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Does an instruction to forget enhance memory for other presented items?

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ABSTRACT

In an item-method directed forgetting paradigm, participants were required to attend to one of two colored words presented on opposite sides of a central fixation stimulus; they were instructed to *Remember* or *Forget* the attended item. On a subsequent recognition test, the *Attended* words showed a typical directed forgetting effect with better recognition of *Remember* words than *Forget* words. Our interest was in the fate of the *Unattended* words. When the study display disappeared before the memory instruction, there was no effect of that instruction on unattended words; when the study display remained visible during presentation of the memory instruction, there was a reverse directed forgetting effect with better recognition of unattended words from *Forget* trials than from *Remember* trials. Incidental encoding of task-irrelevant stimuli occurs following presentation of a *Forget* instruction – but only when those task-irrelevant stimuli are still visible in the external environment.

1. Introduction

Intentionally forgetting unwanted information serves memory by enabling the redistribution of limited capacity cognitive resources (e.g., Taylor, 2005a, 2005b; Taylor & Fawcett, 2011). In the laboratory, intentional forgetting is often studied using a directed forgetting paradigm (see Basden & Basden, 1998). In the item-method version of this paradigm, words are presented one at a time during study, each accompanied or followed by an instruction to *Remember* or *Forget*. A typical finding is that more *Remember* items are correctly recognized than *Forget* items (for a review, see MacLeod, 1998). This directed forgetting effect is not attributable to demand characteristics (MacLeod, 1999) and – at least when tested with recall – is presumed to result from a combination of benefits for performance in the *Remember* condition and costs in the *Forget* condition, relative to when participants must commit all items to memory (Sahakyan & Foster, 2009).

When a directed forgetting effect is obtained in an item-method paradigm, it is typically attributed to processes occurring at encoding rather than at retrieval (Basden, Basden, & Gargano, 1993; Bjork, 1972; although see, Nowicka, Jednoróg, Marchewka, & Brechmann, 2009; Ullsperger, Mecklinger, & Müller, 2000). The most common conceptualization is that the difference in memory performance for *Remember* and *Forget* items is due to differential rehearsal. When the study word is presented on each trial, participants attend to the word and maintain its representation in working memory until they receive a memory instruction. If the instruction is to *Remember* the word, the participant engages in elaborative rehearsal to commit that item to memory; if the instruction is to *Forget*, the participant drops this now-irrelevant item from the rehearsal set and allows its representation to decay.

A question that has been of interest to our laboratory is how the *Forget* item is dropped from the rehearsal set. One possibility is that forgetting involves the passive decay of an unrehearsed memory trace. An alternative possibility is that the intention to *Forget* engages an active cognitive mechanism that limits further *Forget* item processing and commitment to memory.

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Distinguishing between these two accounts requires an assessment of the relative cognitive load associated with instantiating a *Forget* versus a *Remember* instruction. On the one hand, if a *Forget* instruction leads to passive decay of the to-be-forgotten item, instantiating a *Forget* instruction should be relatively less effortful than instantiating a *Remember* instruction. On the other hand, if a *Forget* instruction requires an active withdrawal of processing resources from the to-be-forgotten item, the effort associated with instantiating a *Forget* instruction should be fairly similar to that associated with instantiating a *Remember* instruction (which requires the active commitment of processing resources). Where reaction times (RTs) to detect a visual probe provide a proxy measure of cognitive load (see Kahneman, 1973), Fawcett and Taylor (2008, 2010) demonstrated that instantiating a *Forget* instruction is not only effortful, in the first ∼1.5–2 s it is actually *more* effortful than instantiating a *Remember* instruction. This was revealed by a pattern of longer probe RTs following *Forget* than following *Remember* instructions. Interestingly, when the probe task was changed to require a speeded color discrimination of an otherwise task-irrelevant probe word written in blue or pink font, RTs continued to be longer following *Forget* than following *Remember* instructions, whereas incidental memory formation for the probe words was better following *Remember* than following *Forget* items (Fawcett & Taylor, 2012). Taken together, these findings suggest that instantiating a *Forget* instruction is more effortful than instantiating a *Remember* instruction with consequences for subsequent incidental memory formation.

Critically, longer probe RTs in the first seconds following a *Forget* than following a *Remember* instruction are not attributable to the retrieval and cumulative rehearsal of to-be-remembered items from preceding trials (for discussion, see Fawcett & Taylor, 2008, 2010). Probe RTs are longer following *Forget* than following *Remember* instructions even on the very first study trial (see Fawcett, Taylor, & Nadel, submitted for publication) – that is, even when there are no items to retrieve and rehearse from preceding trials. Probe RTs are also longer on *Forget* trials than on interleaved no-word control trials for which retrieval and cumulative rehearsal of to-be-remembered items from preceding trials would also be expected to occur (Fawcett & Taylor, 2008). Thus, while it is likely that participants do ultimately use the inter-trial interval to cumulatively rehearse *Remember* items from preceding trials, retrieval and cumulative rehearsal of items from preceding *Remember* trials cannot fully account for the greater initial effort associated with instantiating a *Forget* versus *Remember* instruction. Intentional forgetting is not simply a failure to encode the passively decaying *Forget* item during the retrieval and cumulative rehearsal of preceding *Remember* items.

That intentional forgetting involves more than a failure to encode the to-be-forgotten items is confirmed by event-related functional magnetic resonance imaging (fMRI), which shows unique activations in hippocampus and superior frontal gyrus during the study of words that are subsequently forgotten intentionally versus those that are forgotten unintentionally (Wylie, Foxe, & Taylor, 2008). Notably, the successful versus unsuccessful instantiation of a memory intention also activates brain regions critically involved in attentional control networks (Wylie et al., 2008; *cf.* Fan, McCandliss, Fossella, Fombaum, & Posner, 2005). This implicates attentional control not only in the successful instantiation of an intention to *Remember* but also in the successful instantiation of an intention to *Forget*.

