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The Influence of Forward and Backward Associative Strength on False Memories for Encoding Context

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Abstract

Two experiments examined the effects of Forward Associative Strength (FAS) and Backward Associative Strength (BAS) on false recollection of unstudied lure items. Themes were constructed such that four associates were strongly related to a lure item in terms of FAS or BAS and four associates were weakly related to a lure item in terms of FAS or BAS. Further, when FAS was manipulated, BAS was controlled across strong and weak associates, while FAS was controlled across strong and weak associates when BAS was manipulated. Strong associates were presented in one font while weak associates were presented in a second font. At test, lure items were disproportionately attributed to the source used to present lures' strong associates compared to lures' weak associates, both when BAS was manipulated and when FAS was manipulated. This outcome demonstrates that both BAS and FAS influence lure item false recollection, which favors global-matching models' explanation of false recollection over the explanation offered by spreading-activation theories.

Keywords

false memory; recollection; context memory; global matching; spreading activation

Among the most striking characteristics of memory errors is the conviction with which people believe erroneous memories were experienced episodically, commonly referred to as *false recollection* (see Arndt, 2012a for a review). Understanding the factors that produce false recollection is important for both applied and theoretical considerations. In the applied realm, understanding false recollection can aid the development of techniques that distinguish between true and false memories (Fisher, Geiselman, & Amador, 1989). In the theoretical realm, understanding false recollection can test theories of memory (Arndt, 2010; Kimball, Smith, & Kahana, 2007), which was the purpose for which the studies reported in this paper were designed. The research reported in this paper used a common list-learning technique, the Deese-Roediger-McDermott (*DRM*; Deese, 1959; Roediger & McDermott, 1995) paradigm, which involves presentation of a series of study items (e.g., *blanket*, *toasty*, *cozy*, *heater*) that are all related to a single, unstudied item (e.g., *warm*) referred to as the *lure*.

In addition to producing high rates of false recall and recognition (Roediger & McDermott, 1995), lure errors show five key characteristics that suggest they produce false recollection. First, participants often claim to recollect lure items, as opposed to judging them to be familiar (Roediger & McDermott, 1995). Second, participants disproportionately attribute lure items to the source used to present the lures' associates during encoding (Hicks & Hancock, 2002; Hicks & Starns, 2006a; Roediger, McDermott, Pisoni, & Gallo, 2004, but see Payne, Elie, Blackwell, & Neuschatz, 1996), suggesting lure items retrieve specific episodic information that was present when their associates were studied, even though lures were never experienced during encoding. Third, requiring source memory judgments *increases* the probability of lure false alarms compared to old-new recognition (Hicks & Marsh, 2001). Thus, when people are asked to complete a memory task that relies more heavily on recollection, lure errors increase. In comparison, asking participants to provide source memory judgments tends to decrease false memories in other paradigms (e.g., eyewitness suggestibility; Lindsay & Johnson, 1989). Fourth, participants disproportionately attribute lure items to the source of lures' strong Backward Associative Strength (BAS) associates when sources are correlated with BAS (Hicks & Hancock, 2002). Fifth, and finally, when a lure item is tested in a font that was used to present its associates during encoding, participants make *more* errors than when the lure item is tested in a font that was studied, but was not used to show the lure's associates during encoding (Arndt, 2010). These final two outcomes document that lure items produce retrieval of the specific encoding context that was present when the lures' associates were encoded (Arndt, 2012a). Taken together, these results provide compelling evidence that lure items produce subjectively convincing false memories, and do so in part because they inspire retrieval of the encoding context in which their associates were studied.

While there is ample evidence documenting that lure items produce false recollection, less is known about the factors that underlie false recollection. A substantial body of research examining semantic memory's contributions to lure errors has supported the role that the strength of the association from studied items to lure items (i.e., Backward Associative Strength, or BAS) plays in producing both false memory (Gallo & Roediger, 2002; 2003; Howe, Wimmer, Gagnon, & Plumptre, 2009; Roediger, Watson, McDermott, & Gallo, 2001) and false recollection (Arndt, 2006; Hicks & Hancock, 2002). Although many studies have demonstrated that BAS influences false memory and false recollection, interpreting those outcomes as evidence that BAS produced the effects is complicated by the fact that BAS tends to be correlated with the strength of the association from lure items to studied items (*Forward Associative Strength* or *FAS*; Brainerd, Yang, Reyna, Howe, & Mills, 2008). Further, most experiments examining the effect of BAS on false memory, and all of the studies examining the effects of BAS on false recollection, have failed to control the potentially-confounding effects of FAS. Five existing studies have examined conditions that separate the effects of BAS and FAS on false memory. McEvoy, Nelson, and Komatsu (1999) manipulated BAS while controlling FAS, and found that BAS increased both false recall and false recognition. Thus, McEvoy, et al's results document that BAS can influence false memory independent of FAS's potentially-confounding effects. Roediger, et al (2001) showed that BAS, but not FAS, predicted lure item false recall and false recognition, which again suggests that BAS can influence false memory independent of FAS. One potential

