INTENTIONAL FORGETTING DIMINISHES THE LIKELIHOOD OF SEMANTIC ENCODING IN THE ITEM-METHOD PARADIGM

by

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ABSTRACT

The aim of the current study was to determine whether differences in the nature of encoding that underlies to-be-remembered (TBR) vs. to-be-forgotten (TBF) items are responsible for the disparity in the quality of their memory traces. In separate experiments, the study phase of an item-method directed forgetting paradigm was followed by a recognition memory test in which previously studied words were mixed with foils of two types: 1) unrelated foils that had no explicit relation to studied TBR or TBF words and 2) similar foils that either sounded similar (Experiment 1), were visually similar (Experiment 2) or had a similar meaning (Experiment 3) to a studied word. An analysis of similar foil false alarm rates showed that while TBR and TBF words are equally likely to be represented in memory in terms of their acoustic and visual properties, meaning is more likely to be encoded following an intention to remember.

LIST OF ABBREVIATIONS USED

ANOVA	Analysis of Variance
ERP	Event-related potential
fMRI	Functional magnetic resonance imaging
M	Mean
ms	millisecond
SD	Standard deviation

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CHAPTER 1: INTRODUCTION

The following thesis is based upon the manuscript entitled *"Intentional Forgetting Diminishes the Likelihood of Semantic Encoding in the Item-method Paradigm"*, which was submitted for publication in Memory in June 2020 and is awaiting peer review. Although Dr. Tracy L. Taylor was a co-author for this manuscript, Anjali Pandey was the primary contributing author; she collected, analyzed, and interpreted the data and composed the first draft of this paper.

1.1 INTENTIONAL FORGETTING AND THE ITEM-METHOD PARADIGM

While unintentional forgetting is often regarded as undesirable, intentional forgetting of irrelevant information is necessary to keep our memories up to date and relevant for daily functioning. For instance, once you create a new email password you will want to forget the old one so you do not enter it by mistake while trying to access your account. Sometimes, explicit instructions may be given to remember or forget certain information, as is the case when members of a jury are asked to either note a point or disregard evidence that has been deemed inadmissible. This form of intentional forgetting is known as directed forgetting and is studied in the laboratory using variants of the directed forgetting paradigm (see MacLeod, 1998 for a review).

In the item-method directed forgetting paradigm, stimuli are presented one at a time during a study phase and each is followed with equal probability by an instruction to remember or forget. The pattern of results that is typically seen on tests of recall or recognition that follow is termed the directed forgetting effect: memory performance for to-be-remembered items (TBR items) is better than for to-be-forgotten items (TBF items). This difference in memory performance between TBR and TBF items is not due to demand characteristics (MacLeod, 1999).

1.1.1 Mechanisms and representational consequences.

Since the memory instruction follows the study item in the item-method paradigm, the instruction is thought to operate by controlling encoding mechanisms within working memory to either promote or limit further rehearsal and commitment to long-term memory stores. Participants must maintain study item representations in working memory via maintenance rehearsal until receipt of the memory instruction (Craik & Lockhart, 1972; Woodward, Bjork, & Jongeward, 1973). Afterwards, TBR items are selectively rehearsed over TBF items and presumably undergo some form of elaborative rehearsal while TBF items are actively expunged from working memory by an effortful process of inhibition (e.g., Gao, Qi, & Zhang, 2019a; Zacks, Radvansky, & Hasher, 1996) or attention withdrawal (e.g., Fawcett & Taylor, 2010; Taylor, 2005; Taylor & Fawcett, 2011; Taylor, 2018). The probability of TBF items being encoded in long-term memory and later being successfully retrieved on a memory test is, hence, reduced relative to TBR items.

Still, TBF items are correctly remembered more often than foils are mistakenly remembered and this fact implies that these attempts to prevent encoding are not always successful and that lingering representations of some TBF items exist in long-term memory despite the intention to forget. Indeed, there is evidence that efforts to limit encoding are not all-or-nothing (e.g., Bancroft, Hockley, & Farquhar, 2013; Gao, Qi, & Zhang, 2019b) and that successfully retrieved representations of TBF items differ from those of TBR items. For example, in two studies by Fawcett, Taylor and Nadel (2013a;

2013b), participants were instructed to remember or forget portions of continuous video segments and were then tested on their memory for information depicted in those segments. The magnitude of the directed forgetting effect for specific details was larger than for more general information, implying that participants encoded at least the gist of the events they intended to forget, while they formed more detail-rich representations of the events they intended to remember. Similarly, in a study that instructed participants to remember and forget coloured abstract or concrete images, Fawcett, Lawrence and Taylor (2016) reported that participants made more errors in reporting the colour of recognized TBF items than they did reporting the colour of recognized TBR items, suggesting that retrieved representations of TBF items are impoverished compared to those of TBR items (see also Ahmad, Tan, & Hockley, 2019).

It is not clear why TBF item encoding has poorer fidelity than TBR item encoding. If it were simply the case that there was imperfect segregation of TBF and TBR items (e.g., Roediger & Tulving, 1979)—causing some TBF items to be treated as TBR items—then one would expect the characteristics of retrieved TBF items to match those of retrieved TBR items. The fact that retrieved TBF items are distinguishable from retrieved TBR items suggests that this is not the case. Instead, it would seem that when TBF items are encoded they are encoded *differently* than TBR items (see also Thompson, Fawcett, & Taylor, 2011). This difference could arise, for example, because of a "leaky controller"—that is, due to incomplete inhibition (see Wegner, Schneider, Carter, & White, 1987 for an example of how thought suppression relates to this idea) or incomplete attentional withdrawal, such that TBF items are encoded in a similar way to TBR items, but for less time and/or using fewer resources. Alternatively, TBF items could be processed in a kind of “end run” around whatever encoding mechanisms are otherwise engaged for TBR item processing. For example, in the Fawcett et al. (2013a, 2013b) studies, the TBF video segments might have been successfully excluded from visual rehearsal, thereby interfering with later recollection of specific details, but some might have done an “end run” around visual rehearsal mechanisms to be encoded for gist.

1.2 CODING SYSTEMS IN WORKING AND LONG-TERM MEMORY

According to Baddeley and Hitch (1974), working memory refers to the storage and manipulation of information in different short-term stores. The phonological loop stores acoustically coded information maintained by articulatory control processes while the visuo-spatial sketchpad, as the name implies, handles visually and spatially-coded information. While information can be transferred directly from these component stores to long-term memory, the central executive can also direct binding of visual and acoustic codes within the episodic buffer (Baddeley, 2000) which, in turn, can communicate with long-term memory.

Although short-term memory can code both visual and acoustic information, the preferred form of storage in short-term stores is widely accepted as being acoustic, with visually perceived information converted into acoustic codes when possible. Such is the case for visually presented verbal stimuli. As a case in point, Conrad (1964) found that when asked to recall a series of visually presented consonants, participants confused letters that sounded alike but were visually distinct (e.g. V and B), suggesting that the visual items were recoded on the basis of sound. This preference for an acoustic code in short-term memory stores is often contrasted with long-term memory, which primarily employs semantic coding system (Baddeley, 1966). However, Baddeley and Ecob (1970) showed that there are conditions under which items in short-term memory can be coded both acoustically and semantically on input. Indeed, the contribution of semantic traces to short-term memory representations may in fact be automatic (Campoy, Castello, Provencio, Hitch, & Baddeley, 2015) and reflects interactions of long-term memory with short-term working memory systems.