Where the mental representation of a *Forget* item includes its spatial location in the case of words presented in the visual periphery (e.g., Hourihan, Goldberg, & Taylor, 2007), behavioral data suggest that instantiating an intention to *Forget* initiates an effortful withdrawal of attention from the representation of the *Forget* item (Taylor, 2005a). This conclusion follows from a paradigm in which words are presented to the left and right during the study phase of an item-method task. Following the disappearance of each word, a tone instructs participants to *Remember* or *Forget*. Then, a visual target requiring a localization response is presented in the same location as the preceding word or in a different location. The dependent measure of interest is the RT to localize the target to the same versus a different location as the word, as a function of memory instruction. This provides a measure of the inhibition of return (IOR) effect on *Remember* and *Forget* trials.

In a typical IOR task, the initial peripheral onset is a visual stimulus such as an asterisk or a brightening of a box at the peripheral location; there is no word and no requirement to commit anything to memory. In such a task, the typical finding is that RTs are slower for targets that appear in the same location as the preceding peripheral visual onset than in a different location (Posner & Cohen, 1984). This pattern is referred to as an IOR effect. This effect is generated automatically by the onset of the initial peripheral stimulus; however, because the IOR effect can co-occur with, and thereby be obscured by, an opposing facilitatory effect due to the initial capture of attention by the peripheral onset (e.g., Dorris, Klein, Everling, & Munoz, 2002; Ro & Rafal, 1999; Tipper et al., 1997; see Klein, 2000 and Taylor & Klein, 1998 for reviews), the IOR effect does not become apparent in RTs until "unmasked" by the withdrawal of attention from the peripheral location (cf. Danziger & Kingstone, 1999). In this way, the IOR effect can serve as an index of attentional withdrawal.

When the IOR effect is measured within the context of the study trials of an item-method directed forgetting paradigm, the magnitude of this effect is consistently larger following *Forget* than following *Remember* instructions. Because the IOR effect becomes measurable in RTs as attention withdraws from the peripheral location, this *Forget* > *Remember* IOR difference is consistent with a more ready withdrawal of attention following *Forget* than following *Remember* instructions (Fawcett & Taylor, 2010; Taylor, 2005a; Taylor & Fawcett, 2011). While there is some indication that this *Forget* > *Remember* IOR difference may be due to a tendency for attention to dwell on the *Remember* item representation as well as a tendency for attention to withdraw from the *Forget* item representation, the withdrawal of attention on *Forget* trials is the more robust and consistent finding (e.g., Taylor, 2005a) and occurs across a wide range of word-instruction and instruction-target stimulus onset asynchronies (with no indication that a withdrawal of attention is simply slower to occur following a *Remember* instruction; see Taylor & Fawcett, 2011).

Given that an instruction to *Forget* initiates a withdrawal of attention from the representation of the *Forget* word we are left to wonder – where does attention go? In the case of a peripherally presented *Forget* word, is visuo-spatial attention withdrawn to center or reallocated to the location opposite the *Forget* word? Certainly, if attention were reoriented to the opposite location, this could account for the greater IOR effect on *Forget* than on *Remember* trials (i.e., for the magnification of the difference in RTs for targets that appear in the same versus different location as the preceding word).

We know that the cognitive effort associated with instantiating a *Forget* instruction normally consumes limited capacity resources, affecting the incidental commitment of subsequent probe words to memory (Fawcett & Taylor, 2012); but in this case, the probe words were presented in the same location as the *Forget* item and may have therefore been affected by the withdrawal of attention from the *Forget* item representation. It thus follows that if attention is initially reoriented to the location opposite the *Forget* instruction either as a means for, or a consequence of, limiting further processing of the to-be-forgotten item, the resulting release of cognitive processing resources might make them temporarily available for incidental memory formation of distractor items presented at the newly attended location. This would be a very interesting finding because it would suggest that intentional forgetting of one item is associated with increased incidental remembering of another.

To explore this possibility, we presented two words on each trial, one in blue and one in pink. Participants were required to attend to only one of these words. In Experiments 1 and 2, the words disappeared before participants received an instruction to *Remember* or *Forget* the *Attended* word; in Experiment 3, the memory instruction overlapped with the continued presentation of both words. In all three experiments, a yes–no recognition test assessed memory for *all* words presented at study – regardless of their attention status (*Attended*, *Unattended*) or memory instruction (*Remember*, *Forget*). If instantiating the memory instruction for *Attended* words has unintended memory consequences for *Unattended* words, there should be a directed forgetting effect for the *Attended* words (i.e., *Remember* > *Forget* recognition performance) and a REVERSE directed forgetting effect for *Unattended* words (i.e., *Forget* > *Remember* recognition performance).

2. Experiment 1

In Experiment 1, we presented participants with two words on each study trial: One word was blue and the other was pink. Half of the participants were required to attend the blue words; the remaining participants were required to attend the pink words. To ensure that both words were likely to receive at least minimal processing and to be incorporated into a mental image of the learning episode, they were presented only a short distance apart, above and below a central fixation stimulus. The *Attended* word was as likely to appear above as below fixation; thus participants could not select a location to attend until after both words were presented. The memory instruction was presented after the disappearance of these words.

2.1. Method

2.1.1. Participants

Twenty-two undergraduate students participated in exchange for course credit. All participants were tested individually in a session that lasted no more than 1 h. When queried, none reported having participated in other studies of directed forgetting.

2.1.2. Stimuli and apparatus

Stimulus presentation and response collection were controlled by PsyScope 1.5.2 (Cohen, MacWhinney, Flatt, & Provost, 1993) running on a Macintosh G4-400 computer equipped with a 17″ ViewSonic PT775 or Apple Studio color display monitor and Apple Universal Serial Bus keyboard.

A list of 240 nouns was created using an on-line word list generator (http://www.math.yorku.ca/SCS/Online/paivio/). The words on this list had a mean Kucera-Francis (Kucera & Francis, 1967) word frequency of 42.72; imagery rating of 6.15; concreteness rating of 6.42; meaningfulness rating of 6.57; 1.77 syllables; and a mean length of 5.70 letters, with a range of 3–8 letters. Prior to running each participant, custom software was used to randomly assign 60 of these words to an *Attended* list, 60 to an *Unattended* list, and 120 to a *Foil* list; this ensured that unique lists were used for each participant.

