99$, reflecting an overall directed forgetting effect. Unlike in Experiments 1 and 2, there was also strong evidence *for* an effect of recognition cueing, $p\text{H1}=0.97$, which can be seen in Figure 3 as overall greater recognition for cued test items than for uncued test items. This suggests that the inclusion of accuracy feedback in the recognition test prompted use of the recognition cues to improve recognition (even after correcting for false alarms). Critically, however, there was weak evidence *against* a two-way interaction of word type and recognition cueing, $p\text{H0}=0.71$. This suggests that the recognition cues were not any more effective for prompting recognition of Forget words than Remember words.

[Figure 3 about here]

Taken together, the results of Experiments 1-3 converge on the conclusion that providing recognition cues to inform participants of the relative strength/quality of encoded items does not aid recognition (Experiments 1 and 2) unless explicit feedback is also given (Experiment 3). But, even then, there is no particular benefit for Forget words compared to Remember words. Nevertheless, the fact that there was an overall effect of recognition cueing in Experiment 3 but not in the otherwise (nearly) identical Experiment 2 compels a closer examination of the role that feedback played in Experiment 3.

Whereas the shared foil false alarm rate on uncued trials prevents the derivation of separate signal detection measures for Remember and Forget word recognition, the separate false alarm rates on cued trials enable such calculations. Thus restricting our consideration to cued trials, we used the R neuropsychology package (Makowski, 2016) to compute signal detection measures. These data are presented in Table 4; for the sake of completeness, the values are also shown for the mixed design of Experiment 1, but will not be discussed here [see Note 2]. Using the criterion measure, *C*, we compared performance when explicit feedback was given (Experiment 3) to when it was not (Experiment 2); smaller numbers represent relatively more liberal responding. This analysis revealed weak evidence *for* an overall effect of word type (Remember, Forget), pH1=0.74; very strong evidence *for* an effect of experiment, pH1>0.99; and, strong evidence *for* an interaction of word type with experiment, pH1=0.97. As shown in Table 4, this interaction reflects the fact that the values of *C* in Experiment 2 were considerably *more* conservative for cued Forget words (0.77) than for cued Remember words (0.46), whereas in Experiment 3 they were slightly *less* conservative for cued Forget words (0.26) than for cued Remember words (0.30). In other words, providing feedback on the accuracy of recognition performance eliminated the conservative bias that otherwise exists for responding to cued Forget words.

[Table 4 about here]

The fact that performance feedback liberalises responses to cued Forget words more than it does responses to cued Remember words demonstrates that participants can be prompted to exert strategic control over retrieval. But it does not demonstrate that they can use feedback to *improve* retrieval of weakly or poorly encoded items. A shift in criterion implies increased endorsement of both studied and unstudied items, without necessitating improved discriminability of studied items. Indeed, an analogous consideration of d' scores provides very strong evidence *for* greater discriminability of cued Remember items than cued Forget items, pH1>0.99; positive evidence *against* an effect of experiment on item discriminability, pH0=0.89; and, weak evidence *against* an interaction of word type and Experiment, pH0=0.71[1]. In other words, feedback prompts a greater liberalisation of responses to cued Forget items than to cued Remember items, but this is not mirrored by changes in item discriminability (as might happen, for example, if the relatively weak Forget items also received additional scrutiny – e.g., by being evaluated more carefully for evidence of recollective details – as a result of the feedback)[2].

[1] Conclusions based on the two-way interaction of word type and experiment are the same when analyses are instead conducted using the analogous nonparametric measures B''_D (criterion) and A' (discriminability). The analysis of B''_D provides positive evidence *against* an overall difference in criterion for cued Remember and cued Forget words, pH0=0.89; strong evidence *for* more liberal responding in Experiment 3 than in Experiment 2, pH1=0.96; and, positive evidence *for* an interaction, pH1=0.84, with a larger liberal shift due to performance feedback for cued Forget items than for cued Remember items. The analysis of A' provides very strong evidence *for* greater discriminability of cued Remember words than cued Forget words, pH1>0.99; positive evidence *against* a main effect of experiment, pH0=0.89; and, weak evidence *against* an interaction of word type and experiment, pH0=0.51.