1.3 CURRENT EXPERIMENTS

The fact that items in working memory can potentially be encoded based on their visual, acoustic, and/or semantic properties provides a means for distinguishing between the "leaky controller" account of TBF item encoding (i.e., TBF items that escape the intention to forget are encoded in a similar manner to TBR items, but for less time and/or with fewer resources) and the "end run" account (i.e., TBF items that escape the intention to forget perform an "end run" around mechanisms focused on TBR item encoding and are, thereby, encoded via different means). We reasoned that the nature of the underlying encoding could be revealed by assessing the types of false alarms that participants make in responding to unstudied foil items. Accordingly, in three separate experiments that used the item-method directed forgetting paradigm, participants studied a list of words presented one at a time, each followed by an instruction to remember or forget. They then completed a yes/no recognition test that intermixed studied words with unstudied foil items that either had no explicit relation to the TBR and TBF study words (unrelated foils) or that were acoustically (Experiment 1), visually (Experiment 2), or semantically (Experiment 3) similar to those words. The nature of the underlying encoding should be revealed as differences between foil false alarm rates to similar compared to unrelated foils. In other words, acoustic encoding should lead to false alarms based on similar sounds; visual encoding should lead to false alarms based on similar appearance; semantic encoding should lead to false alarms based on similar meaning. The question then is whether the nature of the encoding is similar for TBF and TBR items as suggested by the “leaky controller” account, or whether it differs as suggested by the “end run” account.

CHAPTER 2: EXPERIMENT 1

In Experiment 1 participants studied a list of words, a random half of which were followed by an instruction to remember and the other half by an instruction to forget. Afterwards, participants completed a yes/no recognition memory test which included studied TBR and TBF words and two types of unstudied foils: foils that sounded similar to TBR or TBF words and those that were not explicitly related to study items. We reasoned that if study items were encoded based on their acoustic properties, participants would false alarm to similar foils more often than to unrelated foils. If this was the case, a subsequent comparison of false alarms made to acoustically similar foils of TBR and TBF study items would allow us to determine if acoustic encoding underlies memory only for items we intend to remember, or those that escape our intention to forget as well.

2.1 METHOD

2.1.1 Participants

A total of 36 Dalhousie University students participated in exchange for psychology course credit. All participants were tested individually in a single experimental session that lasted approximately 1hr.

2.1.2 Stimuli and Apparatus

Stimulus presentation and data collection were controlled by 27" iMac computers running Psyscope X (http://psy.cns.sissa.it; cf. Cohen, MacWhinney, Flatt, & Provost, 1993). The computers were equipped with extended universal serial bus keyboards and mice. Fixation crosshairs ("+"), memory instructions, study words, and test words were all center-justified and presented in 72-point Times New Roman Bold. All text was presented in black on a uniform white background—with the exception of the memory instruction, which consisted of a single green "R" (remember) or a single red "F" (forget). A list of 441 pairs of homophones was downloaded from http://www.singularis.ltd.uk/bifroest/misc/homophones-list.html. Both homophones in a pair were excluded if one member of the pair had fewer than 3 letters (e.g., "ad/add"); if they were judged not to be homophonic when spoken in an Anglophone Canadian accent (e.g., "manna/manner"); if one member was a contraction (e.g., "you'll/yule"); and, if it seemed likely that a typical undergraduate participant would be unfamiliar with one or both of the members (e.g., "coign/coin"). This left 214 pairs, from which a total of 160 pairs were selected. These word pairs are presented in Appendix B.

Prior to collecting data from each participant, custom software was used to randomize the list of paired homophones and then allocate them to two 40-pair lists and four 20-pair lists. During the study phase, one 40-pair list and one 20-pair list were designated TBR lists and one 40-pair list and one 20-pair list were designated TBF lists. For half of the participants, the first member of each homophone pair served as the study item; for the other half of participants, the second member of each homophone pair served as the study item. No items from the remaining two 20-pair lists were presented during the study phase.

During the test phase, the same items that served as study words from the 40-item TBR list and from the 40-item TBF list also served as recognition test items. For example, if the word "board" was presented at study, the identical word "board" was also presented at test. In contrast, for the 20-item TBR list and the 20-item TBF list, only the non-studied member of the pair was presented as a recognition test item. In this case, if the word "days" was presented during the study phase, its homophone "daze" was presented during the test phase. With respect to the remaining two 20-item lists of which no items were presented at study, only the first member of one list was presented as an unrelated foil on the recognition test; only the second member of the other list was presented as an unrelated foil.

2.1.3 Procedure

In a verbal overview, participants were instructed that they would be presented with a long list of words, one at a time, each of which would be followed by an instruction to remember or forget. They were told that their memory would later be tested for these words, but no mention was made of the fact that this test would query TBF items as well as TBR items. Participants were not informed that test items might include homophones of studied items. After providing this overview, the researcher left the room so the participant could be alone to complete the study phase and test phase.

2.1.3.1 Study phase. To begin, participants were provided with on-screen written instructions that reiterated the verbal instructions. Participants were invited to recall the researcher if they had any questions; otherwise, they were instructed to depress the space bar to proceed to the study trials. Each study trial began with a 500 ms delay during which the computer monitor remained blank. Following this delay, fixation crosshairs were presented in the center of the computer monitor for 1,000 ms. This fixation stimulus was then replaced by a study word which remained visible for 3,000 ms. This was followed by a 400 ms delay during which the computer monitor remained blank. After this, the memory instruction—a single green "R" or a single red "F"—was presented for 400 ms.

If participants hit any key on the keyboard during the study trials, a computer-generated "incorrect beep" played over the built-in iMac speakers and the message "do not press keyboard during study trials" was presented for 500 ms. The monitor otherwise remained blank until 6,000 ms had elapsed since the start of the delay that marked the beginning of the trial sequence.

A total of 120 study trials were presented. A remember instruction followed the word on a random half of these study trials; a forget instruction followed the word on the other half of the trials.

2.1.3.2 Test phase. After all study trials had been presented, participants were provided with written instructions that described the yes/no recognition test that would follow. These instructions told participants that they would be presented with words, one at a time, and that they were to judge whether they recognized the word from the earlier study trials and to report this using the ‘y’ (yes) and ‘n’ (no) keys on the keyboard. These instructions emphasized that participants should respond 'y' to all words that they recognized from the study trials, regardless of whether the words had been designated TBR or TBF. Participants were invited to recall the researcher if they had any questions. Otherwise, they depressed the space bar to proceed to the test trials. An abbreviated version of the recognition test instructions remained visible at the top center of the computer monitor throughout all test trials.

Each test trial presented a study word at the center of the computer monitor. Beneath this word was a prompt for participants to indicate whether they recognized the word or not. Keyboard presses were echoed to the screen and appeared beside this prompt. Responses were submitted using the return key. There was no time limit to enter a response.