All stimuli were presented on a uniform white background. Text stimuli on the study trials were presented in the PsyScope default font (size-32). One word on each trial was presented in blue; the other was presented in pink. Text stimuli on the recognition trials were presented in black size 18 Arial font.

2.1.3. Procedure

Prior to beginning the experiment, participants received both verbal and written instructions. These instructions informed participants that two words would appear, one above and another below the "+" sign in the center of the computer monitor, and that one of these words would be printed in blue and the other in pink. Half of the participants were instructed to attend to the blue word, as it was the one they might need to remember; the other half were instructed to attend to the pink word, as it was the one they might need to remember. Participants were further instructed that following the disappearance of these words, the "+" would change color. If the "+" changed to green, they were told to remember the attended word; if it changed to red they were told they could forget this word.

2.1.3.1. Familiarization phase. Prior to beginning the experimental trials, participants received four instruction familiarization trials. On each trial, an instruction to *Remember* (green "+") or *Forget* (red "+") was presented in the center of the screen for

Table 1
Proportion of "yes" responses shown as a function of Experiment, Attention Status of the test word when it was presented at study (*Attended*, *Unattended*), and as a function of Item Type (*Remember*, *Forget*, *Foil*). *M* = mean, *SE* = standard error of the mean.

	Item type					
	Remember		Forget		Foil	
	M	*SE*	*M*	*SE*	*M*	*SE*
Experiment 1 (*N* = 22)						
Attended	.7913	.0303	.5820	.0416	.0404	.0074
Unattended	.2013	.0369	.1741	.0319		
Experiment 2 (*N* = 53)						
Attended	.7254	.0290	.5142	.0298	.1076	.0156
Unattended	.1979	.0193	.1967	.0225		
Experiment 3a (*N* = 36)						
Attended	.7284	.0266	.4328	.0359	.0811	.0153
Unattended	.2043	.0293	.2592	.0376		
Experiment 3b (*N* = 24)						
Attended	.7215	.0469	.4242	.0368	.0655	.0121
Unattended	.1262	.0165	.1610	.0223		
Experiment 4 (*N* = 26)						
Attended	.7803	.0369	.7777	.0274	.1128	.0203
Unattended	.2527	.0380	.2321	.0379		

2500 ms. After the first 500 ms of presentation, a relevant verbal descriptor appeared below the memory instruction (e.g., below a green "+" the words: "…means you should remember") and remained visible for the next 2000 ms. There was a 2500 ms intertrial interval during which the computer screen remained blank.

2.1.3.2. Study phase. Following the instruction familiarization trials, participants were presented with the study trials. Each study trial started with the presentation of a black "+" at the center of the computer screen. After 2000 ms, two words were presented for 4000 ms. From a viewing distance of 52 cm, one appeared approximately 1.5° of visual angle above the central "+" stimulus and the other approximately 1.5° of visual angle below. One of these words was printed in blue and the other was printed in pink; each color appeared above and below with equal probability across trials. At 500 ms following the disappearance of the two words, the central "+" stimulus changed with equal probability from black to either red or green and remained visible for 1000 ms. This was followed by a 2000 ms intertrial interval during which the computer screen remained blank. There were a total of 60 study trials; 30 of these presented a *Remember* instruction (green "+") and 30 presented a *Forget* instruction (red "+").

Four buffer trials were presented at the beginning and another four were presented at the end of the study trials to limit the effects of primacy and recency. The buffer trials were identical to the study trials except that the buffer words were the same items for all participants and were always followed by a *Remember* instruction. Recognition of these buffer words was not tested.

2.1.3.3. Recognition phase. The recognition test followed immediately after the last of the buffer trials. Instructions were presented at the top of the computer screen and remained visible throughout the trials. These instructions informed participants that they were to try to recognize all words presented during the study trials. This included both attended and unattended words from both *Remember* and *Forget* trials. Participants were instructed to press "y" (yes) to indicate words that they recognized from the study trials and "n" (no) to indicate words that they did not recognize.

Recognition words were presented one at a time below the task instructions. Keyboard strokes appeared in a black outline box that appeared below the word to be recognized. Responses could be self-corrected while visible on the screen; they disappeared after the participant submitted the response using the spacebar. A recognition hit was defined as a "y" response to any of the 30 attended words from *Remember* trials, 30 attended words from *Forget* trials, 30 unattended words from *Remember* trials, and 30 unattended words from *Forget* trials; a false alarm was defined as a "y" response to any of the 80 'new' items from the *Foil* list.[1]

2.2. Results

The proportions of hits and false alarms are provided in Table 1. To correct for guessing, on a participant-by-participant basis, the proportion of false alarms to unstudied foils was subtracted from the proportion of hits as a function of attention

[1] Due to a computer programming error, the total number of recognition trials was set to 240 even though there were only 80 *Foil* words. This meant that 10 of each of the *Attended* and *Unattended* words in the *Remember* and *Forget* conditions were unintentionally presented twice during the recognition task. Performance on the recognition task considered only the response to the first instance of each repeated word; responses to the second instance were not included in the calculation of recognition accuracy provided in Section 2.2.

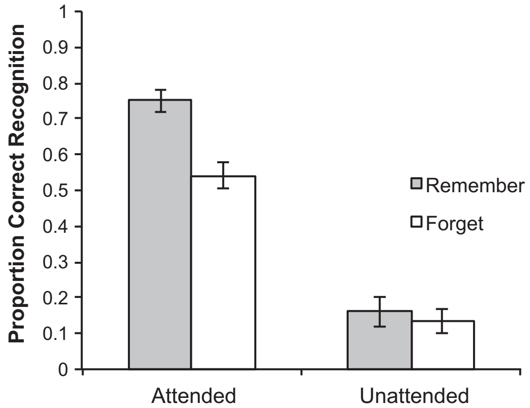

Fig. 1. Experiment 1: Proportion correct recognition, calculated as the difference between the proportion hits and proportion foil false alarms. Data are shown as a function of Attention Status of the test word when it was presented at study (*Attended*, *Unattended*), and as a function of the Memory Instruction presented at study (*Remember*, *Forget*). Error bars depict the standard error of the mean.

status (*Attended*, *Unattended*) and memory instruction (*Remember*, *Forget*). These data are shown in Fig. 1. Analysis of the raw hits or a signal-detection measure such as d' demonstrate the same pattern reported below.