[2] A comparison of the mixed design of Experiment 1 and the blocked design of Experiment 2 (both of which had no performance feedback) is largely unrelated to the purpose of our study. Nevertheless, the interested reader might wonder whether the signal detection measures shown in Table 4 for cued trials were influenced as well by the study design. An comparison of the C values in Experiment 1 (mixed) and Experiment 2 (blocked) provided very strong evidence *for* an overall effect of word type, with more conservative responding to cued Forget words than to cued Remember words, pH1>0.99; positive evidence *against* a main effect of experiment, pH0=0.77; and, weak evidence *against* an interaction of word type with experiment, pH0=0.65. An analysis of d' provided very strong evidence *for* an overall effect of word type, with greater discriminability for cued Remember words than cued Forget words, pH1>0.99; weak evidence *for* a main effect of experiment, pH1=0.66, with overall greater discriminability of cued items in the blocked design of Experiment 2 than in mixed design of Experiment 1; and, weak evidence

General Discussion

Behavioural studies converge on the conclusion that directed forgetting in an item-method task is due to processes operating at encoding (see MacLeod, 1998 for a review). Imaging studies posit additional influences at retrieval (e.g., Nowicka et al., 2009; Paz-Caballero & Menor, 1999; Ullsperger et al., 2004; Van Hooff et al., 2009), as do recent multinomial modeling efforts aimed at understanding item-method directed forgetting in recall (rather than recognition) (Rummel, Marevec, & Kuhlmann, 2016). Noting that encoding control is incomplete and that (a subset of) Forget items may be represented in long-term memory in a weak (e.g., Thompson et al., 2011) or degraded form (e.g., Fawcett et al., 2016), the current study questioned whether retrieval-based strategies might contribute to directed forgetting effects that are measured in behaviour. Our supposition was that recognition decisions might favour a search for strong and/or high-quality representations, thereby favouring retrieval of Remember items over Forget items, even when both are represented in long-term memory.

The recognition cueing results reported by MacLeod (1975) seem to counter this suggestion. However, we argued that the question was nevertheless worth addressing again. As noted, MacLeod's (1975) study not only used very long retention intervals, it also tested memory using a 3-alternative forced-choice recognition test that might not have been as sensitive to retrieval-based strategies as yes-no recognition. As such, across three experiments, we presented a yes-no task in which the test item was sometimes cued as a potential Remember or Forget item. We reasoned that if yes-no recognition decisions tend to favour endorsement of strong and/or high-quality representations, cueing participants to the potential signal strength/quality could alter this strategy and assist retrieval of encoded Forget items (thereby reducing the magnitude of the directed forgetting effect).

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against an interaction of word type with experiment, pH0=0.64. Similar patterns were obtained for the nonparametric measures of A' and B''_D.

Our methods were premised on the notion that cueing participants to the memory instruction that was presented at study might increase their efforts and/or ability to retrieve weakly/poorly encoded Forget items at test. We did not necessarily expect that participants had encoded the Forget instruction itself, but rather that cueing the memory instruction could potentially aid retrieval by informing participants that there might be a relatively weak or impoverished trace associated with item recognition. Nevertheless, work by Burgess, Hockley, and Hourihan (2017) argues that the study context in an item-method task is encoded rapidly, within the first seconds of study word onset, and is therefore unaffected by subsequent memory instructions. The implication is that the memory instruction is effective at controlling encoding but occurs too late to form part of the mental representation of the encoding context. On this basis, one could argue that our recognition cues were ineffective at aiding Forget item retrieval because the instructions did not form part of the encoded study context. However, we would counter this argument in two ways. First, when we added explicit test performance feedback in Experiment 3, recognition improved on cued compared to uncued trials, even if it did not show greater improvement for Forget words compared to Remember words. The fact that there was *any* improvement in the corrected hit rates argues that providing information about the study instruction *can* influence subsequent recognition; it is simply the case that such improvements occur regardless of the strength/quality of the memory trace. Second, we note that when the typical yes-no recognition task is changed to a Remember-Forget-no tagging task, Remember words are more often tagged Remember than Forget; Forget words are more often tagged Forget than Remember (Thompson et al., 2011). Thus, even if the memory instruction does not form an integral part of the encoded study context, there is sufficient information available in the item itself for participants to judge whether it was more likely Remember-instructed or Forget-instructed at study. In other words, participants can use the perceived strength/quality of a test item representation to ascertain the memory instruction presented at study. The corollary is that participants should therefore have been able to use information about the memory instruction presented at study to form an expectation of the strength/quality of the test item representation, whether or not the memory instruction was encoded as part of the study context. The fact that the recognition cues failed to improve recognition for Forget items relative to Remember items in any of our three experiments argues against measurable effects of strength/quality-based retrieval strategies on item-method directed forgetting.