Of the 60 TBR items presented at study, 40 were tested for recognition and 20 had their homophones tested instead. Of the 60 TBF items presented at study, 40 were tested for recognition and 20 had their homophones tested instead. There were also 40 unrelated foils drawn from member pairs for which *neither* item had been presented at study. These are described as unrelated foils because these words were not presented at study and did not have a homophone presented at either study or test. Thus, in total, there were 160 test trials comprised of the random presentation of 40 TBR items, 40 TBF items, 20 homophones of TBR words (hereafter: TBR-Similar), 20 homophones of TBF words (hereafter: TBF-Similar), and 40 unrelated foils. This trial distribution ensured that a "yes" response was objectively correct on half of the trials (i.e., 80/160). A recognition hit was defined as a "yes" response to TBR and TBF items; a false alarm was defined as a "yes" response to any other item.

2.1.3.3 Data analysis. Trials were included for analysis only if a single ‘y’ or ‘n’ response was submitted on the recognition task; recognition hits and false alarms were calculated as the proportion of ‘y’ responses. Descriptive statistics, repeated measures ANOVA and pair-wise t-test comparisons were all calculated using Jamovi 0.9.6.7 (The jamovi project, 2019).

2.2 RESULTS

Before proceeding with our primary analysis of false alarm rates, a repeated measures ANOVA was conducted on the recognition data to analyze the mean percentage of “yes” responses made as a function of word type (TBR, TBF and unrelated foils). This analysis revealed a main effect of word type, $F(2,70) = 123.39$, $MSe = 193.09$, $p<0.05$, $\eta_{p2} = 0.78$ and follow-up pairwise comparisons confirmed 1) significantly greater recognition of TBR items ($M = 72$, $SD = 15$) than TBF items ($M = 52$, $SD = 17$), $t\,(35) = 7.44$, $p < 0.05$, indicative of a directed forgetting effect, and 2) significantly more "yes" responses to TBF items than to unrelated foils ($M = 21$, $SD = 18$), $t\,(35) = 8.67$, $p < 0.05$.

Having thus established a typical pattern of results for an item-method directed forgetting task, we conducted our primary analysis of false alarms, as a function of foil type (TBR-Similar, TBF-Similar, unrelated). These data are shown in Figure 1. This analysis revealed a significant effect of foil type, $F(2, 70) = 12.43$, $MSe = 66.79$, $p < 0.05$ $\eta_{p2} = 0.26$. To determine whether there was evidence for acoustic encoding, we averaged over the TBR-Similar and TBF-Similar foil false alarm rates and compared these to the unrelated foil false alarm rate. This analysis revealed significantly more false alarms to unstudied foil items that shared acoustic properties with studied items ($M = 29$, $SD = 17$), than to unrelated foils ($M = 21$, $SD = 18$), $t\,(35) = 4.92$, $p < 0.05$. There was, however, no significant difference in false alarm rates made to TBR-Similar foils ($M = 31$, $SD = 17$) and TBF-Similar foils ($M = 27$, $SD = 19$), $t\,(35) = 1.95$, $p = 0.06$[1].

2.3 DISCUSSION

The results of Experiment 1 confirmed a typical pattern of results in an item-method directed forgetting task, with better recognition of TBR words than TBF words,

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[1] Given this marginal result, we followed up by re-framing this pairwise comparison as a repeated-measures ANOVA so that we could use the output of the ANOVA table to generate a Bayesian Information Criterion approximation to Bayesian posterior probabilities using the methods recommended by Masson (2011). With probabilities that sum to 1, this analysis enables evidence to be weighed in support of the *null* (H0) versus the alternative (H1) hypothesis. With pH0=0.48 and pH1=0.51, the results are considered ambivalent, according to the labelling convention recommended by Ha, Li, and Patton (2017). This indicates that the evidence provides no clear support for either hypothesis. We are therefore satisfied with the conclusion of the null hypothesis testing, which demands that this result be interpreted as a failure to reject the *null* hypothesis.

and also better recognition of TBF words than unrelated foils. Given that this was the case, the question at the heart of this experiment was whether study items are encoded using acoustic codes and, if so, whether this encoding differs for TBF and TBR words. While false alarms made to acoustically similar foils were, overall, greater than those made to unrelated foils, there was no significant difference in false alarms made to TBR-Similar and TBF-Similar foils. Thus, there was evidence of acoustic encoding of study items, but no compelling evidence that sound was more likely to be encoded following an intention to remember than it was to escape an intention to forget.

It seems probable that this acoustic encoding occurs during the maintenance interval that occurs between initial study word presentation and the memory instruction. When they are presented with the visually presented study words, participants likely recode this to the preferred acoustic code. Then, while they await the memory instruction, they maintain the study word in the phonological loop via subvocal rehearsal. In this way, visually presented TBF and TBR items initially undergo equivalent processing in terms of their sound. Following the delivery of the memory instruction, it can be inferred that any active processes involved in intentional forgetting do not affect the transfer of the acoustic trace to long-term memory. Likewise, we can infer that the elaborative encoding needed to intentionally remember does not occur on the acoustic dimension or—if it does—such a strategy provides no additional recognition performance benefits (see Craik & Tulving, 1975 for how the depth of processing and degree of elaboration interact to influence the retention of words).

At first blush, our findings appear somewhat at odds with a study reported by Kausler and Settle (1975). Their task presented study words and memory cues (colored backgrounds) simultaneously—thus precluding maintenance rehearsal of TBF items—and emphasized acoustic properties by requiring that participants vocally produce all study and test words. Whereas our Experiment 1 showed no difference between false alarms made to TBF-Similar and TBR-Similar foils, Kausler and Settle (1975) reported fewer false alarms to TBF-Similar foils, albeit only when the homophonic foils were orthographically distinct. The discrepancy between our findings and theirs suggests either that 1) acoustic encoding of TBF items depends on maintenance rehearsal prior to the memory instruction, as suggested above, or 2) that false alarms to homophonic foils are driven by orthographic similarity as opposed to phonological similarity.

Since words that sound the same also tend to look similar, in Experiment 2 similar foils were chosen to look but not sound similar to study words. This allowed us to test for visual coding of TBR and TBF items, separately from acoustic encoding.

CHAPTER 3: EXPERIMENT 2

The purpose of Experiment 2 was to determine if visual representations were encoded for remembered TBR and TBF items. Therefore, the method replicated that of Experiment 1 with the exception that, instead of sharing acoustic properties with study items, similar foils included in the recognition test phase were similar in appearance to either studied TBR or TBF words.

3.1 METHOD

3.1.1 Participants

A total of 36 Dalhousie University students participated in exchange for psychology course credit. All participants were tested individually in a single experimental session that lasted approximately 1hr.

3.1.2 Stimuli and Apparatus

Experiment 2 required a list of 160 word pairs that shared similar appearance. Although it was not necessary for the Experiment 1 and 2 lists to overlap, some overlap seemed preferable to none. Thus to start, one member of each pair of homophones used in Experiment 1 was selected. An attempt was made to alter as few letters as possible to create a new word that was neither a homophone nor a synonym of the original word. In the majority of cases, the beginning of the word was left intact, with a single alteration made to a middle or an ending letter (e.g., "bold/bolt"). When possible, a changed character was selected to minimize the introduction or removal of font ascenders/descenders (e.g., "daze" to "doze" rather than "daze" to "date" which would introduce an ascender on the "t" character). In some cases, single letter alterations were not possible and one or more letters needed to be added (e.g., "fright" to "freight") or removed (e.g., "through" to "though"). And there were also instances in which mimicking the physical appearance of a word dictated a change in one or more letters at the beginning of the word (e.g., "bowl" to "howl"). There were 7 instances in which a word could not be readily constructed from either member of an Experiment 1 homophone pair (e.g., "muscle/mussel") so that a new word pair was created (e.g., "vest/vast"). Effort was made to ensure no words were duplicated. The final word list is presented in Appendix B.