problem with Roediger et al.'s (2001) conclusion that FAS did not predict false memory is that the range of mean FAS across the lists they used in their study was limited, varying between .01 and .06, which in turn may have limited the ability of FAS to be a reliable predictor of false memory (Brainerd & Wright, 2005). Indeed, Brainerd and Wright (2005) found that both BAS and FAS influenced false recognition when they were factorially manipulated across a wide range of values. Similar to Brainerd and Wright (2005), Arndt (2012b) manipulated BAS and FAS factorially and found that both variables influenced false recognition under speeded as well as self-paced retrieval conditions. Finally, Howe, et al (2009) presented participants with lists that were either high in both BAS and FAS, high in BAS but low in FAS, or high in FAS, but low in BAS. While Howe, et al.'s (2009) primary goal was to examine how associative strength influenced false recall across early cognitive development, I will focus on the results from the 18 year old group that they tested, since that age group is most comparable to those used in the studies cited above, as well as other studies that examine mature adult memory processes. The 18 year olds in Howe et al.'s study recalled more lures when both BAS and FAS were high compared to when BAS was low and FAS was high or when BAS was high and FAS was low, documenting that both BAS and FAS influence false recall. Further, the effect of lowering BAS on false recall was larger than the effect of lowering FAS. Thus, evidence exists that BAS and FAS have separable effects on false memory and that both variables influence false recognition.

While studies of false memory have documented that both BAS and FAS influence false recognition (Arndt, 2012b; Brainerd & Wright, 2005), and one study has documented that both variables influence false recall (Howe, et al., 2009), the independent role each variable plays in producing false *recollection* of encoding context has never been examined. Specifically, although studies have shown that BAS influences false recollection of encoding context (Arndt, 2006; Hicks & Hancock, 2002), all existing studies have failed to control the potentially-confounding effects of FAS. Of the studies that have separated the effects of BAS and FAS on false memory, three provide data that are consistent with the idea that both BAS and FAS increase false recollection. Brainerd and Wright (2005) found that both variables increased the likelihood of *phantom recollection*, a process that reflects people's belief that a lure was recollected (Brainerd, Wright, Reyna, & Mojardin, 2001). Similarly, Howe, et al.'s (2009) finding that false recall is influenced by both BAS and FAS is consistent with the idea that both variables influence false recollection of encoding context, since recall is generally viewed as more dependent on contextually-based retrieval than recognition (Gillund & Shiffrin, 1984). Finally, Arndt (2012b) found that both BAS and FAS influenced false recognition when retrieval was speeded as well as when it was self-paced. Further, lure false memory *increased* with additional retrieval time, a finding that Arndt (2012b) suggested reflects false recollection of lure items being driven by both BAS and FAS.

However, the results of these prior studies only provide indirect evidence that both BAS and FAS influence false recollection. Specifically, Brainerd and Wright (2005) concluded that BAS and FAS influenced phantom recollection, which is proposed to reflect the subjective experience of recollecting unstudied items. Importantly, while phantom recollection provides people with the subjective experience of recollecting an item's occurrence, the phenomenon is proposed to be underlain by familiarity-based representations rather than recollection-based representations (Brainerd, et al., 2001). Thus, Brainerd and Wright's