A repeated measures analysis of variance (ANOVA) revealed a significant main effect of attention status, $F(1,22) = 119.651$, MSe = 0.046, $p < .0001$, $\eta_g^2 = .695$, with overall greater recognition of *Attended* ($M = 0.646$, $SE = 0.033$) than *Unattended* ($M = 0.147$, $SE = 0.033$) words. There was also a directed forgetting effect, as revealed by a main effect of memory instruction, $F(1,21) = 41.092$, MSe = 0.007, $p < .0001$, $\eta_g^2 = .113$; recognition was better for *Remember* ($M = 0.456$, $SE = 0.020$) than for *Forget* ($M = 0.338$, $SE = 0.030$) words.

These main effects were qualified by a significant two-way interaction of attention status and memory instruction, $F(1,21) = 17.077$, MSe = 0.011, $p = .0005$, $\eta_g^2 = .071$. This interaction can be seen in Fig. 1 as a significant directed forgetting effect in the *Attended* condition, $t(21) = 6.063$, $p < .0001$, and a non-significant directed forgetting effect in the *Unattended* condition, $t(21) = 1.266$, $p = .2194$. A Sign Test confirmed that a significant number of participants showed better performance for *Remember* than *Forget* words in the *Attended* condition, [(R–F) > 0]:19, [(R–F) < 0]:3, [R = F]:0, $p = .0004$, but no systematic difference in the number that showed worse performance for *Remember* than *Forget* words in the *Unattended* condition, [(R–F) > 0]:11, [(R–F) < 0]:8, [R = F]:3, $p = .5841$.

2.3. Discussion

The results of Experiment 1 demonstrate a standard directed forgetting effect in the *Attended* condition, with better recognition of attended *Remember* words than attended *Forget* words. However, there was no evidence that these instructions had consequences for incidental memory formation of distractor items. The unattended items showed no significant incidental effects of the memory instruction. If anything, the results for the *Unattended* condition were opposite of our predictions: The results were in the direction of a directed forgetting effect (see also Fawcett & Taylor, 2012) rather than a *reverse* directed forgetting effect.

Of course, one could argue that the close proximity of the attended and unattended items in Experiment 1 obviated any need to reorient attention following the memory instruction. It could also be argued that the presentation of a visual memory instruction – a meaningful event at fixation – caused attention to dwell centrally thereby preventing any reallocation to the *Unattended* item that might otherwise occur. And there is some evidence to suggest that a central onset at fixation may prevent the differential withdrawal of exogenous attention following *Forget* and *Remember* instructions (Taylor & Fawcett, 2011). To address these issues, Experiment 2 presented the *Attended* and *Unattended* words further in the visual periphery and used an auditory memory instruction.

3. Experiment 2

Experiment 2 presented *Attended* and *Unattended* words further in the visual periphery relative to Experiment 1, to the left and right of fixation. Presenting words to the left and right reduced timing issues associated with the top-to-bottom raster scan needed to display spatially disparate images on-screen with near-simultaneity. And, combined with the presentation of an auditory – rather than a visual – memory instruction, mapped more closely onto the methods of Taylor (2005a), which supported a role of differential attentional withdrawal from *Forget* and *Remember* items (see also Fawcett & Taylor, 2010; Taylor & Fawcett, 2011). The number of participants was also increased substantially relative to Experiment 1 to ensure adequate power to detect a reverse directed forgetting effect in the *Unattended* condition, if present.

3.1. Method

3.1.1. Participants

Fifty-four undergraduate students from Dalhousie University participated in exchange for course credit.

3.1.2. Stimuli and apparatus

The stimuli and apparatus were identical to Experiment 1, except that the memory instruction was a high- (1170 Hz) or low-frequency (260 Hz) tone played over both channels of Sony MDR-XD100 headphones.

3.1.3. Procedure

The procedure was identical to Experiment 1 with the following exceptions. For half of the participants in each attend-color condition, the high-frequency tone served as a *Remember* instruction and the low-frequency tone served as a *Forget* instruction; this tone designation was reversed for the remaining participants.

Prior to beginning the experimental trials, participants received 10 tone familiarization trials; a random half of these trials presented high tones and the other half presented low tones. Each trial presented a descriptor of the tone designation (i.e., “High Tone – Remember”) centered on the computer screen for 3000 ms. After 1000 ms, the indicated tone was presented for 400 ms. No response was required. There was a 1500 ms intertrial interval during which the screen was blank.

Following the tone familiarization trials, participants were presented with the study trials. Each study trial started with the presentation of a plus sign (+) at the center of the computer screen. This stimulus remained visible throughout the trial. After 2000 ms, two words were presented for 4000 ms. From a viewing distance of 52 cm, one was centered approximately 6° of visual angle to the left of the central “+” stimulus and the other was centered approximately 6° of visual angle to the right. One of these words was printed in pink and the other was printed in blue; each color appeared to the left and right with equal probability across trials. After these words disappeared, there was a 500 ms delay, following which the high- or low-frequency tone was played for 400 ms. There was a 2000 ms delay before the start of the next trial.

As in Experiment 1, these study trials were preceded by four buffer trials and followed by four buffer trials. The buffer trials were otherwise identical to the study trials except that the same words were presented to all participants; all buffer words were followed by a *Remember* instruction; and, none of the buffer words were tested at recognition. The recognition test followed immediately after the final buffer trial.

There were a total of 60 study trials; 30 of these presented a *Remember* instruction and 30 presented a *Forget* instruction. There were a total of 240 recognition trials. A recognition hit was defined as a “y” response to any of the 30 attended words from *Remember* trials, 30 attended words from *Forget* trials, 30 unattended words from *Remember* trials, and 30 unattended words from *Forget* trials; a false alarm was defined as a “y” response to any of the 120 ‘new’ items from the *Foil* list.