As was the case for Experiment 1, prior to collecting any data from a participant, custom software was used to randomize these paired words and then allocate them to two 40-pair lists and four 20-pair lists. Words were selected for presentation at study and test in the same manner as described for Experiment 1.

3.1.3 Procedure

The procedure was the same as for Experiment 1 except that foil similarity was based on visual similarity to TBR and TBF items, rather than on a homophonic relationship.

3.2 RESULTS

Similar to Experiment 1, a repeated measures ANOVA was first conducted to analyze the mean percentage of “yes” responses made as a function of word type (TBR, TBF, unrelated foils). This analysis revealed a significant effect of word type, $F(2, 70) = 115.42$, $MSe = 158.94$, $p < 0.05$, $\eta_{p2} = 0.77$. Follow-up pairwise comparisons confirmed 1) a typical directed forgetting effect, $t\ (35) = 8.75$, $p < 0.05$, with greater TBR item recognition ($M = 63$, $SD = 18$) than TBF item recognition ($M = 42$, $SD = 17$) and, 2) significantly more “yes” response to TBF items than to related foils ($M = 18$, $SD = 14$), $t\ (35) = 8.66$, $p < 0.05$.

Having thus established a typical pattern of results for an item-method directed forgetting task, we analyzed the mean percentage of false alarms as a function of foil type (TBR-Similar, TBF-Similar, unrelated). These data are shown in Figure 2. There was a significant effect of foil type, $F(2, 70) = 3.94$, $MSe = 82.35$, $p = 0.02$, $\eta_{p}2 = 0.10$. After averaging over TBR-Similar and TBF-Similar foils, planned comparisons revealed that the foil false alarm rate was significantly higher for similar foils ($M = 22$, $SD = 16$) than for unrelated foils ($M = 18$, $SD = 14$), $t\ (35) = 3.29$, $p < 0.05$. There was, however, no significant difference in false alarms for TBR-Similar foils ($M = 23$, $SD = 16$) and TBF-Similar foils ($M = 21$, $SD = 19$), $t\ (35) = 0.84$, $p = 0.41$.

3.3 DISCUSSION

Like in Experiment 1, the results of Experiment 2 confirmed a typical pattern of results for an item-method directed forgetting task, with greater recognition of TBR items than TBF items, and greater recognition of TBF items than unrelated foil items. Given that this was the case, our main question of interest was whether there was evidence of visual encoding of the visually presented words and, if so, whether this encoding seemed to differ for TBR and TBF items. On this question, our results mirrored those of Experiment 1. We observed overall more false alarms to visually similar foils than to unrelated foils, but no significant difference in the number of visually similar TBR and TBF foils that were falsely recognized. It is just as likely that the visual characteristics of words will be intentionally remembered as it is that they will fail to be forgotten.

Together the results of Experiments 1 and 2 suggest that long-term memory coding systems have both an acoustic and visual component (Baddeley, 2012). Integration of information on these two dimensions may potentially occur within a component of working memory such as the episodic buffer or in long-term memory itself subsequent to encoding. Either way, an intention to forget does not seem to interfere with this process. Following our reasoning for the results of Experiment 1, we can likewise infer that elaborative encoding needed to intentionally remember does not occur on the visual dimension or—if it does—such a strategy does not enhance participants' ability to distinguish studied from unstudied items.

Having thus established that TBF items are not distinguishable from TBR items based on acoustic and visual codes, the goal of Experiment 3 was to determine whether they could be distinguished based on semantic codes.

CHAPTER 4: EXPERIMENT 3

Having tested for acoustic and visual encoding of study items in Experiments 1 and 2 respectively, in Experiment 3 we investigated whether or not the nature of TBR and TBF item encoding differed on the semantic dimension. As with the previous two experiments, similar foils were presented in the recognition test phase, except this time they were similar in meaning to studied items.

4.1 METHOD

4.1.1 Participants

A total of 37 Dalhousie University students participated in exchange for psychology course credit. All participants were tested individually in a single experimental session that lasted approximately 1hr.

4.1.2 Stimuli and Apparatus

Experiment 3 required a list of 160 synonym pairs. To start, one member of each pair of homophones used in Experiment 1 was selected. An attempt was made to find a reasonable synonym for this word, sometimes with the help of http://thesaurus.com or the top hit produced by a google search for the word synonym. As shown in Appendix B, there were 5 instances in which a suitable one-word synonym could not be found for either member of the Experiment 1 homophone pair (e.g., "there/their"). In all but one case, we instead selected the paired item from the Experiment 2 word list (e.g., "there/theme") to generate a synonym with which the Experiment 2 item could be paired (e.g., "theme/subject"). The exception was "quarts/quartz" which had been altered in Experiment 2 to "quarts/quarks" but replaced in Experiment 3 with "quirky/odd".

As was the case for Experiments 1 and 2, prior to collecting data from each participant, custom software was used to randomize the paired words and then allocate them to two 40-pair lists and four 20-pair lists. Words were selected for presentation at study and test in the same manner as described for Experiment 1.

4.1.3 Procedure

The procedure was the same as for Experiments 1 and 2 except that similar foils were synonyms of TBR and TBF items.

4.2 RESULTS

Similar to Experiments 1 and 2, a repeated measures ANOVA was conducted to analyze the mean percentage of "yes" responses as a function of word type (TBR, TBF, unrelated foil). This analysis revealed a main effect of word type, $F(2, 72) = 151.78$, $MSe = 172.29$, $p < 0.05$, $\eta_{p2} = 0.81$. Follow-up pairwise comparisons confirmed 1) a typical directed forgetting effect $t\ (36) = 7.43$, $p < 0.05$, with greater recognition of TBR items ($M = 69$, $SD = 17$) than TBF items ($M = 49$, $SD = 17$) and, 2) significantly more "yes" responses to TBF items than to unrelated foils ($M = 16$, $SD = 18$), $t\ (36) = 12.11$, $p < 0.05$.

A second repeated measures ANOVA analyzed the mean percentage of false alarms as a function of foil type (TBR-Similar, TBF-Similar, and unrelated). These data are shown in Figure 3. This analysis revealed a significant effect of foil type, $F(2, 72) = 7.90$, $MSe = 33.32$, $p < 0.05$, $\eta_{p2} = 0.18$. Planned comparisons revealed that the average false alarm rate was significantly greater for similar foils ($M = 20$, $SD = 20$) than for unrelated foils ($M = 16$ $SD = 18$), $t\ (36) = 3.17$, $p < 0.05$. There were also significantly more false alarms made to TBR-Similar foils (*M* = 22, *SD* = 20) than to TBF-Similar foils (*M* = 19, *SD* = 20), $t\ (36) = 2.34$, $p < 0.05$.