(2005) data that document BAS and FAS increase phantom recollection may not provide evidence that BAS and FAS influence recollection-based false memory. Similarly, Howe et al (2009) interpreted their finding that both BAS and FAS increased false recall to reflect associative activation of lure representations, an explanation that highlights the activation level of acontextual representations in semantic memory (Collins & Loftus, 1975) as the causal factor that produced false recall differences among conditions that varied in BAS and FAS. Finally, Arndt's (2012b) finding that lure errors increased between speeded and self-paced retrieval conditions potentially reflects accrual of additional familiarity-based processes following the speeded retrieval deadline rather than the effects of false recollection. Specifically, Arndt (2012b) chose a speeded retrieval deadline (750 msec) that was consistent with the point in retrieval at which response-signal studies suggest recollection-based processes begin contributing to recognition memory (e.g., Hintzman & Curran, 1994). However, to the extent the speeded retrieval deadline chosen by Arndt (2012b) failed to allow *all* familiarity-based processes to accrue before a response occurred, an increase in lure errors between speeded and self-paced retrieval conditions could have occurred due to the influence of familiarity-based processes, in contrast to Arndt's (2012b) interpretation that the increase reflected the influence of false recollection. Thus, while prior research is consistent with the conclusion that both BAS and FAS increase false recollection, there is reason to believe that familiarity-based processes (Brainerd & Wright, 2005; Arndt, 2012b) or other acontextual representations (Howe, et al., 2009) could have produced the effects of BAS and FAS observed in prior studies. The research reported in this paper sought direct evidence that BAS and FAS influence false recollection by directly probing participants' memory for the encoding context in which they believed lure items were experienced during encoding.

In order to isolate the separate effects of BAS and FAS on false recollection, two stimulus sets were created: one that manipulated FAS while controlling BAS and a second that manipulated BAS while controlling FAS. In order to manipulate FAS, sets of eight study items that *were produced by* the lure in free association were selected, with four of those items having a relatively high probability of being produced by a lure in free association and the other four items having a relatively low probability of being produced by the same lure in free association. Similarly, in order to manipulate BAS, sets of eight study items related to each lure were selected, with four of those items having a relatively high probability of producing the lure in free association and the other four items having a relatively low probability of producing the same lure in free association. Critically, across the four high strength and the four low strength associates for each lure, the strength of the other associative variable was controlled (BAS for FAS manipulations and FAS for BAS manipulations).

These stimulus sets were then used to examine the effects of BAS and FAS on false recollection using a paradigm developed by Hicks and his colleagues (Hicks & Hancock, 2002; Hicks & Starns, 2006a). Specifically, we presented the strong associates of each lure in one source (font) and the weak associates of each lure in a different source (font). When lures were tested, participants were provided with four source options: the font used to study the lure's strong BAS or FAS associates, the font used to study the lure's weak BAS or FAS associates, and two randomly-chosen fonts that were encountered during encoding, but were

used to present a different lure's associates. This procedure allows the evaluation of the extent to which people 1) attribute lure items to a font that was used to study their associates, even though lures were never encountered during encoding, and 2) the extent to which people attribute lures to the font used to present their strong FAS (or BAS) associates in comparison to their weak FAS (or BAS) associates. The extent to which people disproportionately attribute lures to a font used to study their associates over fonts that were shown during encoding, but were not used to study their associates, provides evidence that people believe lures were experienced in an encoding context that was present when their associates were experienced. Further, and critically, the extent to which people disproportionately attribute lures to the font used to study their strong FAS or BAS associates over their weak FAS or BAS associates provides evidence that the variable in question plays a role in producing false recollection.

In addition to the empirical importance of separating the contributions of BAS and FAS to false recollection (e.g., examining the influence of potentially-confounding associative variables), evaluating the independent effects of BAS and FAS on false recollection tests theoretical views of false memory. Specifically, theories generally differ in the processes that they propose underlie false memory in the DRM paradigm. Some theories, such as activation-monitoring theory (Roediger, et al., 2001) or associative-activation theory (Howe, et al., 2009), propose that DRM lure errors reflect the influence of spreading activation from lures' associates to lures' representations in a semantic network (Collins & Loftus, 1975). On the other hand, global-matching models (Arndt & Hirshman; Hicks & Starns, 2006b; Hintzman, 1988) suggest that false memory arises because lure items share similarity (usually semantic) with their studied associates. These differences lead each general class of theories to predict different roles for BAS and FAS in false recollection.¹ Next, I review these theories' general explanations of false recollection and then use those explanations to derive predictions for the role that BAS and FAS should play in producing false recollection.