3.2. Results

The data from one participant were excluded due to a computer crash that compromised the data. The mean proportions of hits and false alarms across the remaining participants are provided in Table 1. As in Experiment 1, the proportion of false alarms to unstudied foils was subtracted on a participant-by-participant basis from the proportion of hits as a function of attention status (*Attended*, *Unattended*) and memory instruction (*Remember*, *Forget*). The resulting means are shown in Fig. 2. Analysis of the raw hits or a signal-detection measure such as d' demonstrate the same pattern reported below.

A repeated measures analysis of variance (ANOVA) revealed a significant main effect of attention status, $F(1,52) = 212.915$, MSe = 0.044, $p < .0001$, $\eta_g^2 = .600$, with overall greater recognition of *Attended* ($M = 0.512$, $SE = 0.029$) than

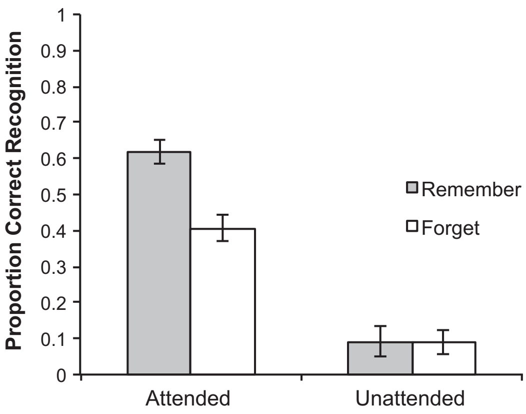

Fig. 2. Experiment 2: Proportion correct recognition, calculated as the difference between the proportion hits and proportion foil false alarms. Data are shown as a function of Attention Status of the test word when it was presented at study (*Attended*, *Unattended*), and as a function of the Memory Instruction presented at study (*Remember*, *Forget*). Error bars depict the standard error of the mean.

Unattended (M = 0.090, SE = 0.011) words. There was also a directed forgetting effect, as revealed by a main effect of memory instruction, $F(1,52) = 50.427$, MSe = 0.012, $p < .0001$, $\eta_g^2 = .087$; recognition was better for *Remember* (M = 0.354, SE = 0.019) than for *Forget* (M = 0.248, SE = 0.017) words.

These main effects were qualified by a significant two-way interaction of attention status and memory instruction, $F(1,52) = 66.791$, MSe = 0.009, $p < .0001$, $\eta_g^2 = .085$. This interaction can be seen in Fig. 2 as a significant directed forgetting effect in the *Attended* condition only, $t(52) = 8.573$, $p < .0001$; recognition of *Unattended* words was essentially identical on *Remember* and *Forget* trials, $t(52) = 0.091$, $p = .9280$. A Sign Test confirmed that a significant number of participants showed better performance for *Remember* than *Forget* words in the *Attended* condition, [(R–F) > 0]:48, [(R–F) < 0]:3, [R = F]:2, $p < .0001$, but no systematic difference in the number who showed worse performance for *Remember* than *Forget* words in the *Unattended* condition, [(R–F) > 0]:24, [(R–F) < 0]:25, [R = F]:4, $p = .3919$.

3.3. Discussion

Like Experiment 1, the results of Experiment 2 reveal a directed forgetting effect in the *Attended* condition but no reverse directed forgetting effect in the *Unattended* condition. Importantly, recognition performance in the *Unattended* condition, after being corrected for guessing, was greater than 0 in both the *Remember*, $t(52) = 7.549$, $p < .0001$, and *Forget*, $t(52) = 6.654$, $p > .0001$, conditions. In other words, the *Unattended* items were recognized at a significantly higher rate than is accounted for by guessing alone. This is important because it demonstrates that despite the physical distance between the *Attended* and *Unattended* items on the computer screen, participants showed some incidental memory formation for the *Unattended* items. This is likely due to the need to use the item color to select the *Attended* from the *Unattended* item: Selection based on color often involves obligatory processing of the word (e.g., Stroop, 1935). Even so, the memory instruction did not operate on the mental representation of these items to further influence the success of their incidental encoding – either as an automatic consequence of the instantiation of a *Forget* instruction or as a strategy to actively seek distraction from *Forget* item processing.

4. Experiments 3a–b

Together, the results of Experiments 1 and 2 converge on the conclusion that when participants are instructed to *Forget* a mental representation of a previously presented peripheral word, there is no consequent increase in the tendency to form an incidental memory of a task-irrelevant item presented at the opposite location. Nevertheless, even if *Forget* and *Remember* instructions do not differentially free processing resources for incidental memory formation of internally represented distractors, it is possible that they do so for externally represented distractors. The goal of Experiment 3 was to test this possibility by keeping the word display visible during the presentation of the memory instructions.

4.1. Method

4.1.1. Participants

We performed two separate replications of this experiment, one with 36 participants (Experiment 3a) and another with 24 participants (Experiment 3b). In the second replication, one of the original 24 participants was replaced due to a reported failure to comply with the task instructions.

4.1.2. Stimuli and apparatus

The stimuli and apparatus were identical to Experiment 2, except that the memory instruction was a high- (1170 Hz) or low-frequency (260 Hz) tone presented through the built-in computer speakers.

4.1.3. Procedure

The procedure was identical to Experiment 2 except for the timing of study trial events. Each study trial started with the presentation of a "+" at the center of the computer screen. After 2000 ms, both words appeared on opposite sides of the central "+" for 4000 ms. At 2000 ms following the onset of the two words, the tone serving as the memory instruction played for 400 ms. This meant that words continued to be visible for 1600 ms after the tone ended. There was a 2000 ms delay before the start of the next trial, during which the computer screen remained blank.

As in Experiments 1 and 2, there were four buffer trials at the beginning and four buffer trials at the end of the study list that were otherwise identical to the study trials except that the same words were presented to all participants; all buffer words were followed by a *Remember* instruction; and, none of the buffer words were tested at recognition. The recognition test followed immediately after the final buffer trial.