In Experiment 3, we added explicit performance feedback to the recognition cueing. Explicit feedback could reasonably be expected to encourage the additional effort that imaging studies suggest is needed for Forget item retrieval and that is certainly needed for interpreting and acting on the coloured recognition cue. Performance feedback is also known to prompt dynamic shifts in criterion setting for strength-based decisions (Verde and Rotello, 2007; see also Estes & Maddox, 1995; Rhodes & Jacoby, 2007). Indeed, a comparison of criterion scores across Experiments 2 and 3 confirmed that performance feedback eliminated the conservative response bias that otherwise occurs for cued Forget items compared to cued Remember items. That said, however, a corresponding analysis of d' scores did not reveal any effects on item discriminability. This suggests that explicit performance feedback encouraged participants to respond "yes" more often to cued Forget words as well as to their corresponding foil words; it did not make responses more discerning. Thus, cueing participants to the expected strength/quality of studied items – whether these recognition cues are presented alone (Experiments 1 and 2) or in combination with performance feedback (Experiment 3) – does not prompt greater recognition of Forget words compared to Remember words: The advantage for Remember word recognition over Forget word recognition is maintained.

We have been intentionally circumspect about identifying the potential retrieval-based strategies that we thought might be aided by cueing the memory instruction. The behavioural literature on directed forgetting effects obtained using an item-method paradigm converge on encoding processes to the exclusion of retrieval processes (e.g., see MacLeod, 1998 for a review). The only hint that there may be additional processes operating at retrieval come from imaging studies which provide neural markers of decreased accessibility and increased effort associated with Forget item retrieval (e.g., Nowicka et al., 2009; Paz-Caballero & Menor, 1999; Ullsperger et al., 2004; Van Hooff et al., 2009). These neural markers provide an insufficient basis for making *a priori* assumptions about the kinds of retrieval-based strategies that might be at play. But we reasoned that any such strategies would necessarily depend on differences in the strength and/or quality of Forget item traces compared to Remember item traces – since these are known differences between encoded items – and could therefore potentially be revealed by alerting participants to these characteristics viz. recognition cueing. Had our manipulations of recognition cueing and/or performance feedback increased the accuracy of Forget item recognition – and, by extension, reduced the magnitude of the directed forgetting effect – we would be in a position to further query and characterise the nature of potential retrieval-based operations. However, absent such an effect, there is no reason to presume a role for retrieval-based operations in a typical item-method directed forgetting task. And while we allow for the possibility that retrieval-based mechanisms may yet be uncovered in behaviour using methods that cue participants on a dimension other than expected strength/quality, we think it more likely that neural markers of decreased accessibility and increased effort associated with Forget item retrieval (e.g., Nowicka et al., 2009; Paz-Caballero & Menor, 1999; Ullsperger et al., 2004; Van Hooff et al., 2009) reflect the long-term consequences of the memory intentions formed at encoding, and not additional processes that operate at retrieval to actively limit Forget item recognition.

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Tables

No Recognition Cues		
Word Type	**Test Item Colour**	**Mean "Yes" Responses**
Remember	Black	0.62 (0.03)
Forget	Black	0.39 (0.03)
Foil	Black	0.17 (0.02)
Recognition Cues		
Remember	Green	0.67 (0.03)
Foil	Green	0.20 (0.02)
Forget	Red	0.37 (0.03)
Foil	Red	0.16 (0.02)

Table 1. Mean proportion "yes" responses in Experiment 1, as a function of word type (Remember, Forget, Foil) and recognition cueing (No Recognition Cues, Recognition Cues). These data represent proportion hits to Remember and Forget items and proportion false alarms to Foils. Test item colour is also shown, with Black colour providing no information, Green colour cueing potential Remember items, and Red colour cueing potential Forget items. The numbers in parentheses are the standard error of the mean.