Spreading activation theories (Howe, et al., 2009; Roediger, et al., 2001) argue that lure false memory is a result of activation spreading from a lures' associates to lures' representations in semantic memory (Collins & Loftus, 1975). Thus, variables which increase the amount of activation that spreads from lures' associates to lures' representations in semantic memory increase the activation level of lure representations, which in turn increases the probability people will mistakenly believe a lure was recently experienced. In order to explain false *recollection*, these theories generally suggest that high levels of lure representation activation can lead lures to become associated with features of encoding context (Roediger, et al., 2001) or that the network of associations between studied items and lure items are marked as episodically experienced when they are activated during encoding of a lure's associates (Howe, 2006; Hutchison & Balota, 2005). Later, during retrieval, lure representations that are directly associated with encoding context or that have associations with studied items that were marked as episodically experienced will lead people to falsely recollect lure items.

¹While fuzzy-trace theory (Brainerd, et al., 2001) also provides an account of many false memory phenomena, I do not consider it here because it presently does not provide an account of the specificity of peoples' beliefs about the encoding context in which lure items were studied (see Arndt, 2010, 2012a for explication of this point).

For example, consider the finding that people tend to attribute lure items to the source of lures' strong BAS associates in comparison to lures' weak BAS associates (Hicks & Hancock, 2002). Activation of a lure's representation in semantic memory is unable to explain this finding, because semantic memory activation alone does not provide information about the source of a representation's activation. As noted previously, spreading activation theories employ processes that occur during encoding, such as the building of associations between activated lure representations and encoding context or episodic marking of study items' associative networks that were activated during encoding (Howe, 2006; Hutchison & Balota, 2005) to explain why lure items are sometimes falsely recollected. Each of these explanations within the general spreading activation framework highlights the role that the amount of activation that spreads from study items' representations to lure representations during encoding is key in explaining why people believe lures were experienced in a specific encoding context. As a result, factors that increase lure representation activation during encoding will produce a greater tendency for lure items to be judged as episodically experienced. Thus, because strong BAS associates activate lure representations more than weak BAS associates, lures will be more likely to be remembered as occurring in the same encoding context as strong BAS associates compared to the encoding context of their weak BAS associates are being encoded.

In contrast, spreading activation theories would not expect FAS to influence false recollection. Specifically, while BAS provides a metric of how much activation will spread to a lure's representation when its associates are studied, FAS provides a metric of how much a lure item will activate its associates when the lure is experienced, an event that never occurs during encoding. Thus, while BAS can produce differentially-strong associations between a lure representation and the encoding contexts encountered when the lure's strong and weak associates are studied, and can produce greater marking of the associations between study items and lure representations for strong compared to weak associative connections, FAS differences should not produce differential activation of the lure during encoding as long as it is not confounded with BAS. In turn, FAS should not produce differences in the likelihood that a lure's associative network is episodically marked, or differences in the likelihood a lure representation will be associated with encoding context, leading activation-based theories to predict that manipulations of FAS should not influence false recollection. In summary, spreading activation theories generally predict that increases in BAS, but not FAS, should increase false recollection.

Global-matching models (Arndt & Hirshman, 1998; Hicks & Starns, 2006b; Hintzman, 1988) propose that lure errors arise from the fact that lure items moderately match the memory traces of their studied associates during memory retrieval. Specifically, these models assume that a test item activates traces in memory based upon how similar a test item is to those memory traces. The activation of traces in memory is then summed, producing an overall level of memory activation produced by a test item. For studied items, most of the memory activation will result from the study item strongly matching its encoded trace in memory. In comparison, lure items do not tend to match any single memory trace well, but instead produce several moderate matches to the memory traces of their studied associates. As a result of the summing of a number of smaller matches, lure items can produce substantial activation of memory as a whole, leading people to believe they were studied. In

order to explain false recollection, global-matching models suggest that memory traces are composed of both item information and contextual information (Hicks & Starns, 2006b). At retrieval, a memory probe is constructed that contains both item and contextual information present in the memory probe. As with its explanation of lure errors in general, the extent to which a memory probe composed of item and contextual information activates memory determines how much evidence there is that a test item was studied in a particular context.