There were a total of 60 study trials; 30 study trials presented a *Remember* instruction and 30 presented a *Forget* instruction. There were 240 recognition trials. A recognition hit was defined as a "y" response to any of the 30 attended words from *Remember* trials, 30 attended words from *Forget* trials, 30 unattended words from *Remember* trials, and 30 unattended words from *Forget* trials; a false alarm was defined as a "y" response to any of the 120 'new' items from the *Foil* list.

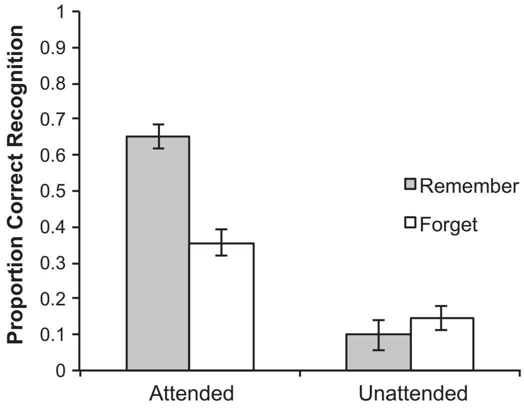

Fig. 3. Experiment 3: Proportion correct recognition, calculated as the difference between the proportion hits and proportion foil false alarms. Data are shown as a function of Attention Status of the test word when it was presented at study (*Attended*, *Unattended*), and as a function of the Memory Instruction presented at study (*Remember*, *Forget*). Error bars depict the standard error of the mean.

4.2. Results

The proportions of hits and false alarms are provided in Table 1 according to whether the data were derived from the first replication (Experiment 3a) or the second replication (Experiment 3b). The proportion of false alarms to unstudied foils was subtracted from the proportion of hits as a function of attention status (*Attended*, *Unattended*) and memory instruction (*Remember*, *Forget*) on a participant-by-participant basis. In a preliminary analysis, these data were analyzed in a mixed ANOVA, with attention status (*Attended*, *Unattended*) and memory instruction (*Remember*, *Forget*) as within subjects variables and Experiment (a, b) as a between subjects variable. This analysis revealed no significant main effect of Experiment, $F(1,58) = 1.502$, MSe = 0.040, $p = .2253$, $\eta_g^2 = .009$, and no interaction of Experiment with any other factor (all $ps > .1045$). As such, for the following analyses, the data from both replications were combined. The mean data are shown in Fig. 3.

A repeated measures analysis of variance (ANOVA) revealed a significant main effect of attention status, $F(1,59) = 247.100$, MSe = 0.035, $p < .0001$, $\eta_g^2 = .575$, with overall greater recognition of *Attended* ($M = 0.503$, $SE = 0.021$) than *Unattended* ($M = 0.122$, $SE = 0.014$) words. There was also a directed forgetting effect, as revealed by a main effect of memory instruction, $F(1,59) = 64.839$, MSe = 0.014, $p < .0001$, $\eta_g^2 = .127$; recognition was better for *Remember* ($M = 0.374$, $SE = 0.014$) than for *Forget* ($M = 0.250$, $SE = 0.016$) words.

These main effects were qualified by a significant two-way interaction of attention status and memory instruction, $F(1,59) = 92.895$, MSe = 0.019, $p < .0001$, $\eta_g^2 = .215$. This interaction can be seen in Fig. 3 as a significant directed forgetting effect in the *Attended* condition, $t(59) = 10.550$, $p < .0001$, and a significant *reverse* directed forgetting effect in the *Unattended* condition, $t(59) = -2.603$, $p = .0117$. This reversed directed forgetting effect had been marginally significant in the first replication with 36 participants, $t(35) = -1.925$, $p = .0623$, and significant in the second replication with 24 participants, $t(23) = -2.386$, $p = .0257$. For the overall data, a Sign Test confirmed that a significant number of participants showed better performance for *Remember* than *Forget* words in the *Attended* condition, [(R–F) > 0]:55, [(R–F) < 0]:5, [R = F]:0, $p < .0001$, and worse performance for *Remember* than *Forget* words in the *Unattended* condition [(R–F) > 0]:20, [(R–F) < 0]:34, [R = F]:6, $p < .0067$.

4.3. Discussion

The results of Experiment 3 reveal that when a memory instruction occurs during the continued presentation of *Attended* and *Unattended* items, participants incidentally encode more *Unattended* items during a *Forget* trial than during a *Remember* trial. Taken together with the results of Experiments 1 and 2, this suggests that a memory instruction influences the encoding of unattended items but only so long as they continue to be visible in the external environment. Even so, the continued presence of the unattended items during the presentation of the memory instruction has a relatively small effect on performance. Whereas the magnitude of the directed forgetting effect for *Attended* items was 30%, the magnitude of the reverse directed forgetting effect for *Unattended* items was 5%. Expressed as a proportion of the average recognition performance for the condition (i.e., [(*Forget* − *Remember*)/((*Forget* + *Remember*)/2]), the directed forgetting effect was 60% of the average for *Attended* items and the reverse directed forgetting effect was 40% of the average for *Unattended* items.

5. Experiment 4

To isolate the costs and benefits associated with *Remember* and *Forget* instructions in the *Attended* and *Unattended* conditions, Experiment 4 repeated the methods of Experiment 3 except that the tones conveyed no meaning; participants were instructed to commit all attended items to memory.

The notion of costs and benefits derives from the typical directed forgetting effect in which memory performance is better for *Remember* items than for *Forget* items. This difference is theoretically attributable to relatively worsened performance for *Forget* items (costs) and/or relatively improved recognition of *Remember* items (benefits). Although it is not clear that a *Remember*-all condition is an appropriate neutral baseline against which to measure costs and benefits (see Jonides & Mack, 1984 for a discussion) – especially when it is necessarily a between-subjects manipulation – this is the condition that has been used in the literature to assess costs and benefits for recall (e.g., Sahakyan & Foster, 2009). In keeping with this precedent, we will thus use performance in the *Remember*-all condition of Experiment 4 to assess the costs and benefits for recognition in Experiment 3. The question is whether the directed forgetting effect in the *Attended* condition is due to benefits to *Remember* items and/or costs to *Forget* items and whether the reverse directed forgetting effect in the *Unattended* condition is due to the opposite pattern – costs to *Remember* items and benefits to *Forget* items.