Word Type	Test Item Colour	Mean "Yes" Responses
No Recognition Cues		
Remember	Black	0.69 (0.03)
Forget	Black	0.42 (0.03)
Foil	Black	0.16 (0.03)
Recognition Cues		
Remember	Green	0.66 (0.04)
Foil	Green	0.11 (0.02)
Forget	Red	0.40 (0.03)
Foil	Red	0.14 (0.02)

Table 2. Mean proportion "yes" responses in Experiment 2, as a function of word type (Remember, Forget, Foil) and recognition cueing (No Recognition Cues, Recognition Cues). These data represent proportion hits to Remember and Forget items and proportion false alarms to Foils. Test item colour is also shown, with Black colour providing no information, Green colour cueing potential Remember items, and Red colour cueing potential Forget items. The numbers in parentheses are the standard error of the mean.

Word Type	Test Item Colour	Mean "Yes" Responses
No Recognition Cues		
Remember	Black	0.77 (0.00)
Forget	Black	0.49 (0.01)
Foil	Black	0.22 (0.00)
Recognition Cues		
Remember	Green	0.75 (0.00)
Foil	Green	0.12 (0.00)
Forget	Red	0.57 (0.01)
Foil	Red	0.27 (0.00)

Table 3. Mean proportion "yes" responses in Experiment 3, as a function of word type (Remember, Forget, Foil) and recognition cueing (No Recognition Cues, Recognition Cues). These data represent proportion hits to Remember and Forget items and proportion false alarms to Foils. Test item colour is also shown, with Black colour providing no information, Green colour cueing potential Remember items, and Red colour cueing potential Forget items. The numbers in parentheses are the standard error of the mean.

Word Type	Test Item Colour	d'	C
Experiment 1: Recognition Cues			
Remember	Green	1.38 (0.01)	0.24 (0.01)
Forget	Red	0.75 (0.02)	0.74 (0.01)
Experiment 2: Recognition Cues			
Remember	Green	1.83 (0.02)	0.46 (0.01)
Forget	Red	0.95 (0.01)	0.77 (0.01)
Experiment 3: Recognition Cues			
Remember	Green	1.99 (0.02)	0.30 (0.01)
Forget	Red	0.84 (0.02)	0.26 (0.01)