4.3 DISCUSSION

Like Experiments 1 and 2, Experiment 3 revealed the typical pattern of results for an item-method directed forgetting task, with better recognition of TBR items than TBF items, and better recognition of TBF items than unrelated foils. Given that this was the case, the key question was whether long-term memory representations of TBF items would differ from TBR items on the dimension of meaning. As it turned out, not only were similar foils more likely to be falsely recognized, on average, than unrelated foils, this tendency was greater when these similar foils were synonyms of TBR items rather than synonyms of TBF items. These results suggest that semantic properties of a word are more likely to be encoded in memory if one tries to remember it and the process of forgetting somehow prevents encoding of the meaning of a word.

Whereas the long-term representations of TBF items are as likely as TBR items to contain information about the acoustic and visual properties of the study word, they are less likely to contain information about the semantic properties. According to the selective rehearsal explanation of directed forgetting, unwanted processing of TBF items is terminated following the presentation of a memory instruction whereas TBR items are further processed via elaboration. This suggests that establishing connections with semantic information in long-term stores can serve to anchor TBR representations in memory while TBF items are denied access via this route. This accords with a study reported by Geiselman, Rabow, Wachtel and Mackinnon (1985) which showed that generating synonyms of study items as they were presented eliminated TBR-TBF differences on a subsequent recognition memory test: Deep processing of TBF items during synonym generation presumably increased the probability that these item representations would be retained in long-term memory.

CHAPTER 5: GENERAL DISCUSSION

5.1 SUMMARY OF FINDINGS

The goal of the current study was to determine how memory representations of words formed as a result of an intention to remember and in spite of an intention to forget differ in terms of their acoustic, visual and semantic properties. Across three experiments that employed an item-method directed forgetting paradigm, we observed better recognition of TBR items than TBF items (a directed forgetting effect) and better recognition of TBF items than unrelated foils. This confirmed that participants attempted to intentionally remember and forget according to instruction. The critical manipulation was that some foils in the test phase were similar to studied TBR items and TBF items, based on sound (Experiment 1), appearance (Experiment 2), or meaning (Experiment 3). False alarms made to these similar foils on the recognition test were compared to those made to unrelated foils, the rationale being that if participants falsely recognized a greater number of similar foils it would imply that the shared dimension was encoded in the memory trace for the study word. If so, the question was whether these encoded properties were equally represented as a function of attempts to intentionally remember and forget. Our results showed that while TBR and TBF items are represented in memory as a multi-dimensional (acoustic, visual, and semantic) code, the meaning of a word is less likely to survive an attempt to forget.

5.2 CONNECTION TO THEORIES OF DIRECTED FORGETTING, WORKING MEMORY AND CODING SYSTEMS

Our findings are consistent with the selective rehearsal account of item-method directed forgetting (Basden, Basden, & Gargano, 1993; Bjork, 1972) which, in its simplest form, states that TBR items are selectively rehearsed over TBF items leading to

TBR items being better encoded in memory. This differential rehearsal can be positioned within the framework of a multi-component working memory model (Baddeley, 2000). Prior to the presentation of a memory instruction, participants are presumed to recode visually presented words into an acoustic code and then to refresh this representation during the word-instruction delay via maintenance rehearsal. Maintenance rehearsal, as per its name, serves only to maintain superficial properties of the study word (acoustic and visual) in working memory and does not contribute to the directed forgetting effect observed on subsequent recall and recognition tests (see Paller, 1990 for an example of directed forgetting in the absence of maintenance rehearsal). While acoustic properties are processed in the phonological loop, visual properties such as the orthographic characteristics of the study words are refreshed on the visuo-spatial sketchpad. Following the delivery of the memory instruction, rehearsal for TBF items is thought to cease and elaborative rehearsal is initiated for TBR items, serving to commit the items to memory by establishing connections (most importantly semantic ones) with information in long-term stores.

The fact that not all properties of words investigated in these experiments were represented in retrieved TBR and TBF item traces with equal probability (i.e. meaning was less likely to be represented for TBF items than for TBR items) bolsters previous research suggesting that TBR and TBF segments of continuous events are encoded with varying levels of detail (Fawcett et al., 2013a; 2013b). Together, these findings reinforce the notion that encoding of memories (intentional or unintentional) within the item-method paradigm is not an "all-or-nothing" phenomenon (e.g., Bancroft et al., 2013; Gao et al., 2019b). However, the TBR-TBF difference noted in our study with respect to the likelihood of meaning being represented in the memory trace of a study word appears to be inconsistent with the Fawcett et al. (2013a; 2013b) finding that gist was just as likely to be encoded for remember instructed segments of a video as it was for forget instructed segments. Perhaps in order to make sense of the overall storyline of the video, participants had to remember at least the gist, if not the details, of the TBF segments since the TBF segments were interleaved with the TBR segments, effectively interrupting the otherwise continuous event sequence. In fact, when Fawcett et al. (2013a) encouraged conceptual encoding of the video by having participants concurrently complete an event segmentation task, though memory for general details was not later tested, TBR-TBF differences for relatively detailed statements persisted, suggesting that encoding the details of TBF segments is not essential to conceptualizing the overall story line. This type of relational processing was not required for our experiment where the study list was a series of unrelated words.

Whether encoding is performed intentionally as for TBR items or occurs incidentally as for TBF items, at some point, formation of a multi-dimensional memory trace is based on the availability of acoustic, visual and/or semantic properties of the study item. This integration could occur within long-term memory itself (Baddeley, 2012). However, because item-method directed forgetting concerns the manipulation of encoding mechanisms, it seems more likely that it would occur within a component of working memory such as the episodic buffer (Baddeley, 2000). This buffer passively stores and displays bindings of information in single modalities (such as the binding of colour and shape in the visual modality) that can occur within the slave systems (phonological loop and visuo-spatial sketchpad) or outside of working memory

(Baddeley, 2012). Further manipulation of these single modality bindings in the buffer, as well as the integration of cross-modal characteristics of stimuli and information from long-term memory (Goday & Galera, 2011), is thought to require cognitive resources mediated by the central executive.

One view of intentional forgetting in the item-method paradigm is that it is an active process and evidence from reaction times to post-instruction probes suggest that it is initially even more effortful than remembering (Fawcett & Taylor, 2008; see also Fawcett & Taylor, 2012). The authors interpreted the finding that reaction times to post-forget instruction probes were longer than to post-remember instruction probes to mean that instantiating a forget instruction involves recruiting cognitive mechanisms to limit further processing of TBF items and free executive resources to process TBR items instead (see also Taylor, 2018). It could be that the effortful element of forgetting involves preventing binding of semantic information from long-term memory with TBF item representations in the episodic buffer. Cognitive resources that may otherwise have been devoted to this binding could then be redirected to TBR items, facilitating semantic connections with long-term memory through the elaborative processing. This would be congruent with active accounts of both forgetting and binding in the episodic buffer.