5.1. Method

5.1.1. Participants

Initially, 26 participants participated in exchange for course credit. One participant responded "yes" to all items on the recognition memory test (foils and studied words) and so was later replaced. All participants were tested individually in a session that lasted no more than 1 h. When queried, none reported having participated in other studies of directed forgetting.

5.1.2. Stimuli and apparatus

The stimuli and apparatus were identical to Experiment 3.

5.1.3. Procedure

The procedure was identical to Experiment 3, except that the high- and low-frequency tones were task-irrelevant. As such, there were no tone familiarization trials. Participants were told that the high- and low-frequency tones presented during the study trials were task-irrelevant alerting signals; they were instructed to commit all *Attended* words to memory.

5.2. Results

The proportions of hits and false alarms are provided in Table 1; because memory instruction had no meaning in this experiment we collapsed across this variable prior to analysis. The proportion of false alarms to unstudied foils was subtracted from the proportion of hits as a function of attention status (*Attended*, *Unattended*) on a participant-by-participant basis. These corrected data were analyzed in a repeated-measures ANOVA as a function of attention status (*Attended*, *Unattended*). This analysis revealed a significant difference, with overall greater recognition of *Attended* items ($M = 0.667$, $SE = 0.036$) than *Unattended* ($M = 0.129$, $SE = 0.30$) items, $F(1,25) = 133.168$, MSe = 0.0282, $p < .0001$, $\eta_g^2 = .727$.

To facilitate comparison with the results of Experiment 3 for which the tones served as memory instructions, tone presentation in Experiment 4 was dummy-coded as *Remember* and *Forget* instructions (with assignment of high- and low-tones to the dummy codes counterbalanced across participants). The corrected hit rates were analyzed in an ANOVA with memory instruction (*Remember*, *Forget*) and attention condition (*Attended*, *Unattended*) as within-subjects variables and Experiment (Experiment 3, Experiment 4) as a between-subjects variable. This analysis revealed a significant main effect of Experiment, $F(1,84) = 11.759$, MSe = 0.045, $p = .0009$, $\eta_g^2 = .051$, which interacted significantly with memory instruction, $F(1,84) = 15.443$, MSe = 0.015, $p = .0001$, $\eta_g^2 = .023$, and attention condition, $F(1,84) = 10.511$, MSe = 0.041, $p = .0017$, $\eta_g^2 = .042$. These effects were further qualified by a significant three-way interaction, $F(1,84) = 35.065$, MSe = 0.017, $p < .0001$, $\eta_g^2 = .056$. Planned comparisons on the three-way interaction revealed that there were significant costs of directed forgetting: Recognition of *Attended* words under the remember-all instructions of Experiment 4 was better than recognition of *Attended* words in the *Forget* condition of Experiment 3, $t(84) = 7.320$, $p < .0001$. There were, however, no significant benefits of directed forgetting: Recognition of *Attended* words under the remember-all instructions of Experiment 4 was no better than recognition of *Attended* words in the *Remember* condition of Experiment 3, $t < 1$. Critically, incidental recognition of *Unattended* words in Experiment 4 was not significantly different from that of *Unattended* words presented on *Forget* trials of Experiment 3, $t < 1$, or on *Remember* trials of Experiment 3, $t(84) = 1.329$, $p > .1876$. Stated another way, there was no evidence that the significant reverse directed forgetting effect in Experiment 3 was due to a reliable increase in incidental memory formation on *Forget* trials and/or a reliable decrease in incidental memory formation on *Remember* trials.

5.3. Discussion

A comparison to the *Remember*-all manipulation of Experiment 4 suggests that the directed forgetting effect obtained for *Attended* items in Experiment 3 was attributable to significant costs in the *Forget* condition in the absence of significant benefits in the *Remember* condition. The reverse directed forgetting effect obtained for *Unattended* items in Experiment 3 was attributable to neither significant benefits in the *Forget* condition nor to significant costs in the *Remember* condition.

The finding of costs without benefits for recognition in the *Attended* condition is at odds with Sahakyan and Foster's (2009) report of both costs and benefits for recall in an item-method task. Although possible, it seems unlikely that the mechanisms underlying the directed forgetting effect are different for recall and recognition tasks. Instead, the costs to later recognition of *Forget* items may simply be more robust than the benefits to later recognition of *Remember* items. In any case, the fact that neither the costs nor the benefits were significant in the *Unattended* condition is perhaps not surprising. Total costs + benefits represented by the magnitude of the reverse directed forgetting effect were small, even if statistically significant and so its constituent parts would be even smaller. There was no strong evidence to suggest that costs to the *Attended* item due to the *Forget* instruction are reversed to benefits for the *Unattended* item in the opposite location.

6. General discussion

The results of the present study are clear: There is no evidence of increased incidental encoding of other task-irrelevant stimuli that form part of the mental representation of a to-be-forgotten versus a to-be-remembered learning episode (Experiments 1 and 2). Under some conditions, processing resources may become available for incidental encoding of other task-irrelevant stimuli still visible in the external environment. Nevertheless, any such effects are small (Experiment 3).

Wylie et al. (2008) observed that enacting an instruction to Forget resulted in the activation of brain regions associated with processing elements of the external environment. They speculated that this activity could represent a shift away from the episodic representation of the *Forget* instructed information towards other information readily available in the environment. This argument dovetails nicely with research that has linked the presence of an early frontal brainwave component to the neural suppression of the physical trace associated with the preceding study word following an instruction to *Forget* (see Paz-Caballero & Jiménez, 2004; see also, Lee, Lee, & Fawcett, in press). Together with slower RTs (e.g., Fawcett & Taylor, 2008) and greater IOR following Forget compared to *Remember* instructions (e.g., Taylor, 2005a; Taylor & Fawcett, 2011), these findings converge to suggest that instantiating a *Forget* instruction engages frontal control mechanisms to cease rehearsal of the to-be-forgotten item in a way that is akin (e.g., Hourihan & Taylor, 2006) – even if not identical (see Fawcett & Taylor, 2010) – to stopping the execution of a planned but unwanted overt motor response.