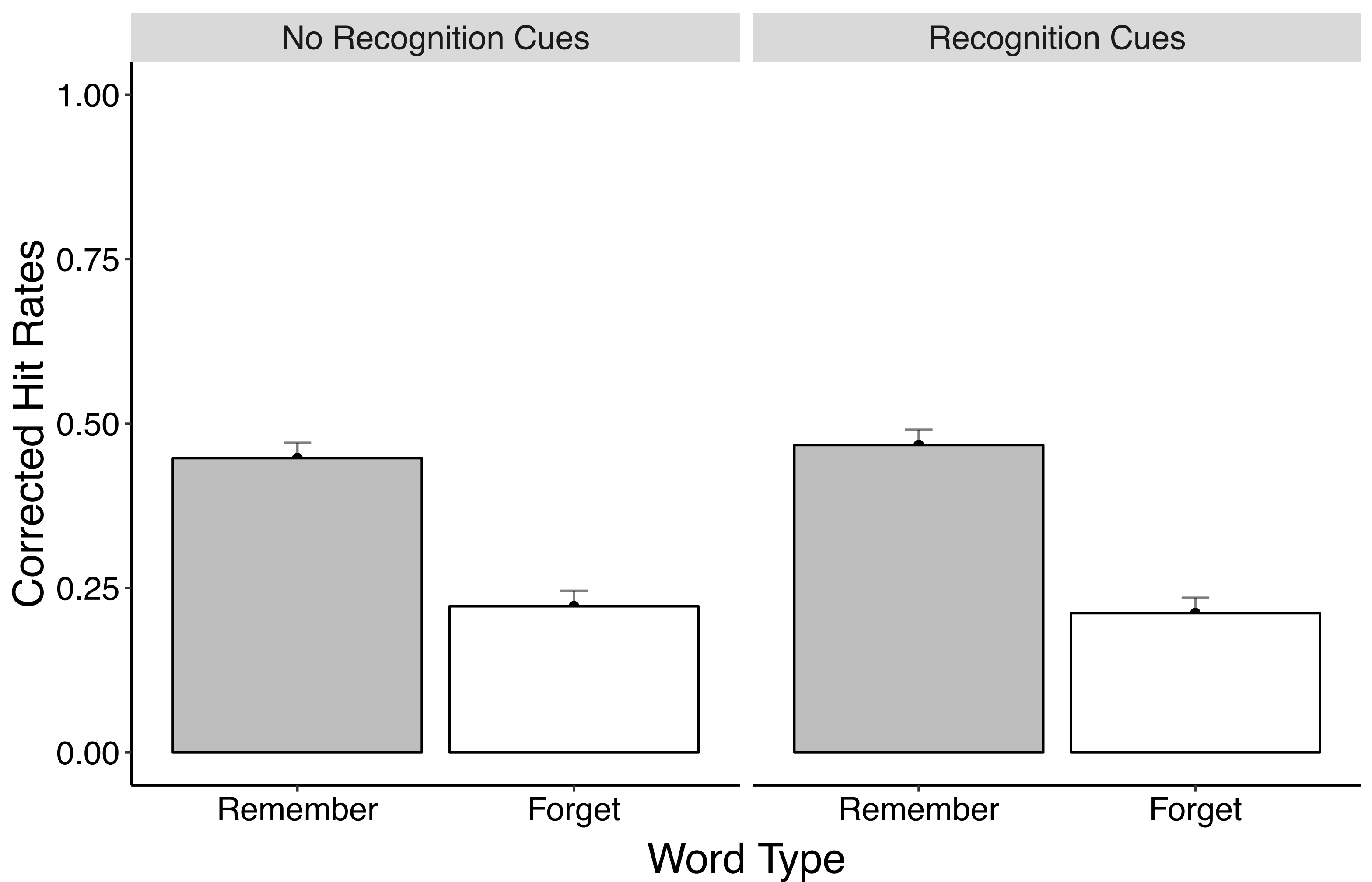
Table 4. Mean d-prime (d') and criterion (*C*) value for cued trials only, Experiments 1, 2, and 3. Data are shown as a function of word type (Remember, Forget) and test item colour (Green, Red). The numbers in parentheses are the standard error of the mean.

Figures Captions

Figure 1. Corrected recognition hit rates (hits for studied items – false alarms for foils in the corresponding colour) in Experiment 1, as a function of word type (Remember, Forget) and recognition cueing (No Recognition Cues, Recognition Cues). On trials with no recognition cues, test items were coloured black; on trials with recognition cues, test items were coloured green to cue a potential Remember item, or red to cue a potential Forget item. Presentation of cued and uncued recognition trials was intermixed within a single block of trials. Error bars are Fisher's Least Significance Difference.

Figure 2. Corrected recognition hit rates (hits for studied items – false alarms for foils in the corresponding colour) in Experiment 2, as a function of word type (Remember, Forget) and recognition cueing (No Recognition Cues, Recognition Cues). On trials with no recognition cues, test items were coloured black; on trials with recognition cues, test items were coloured green to cue a potential Remember item, or red to cue a potential Forget item. Presentation of cued and uncued recognition trials was blocked. Error bars are Fisher's Least Significance Difference.

Figure 3. Corrected recognition hit rates (hits for studied items – false alarms for foils in the corresponding colour) in Experiment 3, as a function of word type (Remember, Forget) and recognition cueing (No Recognition Cues, Recognition Cues). On trials with no recognition cues, test items were coloured black; on trials with recognition cues, test items were coloured green to cue a potential Remember item, or red to cue a potential Forget item. Presentation of cued and uncued recognition trials was blocked. Error bars are Fisher's Least Significance Difference.