Interestingly, experiments by Lee, Lee and Fawcett (2013) support the idea that participants continue to engage with the semantic representation of TBF items in the short term, despite our evidence that semantic information is less likely to be represented for TBF items than for TBR items in the longer term. The authors integrated a colour-naming task into the study phase of the item-method paradigm. They argued that any processing resources devoted to study items following presentation of the memory instruction would interfere with the allocation of cognitive resources to the colour-naming task, thus interfering with the ability to make a speeded response indicating the colour of a post-instruction probe, which was either a repeated study item or novel word. As TBF items were considered less likely than TBR items to be allocated further processing resources following presentation of the memory instruction, interference from the study item on colour-naming (indexed by slower reaction times to post-instruction probes) was predicted to be reduced for repeated probes following a forget instruction compared to those following a remember instruction. As predicted, colour-naming interference was reduced for repeated TBF words compared to repeated TBR words, but only when the repeated item was perceptually matched to the study item. This suggests that the initial response to a forget instruction may be to withdraw processing resources away from the perceptual representation of a TBF item, with effects on semantic processing either occurring later and/or as a result of an "unbinding" of the perceptual representation from its semantic representation within the episodic buffer.

The idea that semantic processing of TBF items is ultimately reduced following an instruction to forget is endorsed by Lin, Kuo, Liu, Han and Chang (2013) who noted a reduced N400 semantic priming effect in a task that presented participants with a prime, remember or forget instruction, and target in sequence and required them to make lexical decisions to semantically related and unrelated targets. Also, fMRI data indicate that the right superior and middle frontal gyrus, along with the right inferior parietal lobe, are more active when a TBF item is successfully forgotten than when a TBR item is incidentally forgotten (Nowicka, Jednoro´rog, Wypych, & Marchewka, 2009; Rizio & Dennis, 2013; Wylie, Foxe, & Taylor, 2008). It is unlikely that this activity merely indicates a greater incidence of passive rest during forget trials because activation of the right dorsolateral prefontal cortex (DLPFC) predicts decreased medial temporal lobe (MTL) activity (Rizio & Dennis, 2013) instead of the increased MTL activity that would be associated with engagement of the default mode network (Vincent, Kahn, Snyder, Raichle, & Buckner, 2008). ERP studies have also shown that sustained prefrontal activity occurring after a forget instruction (Paz-Caballero, Menor, & Jiménez, 2004) is localized to the DLPFC (Hauswald, Schulz, Iordanov, Kissler, 2011), substantiating the view that a right prefrontal-MTL network is recruited during an episode of intentional forgetting to limit encoding.

Finally, since it was only in Experiment 3 that the shared property (meaning) between study words and similar foils was more likely to be contained in memory traces formed as a result of intentional remembering, semantic coding seems to be the primary and most durable long-term coding system. Though acoustic and visual codes also comprise part of our long-term memories, it appears to be the semantic dimension that drives item-method directed forgetting of unrelated words by benefitting recognition performance for TBR items.

5.3 CONCLUSION

In summary, the processes of intentional remembering and forgetting have different consequences on retrieved memory representations for studied items. While acoustic and visual properties are encoded in both TBR and TBF item traces with similar probability, semantic properties are more likely to be encoded following an intention to remember. These results appear to support the 'end-run' account of TBF item encoding as TBF items that survive attempts to forget seem to eschew the semantic encoding processes that serve to commit TBR items to long-term memory.

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APPENDIX A: FIGURES

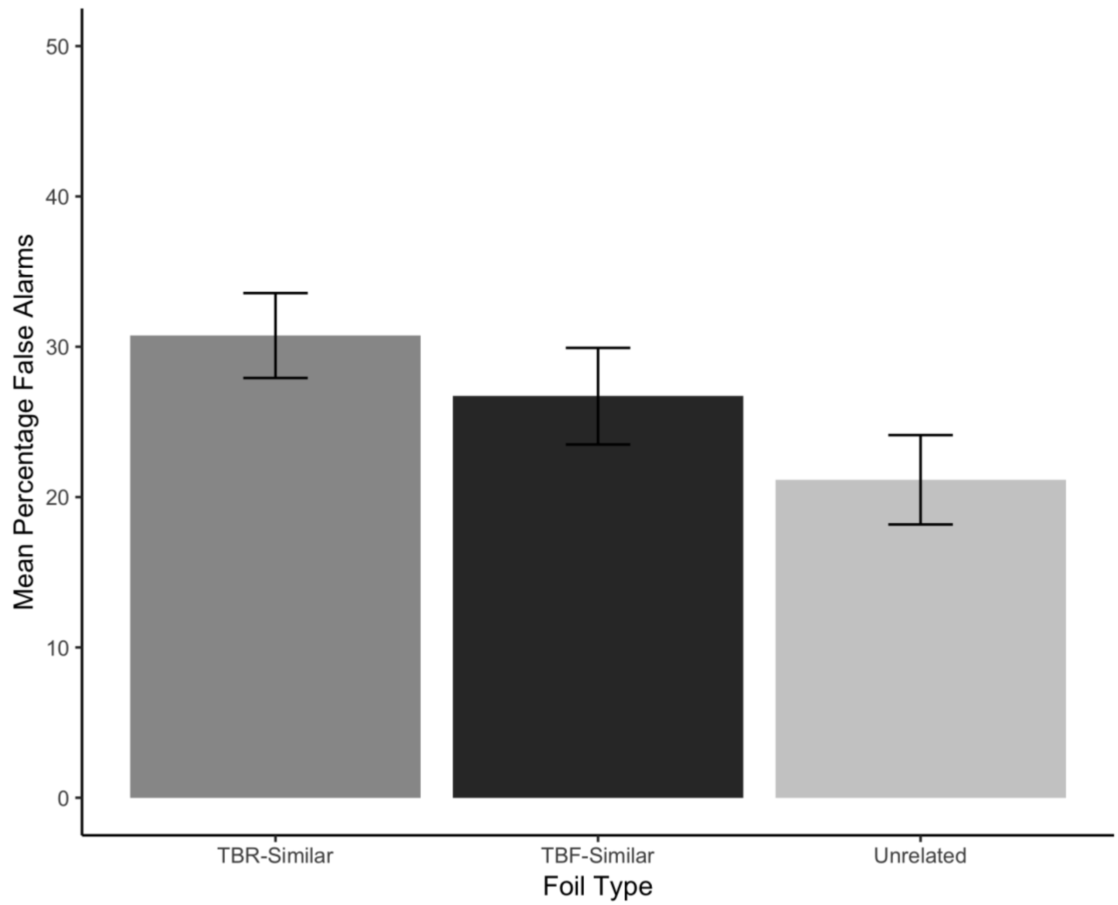

Figure 1. Experiment 1: Mean percentage of false alarms on the recognition memory test as a function of foil type (TBR-Similar, TBF-Similar, unrelated). Error bars represent one standard error of the mean.