In the present study, we contemplated whether ceasing the unwanted covert rehearsal of a to-be-forgotten item might be associated with incidental encoding of a distractor item during a shift of attentional resources away from the *Forget* item (Taylor, 2005a; Taylor & Fawcett, 2011). While on the surface, distractor processing would seem counter to the task of committing to-be-remembered items to memory, we did not conceive of distractor processing as a goal in and of itself; instead, we reasoned that distractor processing might occur either as a means or a consequence of attentional disengagement from the *Forget* item. In this way, distractor processing could provide insight into the mechanisms that facilitate mental task switching away from *Forget* item processing and ultimately towards selective rehearsal of *Remember* items. On this, the results of the present study are clear. If incidental encoding of distractor items occurs on *Forget* trials, it does not occur for distractor items that comprise the mental representation of the studied episode; instead, such encoding appears to be limited to distractors in the *physical* environment. This is certainly consistent with Wylie et al.'s (2008) suggestion that intentional forgetting may involve a shift of attention from internal to external representations. Whether this occurs as a means of disengaging limited capacity attentional resources from *Forget* items to foster subsequent retrieval and cumulative rehearsal of to-be-remembered items, or whether it is coincident with a search of internal *Remember* item representations remains to be determined.

One issue that bears consideration is whether there was sufficient processing of the *Unattended* item for it to benefit from any subsequent reallocation of processing resources to its representation in memory. In other words, there may have been a reallocation of processing resources to the mental representation of the distractor but this distractor may not have been processed deeply enough during study for this shift of attention to result in a measurable effect on recognition memory; observing a reverse directed forgetting effect in subsequent recognition may require that the *Unattended* distractor be processed more fully during study so that a subsequent shift of processing resources to its mental representation can lead to implicit encoding.

While this certainly warrants further investigation, we have reason to believe that the *Unattended* items were likely encoded sufficiently to support memory formation in the event that processing resources had been reallocated to their mental representation. We base this conclusion on two observations. First, incidental recognition of *Unattended* words was above that of the unstudied foils; the values plotted for the *Unattended* condition in Figs. 1 and 2 represent incidental memory formation after correcting for foil false alarms. Thus, there was evidence of incidental memory formation when the *Unattended* items were extinguished prior the memory instruction, just no evidence that this incidental memory formation varied with memory instruction. While it is possible that the recognition of *Unattended* items is attributable to perceptual fluency alone rather than to a recollective process, our second observation notes that our study trials presented participants with an *Attended* and an *Unattended* item on each trial, the locations of which varied from trial-to-trial. This meant that participants could not focus visuo-spatial attention ahead of item presentation and, instead, had to use the color of the presented items to select the one they were instructed to attend. As we have already noted, selection based on color often involves obligatory processing of the word (e.g., Stroop, 1935). There is additional evidence that selecting one of two simultaneously presented words based on color produces semantic processing of the unattended word (Tipper & Driver, 1988). Indeed, even though semantic processing is modulated by focused spatial selective attention (e.g., McCarthy & Nobre, 1993) it can nevertheless occur in the absence of focused attention (e.g., Fuentes, Carmona, Agis, & Catena, 1994).

Even if semantic processing occurred for the *Unattended* item as we presume, it is likely that the most salient semantic properties of the episode were associated with the *Attended* items. As such, on a *Forget* trial, a shift of processing resources to the *Unattended* item might have served to limit further processing and commitment of the *Forget* word to memory even without any concomitant increase in incidental memory formation for the *Unattended* item: The shift could be associated with a cessation of *Forget* item rehearsal without necessarily benefitting incidental encoding of the *Unattended* item at the opposite location. Our current results cannot rule out this possibility entirely. But given that there is incidental encoding of attended distractors in visual search (e.g., Williams, Henderson, & Zacks, 2005), we expect that if a *Forget* instruction prompted the reallocation of attention to the location opposite the *Attended* word, there would have been evidence of increased incidental memory encoding of the distractor item.

In summary, the current findings demonstrate that task-irrelevant elements that form the mental representation of a learning episode are not encoded incidentally following a *Forget* versus a *Remember* instruction. If anything, Experiment 1 revealed a trend for participants to be *less* likely to recognize *Unattended* items on *Forget* compared to *Remember* trials (see also Fawcett & Taylor, 2012). To the extent that memory tends to increase for items that are in the focus of attention (McCarthy & Nobre, 1993) and to the extent that the irrelevant distractors were processed sufficiently during initial presentation (e.g., Fuentes et al., 1994) to benefit from subsequent attentional focus, this finding suggests that re-orienting attention away from a *Forget* item towards the opposite location likely does not account for the robust *Forget* > *Remember* IOR differences that are observed in item-method directed forgetting (Fawcett & Taylor, 2010; Taylor, 2005a; Taylor & Fawcett, 2011); indeed, recent data collected in our lab shows that RTs following a *Forget* instruction are slowest for visual targets presented at the same location as the *Forget* item, compared to three other locations (Thompson, Hamm, & Taylor, submitted for publication). Only in Experiment 3 did we observe any evidence that instantiating a *Forget* instruction may be associated with incidental encoding of distractor items; this occurred only when both the study and distractor items remained visible after presentation of the memory instruction. These findings demonstrate that once part of an episode has been labeled as irrelevant by virtue of a *Forget* instruction, cognitive resources are unlikely to be become available for encoding other aspects of the episode that are no longer visible in the external environment. This does not mean, however, that distractor items remain entirely unprocessed. Indeed, our results showed that incidental memory formation did occur; it just did not differ according to memory instruction. Thus, it seems likely that *Unattended* items did receive some processing on both *Remember* and *Forget* trials and that this would be revealed by priming or other measures of processing that do not depend on explicit recognition. Nevertheless, we were primarily interested in the question of whether intentional forgetting of one item might lead to incidental remembering of another; on this our results are clear: If this does occur, it is only when the distractor item remains visible in the environment.

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