No Recognition Cues
Recognition Cues
Corrected Hit Rates
1.00
0.75
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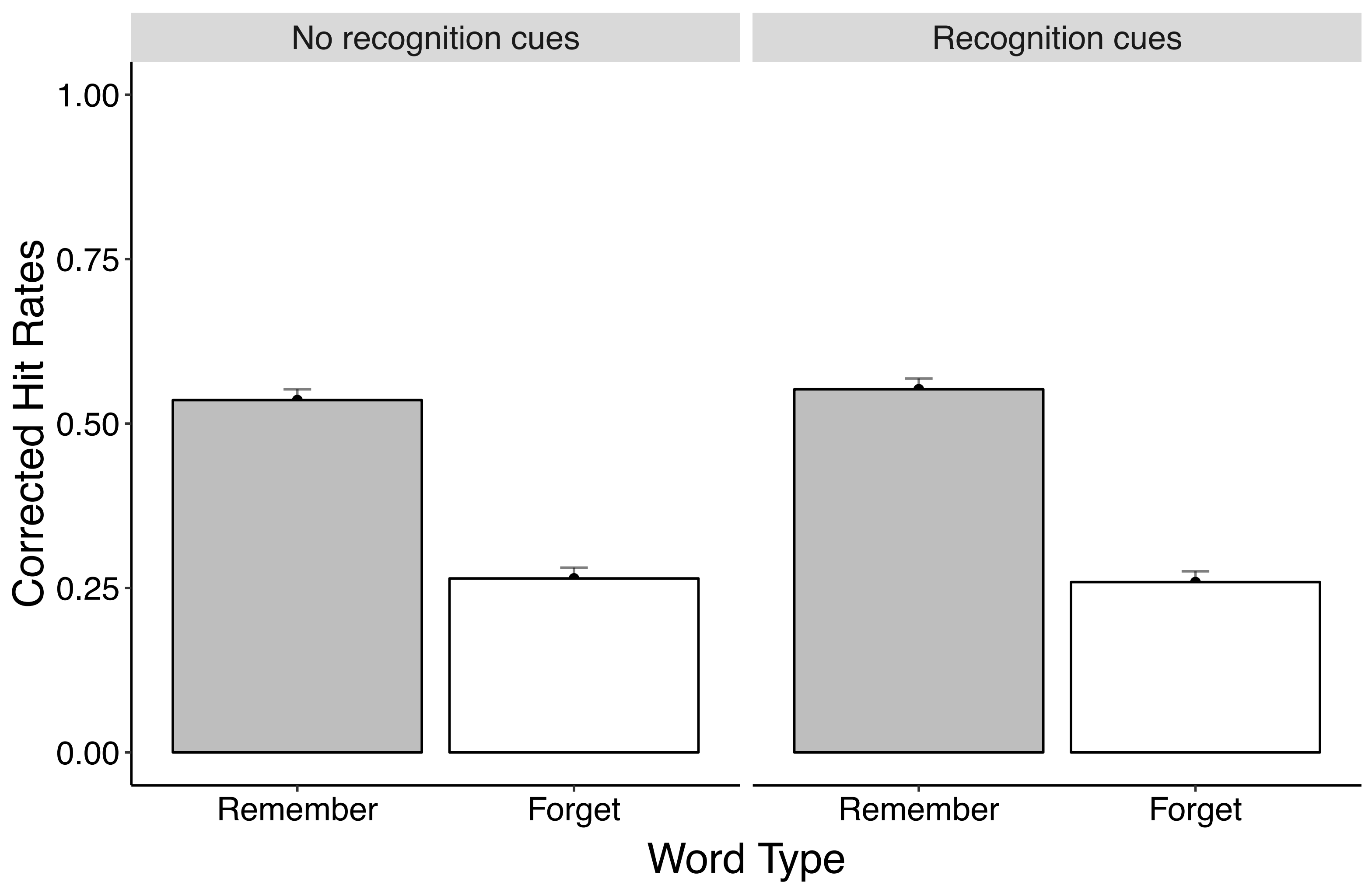
Remember
Forget
Remember
Forget
Word Type