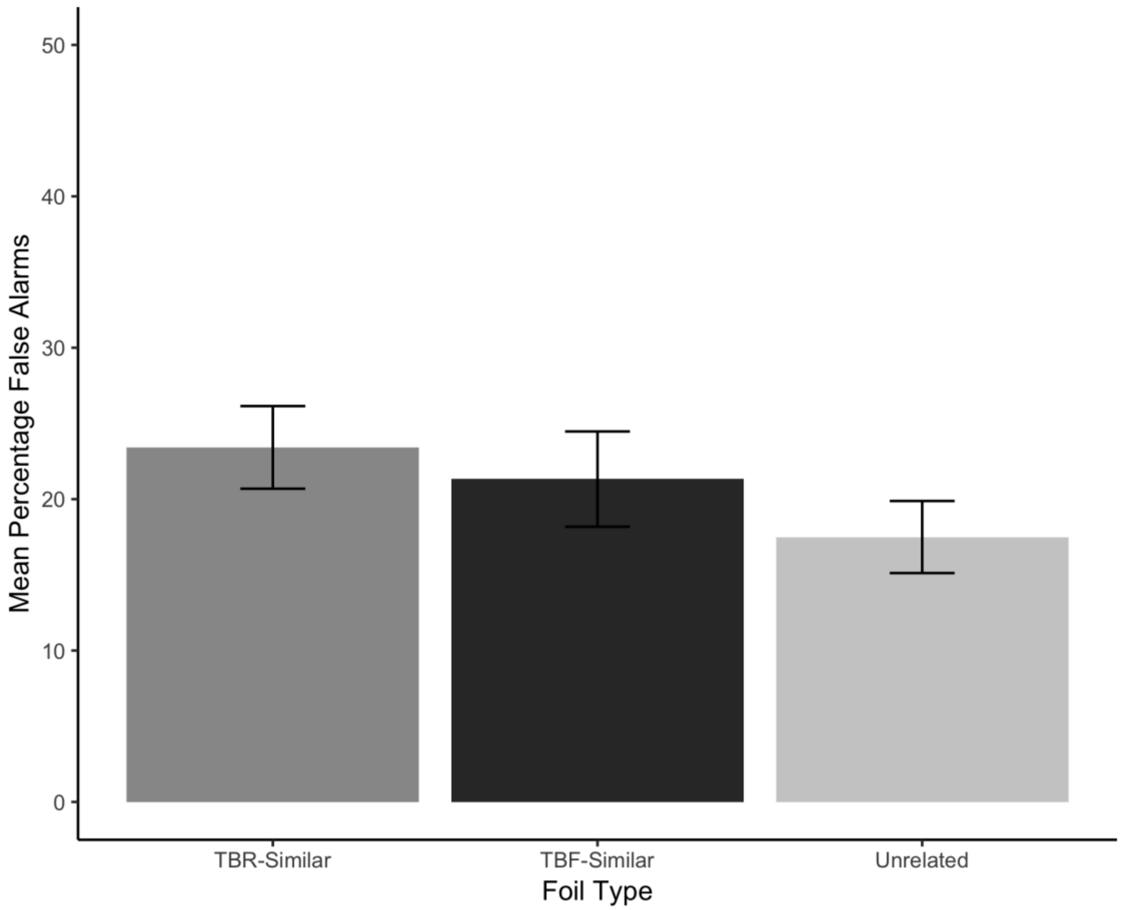

Figure 2. Experiment 2: Mean percentage of false alarms on the recognition memory test as a function of foil type (TBR-Similar, TBF-Similar, unrelated). Error bars represent one standard error of the mean.

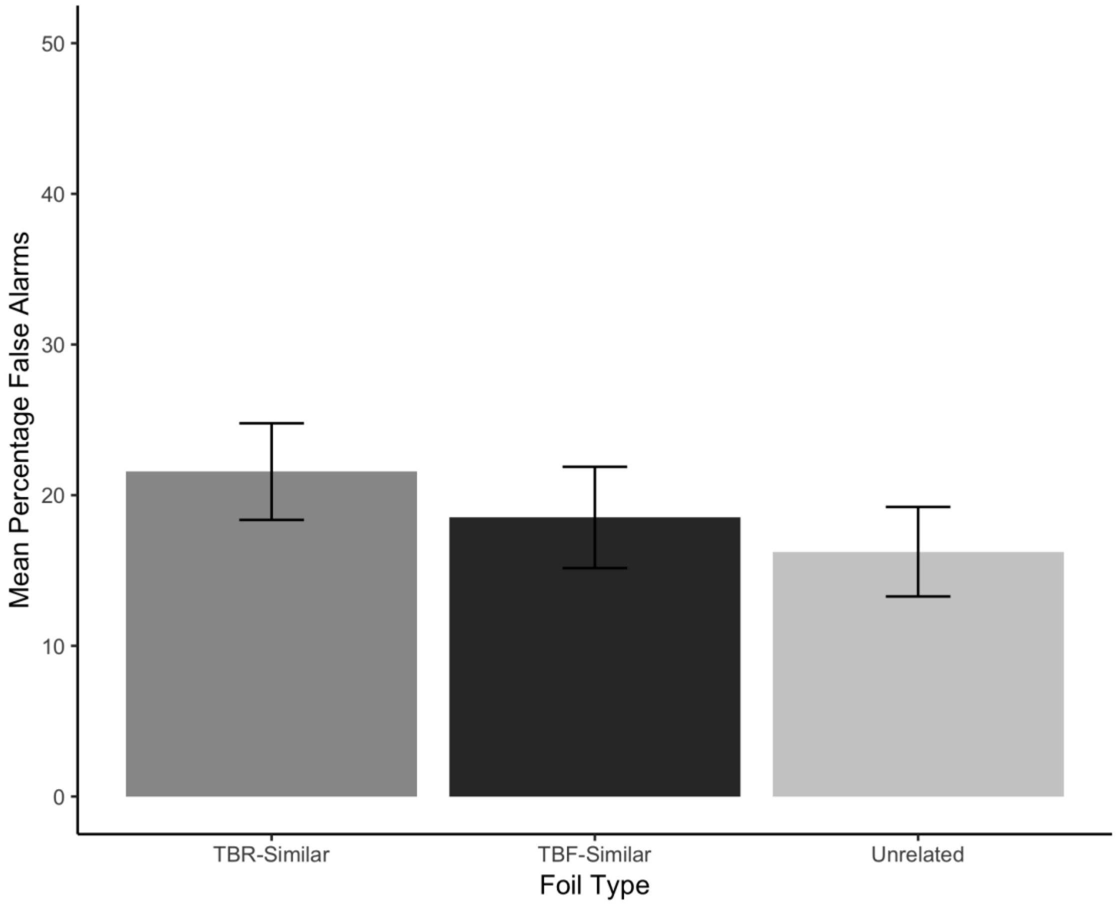

Figure 3. Experiment 3: Mean percentage of false alarms on the recognition memory test as a function of foil type (TBR-Similar, TBF-Similar, unrelated). Error bars represent one standard error of the mean.

APPENDIX B: EXPERIMENT WORDLISTS

Lists of word pairs used in Experiment 1 (similar sound), Experiment 2 (similar appearance), and Experiment 3 (similar meaning). Pairs are alphabetized based on the first member of the similar sounds pair. **Bold** indicates word pairs that were not based on Experiment 1 items.

Experiment 1: Similar Sound		Experiment 2: Similar Appearance		Experiment 3: Similar Meaning	
1	2	1	2	1	2
air	heir	heir	hair	heir	successor
aisle	isle	**opal**	**oval**	aisle	corridor
allowed	aloud	**commend**	**comment**	aloud	audibly
ate	eight	ate	ale	ate	ingested
bail	bale	bale	bake	bail	bond
bald	bawled	bawled	baled	bawled	bellowed
bare	bear	bear	dear	bare	naked
baron	barren	barren	barrel	barren	empty
base	bass	bass	brass	base	headquarters
beach	beech	beech	bench	beach	shoreline
bean	been	bean	beam	bean	legume
belle	bell	bell	belt	belle	debutante
berry	bury	berry	ferry	bury	conceal
berth	birth	birth	birch	berth	bunk
billed	build	billed	billet	build	construct
board	bored	bored	bared	board	plank
bold	bowled	bold	bolt	bold	daring
boos	booze	boos	boots	boos	jeers
bough	bow	bow	how	bough	limb
boy	buoy	boy	bog	boy	lad
brake	break	break	beak	break	fracture
bread	bred	bread	broad	bred	reproduced
brews	bruise	brews	brows	brews	ferments
bridal	bridle	bridal	tidal	bridle	harness
buy	bye	buy	bug	buy	purchase
byte	bite	bite	bits	bite	chomp
cede	seed	seed	send	cede	surrender
ceiling	sealing	sealing	seating	ceiling	roof
cell	sell	cell	call	sell	vend
cent	scent	scent	scant	scent	aroma
cereal	serial	serial	serious	cereal	grain
cheap	cheep	cheep	cheer	cheap	inexpensive

chord	cord	cord	card	cord	rope
cite	sight	cite	city	sight	vision
coarse	course	course	court	course	class
creak	creek	creek	creed	creek	brook
crews	cruise	crews	crows	cruise	sail
cue	queue	cue	cub	cue	hint
currant	current	current	currency	current	ongoing
days	daze	daze	doze	daze	stupor
die	dye	die	dine	die	perish
dual	duel	duel	duet	dual	double
earn	urn	earn	ear	earn	attain
fair	fare	fair	fail	fair	just
faze	phase	phase	phrase	phase	stage
feat	feet	feat	fear	feat	achievement
find	fined	fined	fired	fined	charged
fir	fur	fir	firm	**firm**	**rigid**
flair	flare	flare	flame	flair	glamour
flea	flee	flee	floe	flee	depart
flew	flu	flu	fly	flew	soared
flex	flecks	flecks	flocks	flex	bend
floe	flow	flow	blow	flow	movement
flour	flower	flour	floor	flower	blossom
for	four	for	far	four	quartet
foul	fowl	foul	fool	foul	putrid
friar	fryer	friar	briar	friar	monk
gait	gate	gate	gale	gait	walk
gene	jean	gene	gone	jean	denim
gorilla	guerilla	gorilla	vanilla	gorilla	ape
grate	great	great	greet	great	fantastic
grisly	grizzly	grizzly	drizzly	grisly	gruesome
groan	grown	grown	growl	grown	matured
guessed	guest	guest	quest	guest	visitor
hair	hare	hare	harm	hare	rabbit
hall	haul	hall	hail	haul	carry
hangar	hanger	hanger	hunger	**hunger**	**appetite**
hay	hey	hay	lay	hay	grass
heal	heel	heal	hear	heal	cure
higher	hire	hire	tire	hire	appoint
him	hymn	him	hum	hymn	carol
hoarse	horse	hoarse	hearse	hoarse	gruff

knead	need	need	nerd	need	require
knight	night	night	light	night	evening
knot	not	not	note	knot	tangle
knows	nose	nose	none	nose	snout
lain	lane	lane	land	lane	avenue
lam	lamb	lamb	limb	lam	escape
laps	lapse	laps	lips	lapse	failure
lean	lien	lean	leap	lean	slant
licker	liquor	licker	ticker	liquor	alcohol
lie	lye	lie	line	lie	deceive
links	lynx	links	blinks	links	connections
load	lode	lode	lobe	load	capacity
loot	lute	lute	late	loot	money
made	maid	maid	mad	maid	servant
main	mane	mane	mare	main	major
maize	maze	maze	raze	maize	corn
mall	maul	mall	mill	mall	market
marshal	martial	martial	partial	martial	military
medal	meddle	meddle	middle	meddle	intrude
might	mite	mite	mute	might	force
mind	mined	mined	mired	mind	intellect
miner	minor	minor	manor	minor	trivial
missed	mist	mist	mast	mist	fog
morning	mourning	morning	moaning	mourning	grief
muscle	mussel	**vest**	**vast**	muscle	brawn
naval	navel	navel	novel	naval	marine
none	nun	none	nine	nun	sister
ode	owed	owed	owned	owed	indebted
packed	pact	pact	tact	pact	agreement
pail	pale	pail	pain	pail	bucket
pause	paws	paws	pawn	pause	delay
peak	peek	peak	perk	peek	glimpse
pedal	peddle	peddle	puddle	peddle	solicit
peer	pier	peer	pear	pier	dock
plain	plane	plane	place	plane	aircraft
pleas	please	please	lease	please	gratify
plum	plumb	plumb	plump	plumb	vertical
pole	poll	pole	pile	poll	ballot
praise	prays	prays	plays	praise	commend
principal	principle	**prince**	**prance**	principal	main

profit	prophet	profit	profess	profit	proceeds
quarts	quartz	**quarts**	**quarks**	quirky	odd
rain	reign	rain	ran	rain	precipitation
rap	wrap	rap	rip	wrap	encase
read	reed	read	red	read	study
right	write	**fright**	**freight**	right	correct
ring	wring	wring	wrong	wring	twist
road	rode	road	rod	road	highway
rose	rows	rose	rise	rose	ascended
rye	wry	wry	wiry	wry	witty
sale	sail	sale	salt	sale	deal
saver	savour	savour	saviour	savour	taste
scene	seen	**racket**	**racked**	seen	witnessed
sea	see	sea	seal	sea	ocean
seam	seem	seem	seek	seam	joint
seize	sees	sees	seeds	seize	capture
sew	sow	sow	saw	sow	scatter
side	sighed	sighed	signed	side	edge
sign	sine	sine	since	sign	inscribe
slay	sleigh	slay	slap	slay	kill
some	sum	sum	sun	sum	total
son	sun	son	sin	son	boy
sore	soar	sore	snore	sore	hurt
spade	spayed	spayed	sprayed	spade	shovel
stair	stare	stair	stir	stair	step
stake	steak	steak	teak	stake	brace
steal	steel	steel	steep	steal	pilfer
storey	story	story	stormy	story	narrative
straight	strait	strait	trait	strait	inlet
sweet	suite	sweet	sweat	sweet	sugary
tacks	tax	tacks	ticks	tacks	pushpins
tale	tail	tale	tile	tale	fiction
teas	tease	teas	team	tease	mock
there	their	there	theme	**theme**	**subject**
threw	through	through	though	threw	tossed
told	tolled	told	toll	told	instructed
two	too	too	tool	too	also
vial	vile	vile	vale	vile	horrid
wait	weight	wait	waif	wait	delay
waive	wave	wave	wane	wave	breaker

weather	whether	whether	whither	weather	climate
where	wear	wear	weak	where	location
which	witch	witch	watch	witch	sorceress
whine	wine	wine	wind	whine	whimper
wholly	holy	wholly	holly	wholly	completely
wood	would	wood	word	wood	lumber
yoke	yolk	yoke	yak	yoke	tether
your	yore	yard	yarn	**yard**	**lawn**