No recognition cues
Recognition cues
Corrected Hit Rates
1.00
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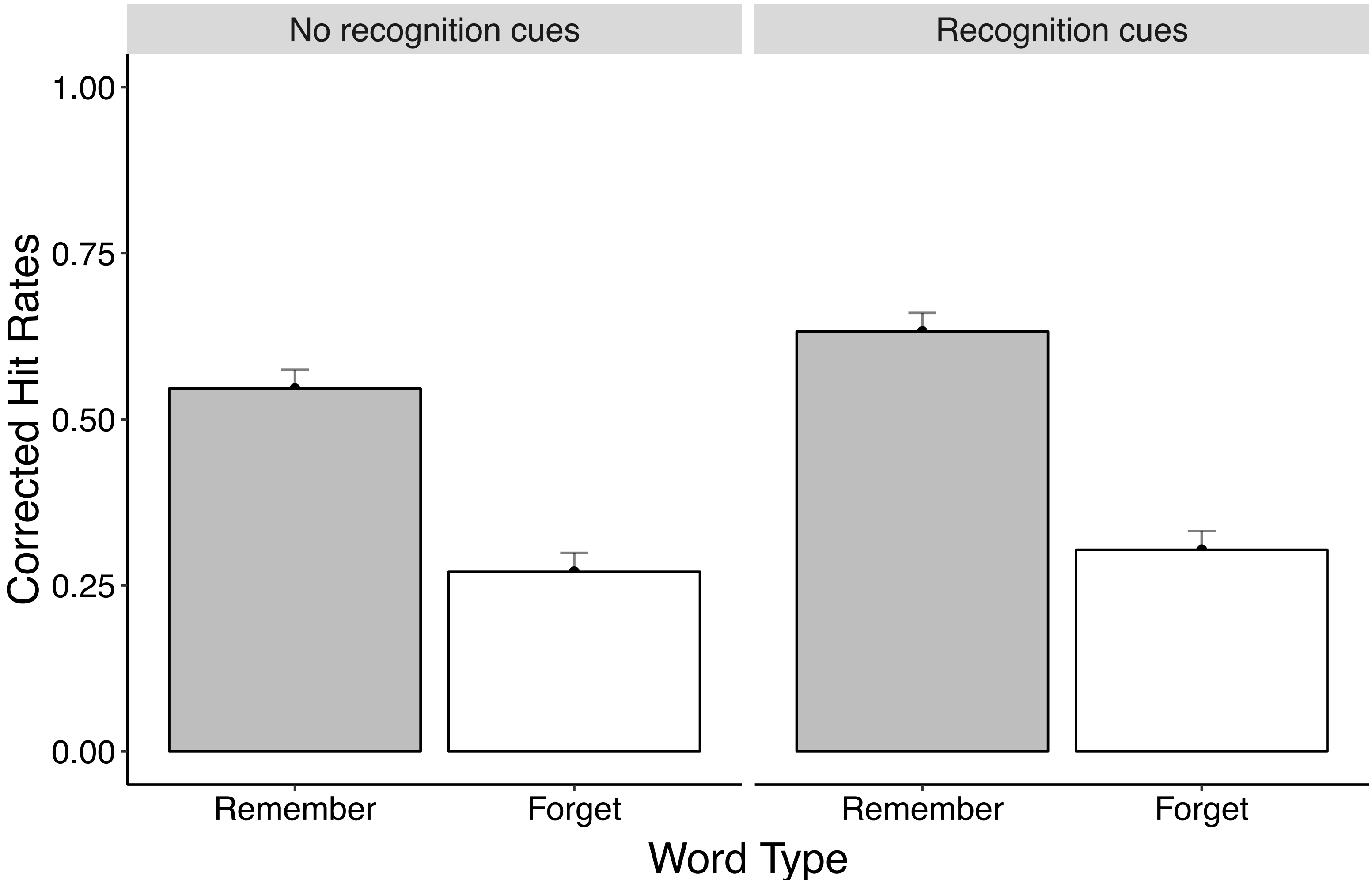
Remember
Forget
Remember
Forget
Word Type


No recognition cues
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Corrected Hit Rates
1.00
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Remember
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Remember
Forget
Word Type