Importantly, global-matching models implement an assumption known as *interactive cueing* (Clark & Gronlund, 1996), which allows them to explain memory for encoding context, such as how people retrieve studied items' encoding context as well as why lure items retrieve contextual information that was present when their associates were studied. Interactive cueing is the notion that test items that match both item and contextual information in a single memory trace produce more activation compared to test items that match item information in one trace and contextual information in a second trace. With regard to studied items, interactive cueing allows people to distinguish between sources that were studied with a particular item from sources that were not. Specifically, when memory is probed with a studied item and the source encountered with it during encoding, it will match both item and contextual information in a single memory trace, producing greater activation of memory than when memory is probed with a studied item and a source that was encountered with a different item during encoding, which will match item information in one trace and source information in a second trace. Importantly, interactive cueing also enables global-matching models to explain why lures retrieve the encoding context experienced with their studied associates even though they were never experienced during encoding. For example, consider the finding that lure items are attributed to the source used to present their associates more often than they are attributed to a source that was presented during encoding, but was used to present a different lure's associates (Roediger, et al., 2004). Global-matching models explain this finding by suggesting that a lure matches item and contextual information in the same memory traces (those of its associates) when memory is probed with the lure item and the source encoded with its studied associates. In contrast, when memory is probed with a lure item and a source that was not encoded with its studied associates, the resulting memory probe will match item information in one set of traces (those of its associates) and contextual information in other memory traces (the traces of items studied in that source). Thus, interactive cueing will occur in the former case, but not in the latter, producing a stronger memory signal when memory is probed with a lure item and the source encoded with its studied associates. This account can also explain why people tend to attribute lure items to the source of the lure's strong BAS associates (Hicks & Hancock, 2002). In particular, global-matching models suggest that a lure's strong BAS associates have memory representations that are more similar to the lure than its weak BAS associates. As a result, when memory is probed with a lure item and the source of its strong BAS associates, the probe will match the contents of memory better than when memory is probed with a lure item and the source of the lure's weak BAS associates, producing a bias to attribute lures to the source of its strong BAS associates.

Given that they characterize memory retrieval as being based upon the similarity between a test probe and traces in memory, global-matching models expect both BAS and FAS to influence the extent to which a lure item matches the traces of its studied associates in

memory. Specifically, global-matching models view both BAS and FAS to be metrics of the similarity between studied associates and lure items (Arndt, 2010; 2012b; Arndt & Hirshman, 1998; Hintzman, 1988), such that increases in either variable should increase how much lure items match the memory traces of their studied associates during retrieval. In turn, this should produce higher rates of false recollection when memory is cued with the context used to study a lure's strong FAS or BAS associates compared to when memory is cued with the context used to study a lure's weak FAS or BAS associates.

In summary, both spreading activation theories and global-matching models can explain why lure items produce retrieval of encoding context, but the theories rely on fundamentally different underlying mechanisms to do so. In turn, the mechanisms proposed by these theories lead them to produce different predictions for the effects of BAS and FAS on false recollection – spreading activation theories suggest that BAS alone should affect false recollection, while global-matching models argue that both BAS and FAS should affect false recollection. Critically, existing data that have examined the role of BAS on false recollection (Arndt, 2006; Hicks & Hancock, 2002; Hicks & Starns, 2006a) fail to adjudicate between the two theories, because both spreading activation theories and global-matching models predict BAS should influence false recollection. Further, no existing studies have separated the contribution of FAS from BAS in producing false recollection, nor have any existing studies examined the role that FAS alone plays in producing false recollection. Thus, the studies reported in this paper will be the first to separate the influence of FAS and BAS on false recollection, which in turn will enable them to test the explanations of false recollection offered by spreading activation theories and global-matching models.

Method

Participants

Participants were 108 (Experiment 1a, FAS manipulation) and 72 (Experiment 1b, BAS manipulation) Middlebury College students, who participated as part of a research appreciation requirement or in exchange for \$10 payment.

Materials

For each experiment, 60 sets of eight items (*themes* hereafter) that were related to a single item (*lure* hereafter) in free association were selected as stimuli from the University of South Florida Free Association norms (Nelson, McEvoy, & Schreiber, 1998). For Experiment 1a, all eight associates *were produced by* the lure item in free association with a nonzero probability. For Experiment 1b, all eight associates *produced* the lure item in free association with a nonzero probability. Four of the associates in each set were *strong* associates, while the other four associates were *weak* associates. In Experiment 1a, where FAS was manipulated, all four strong associates were produced by the lure in free association with a higher probability than any of the four weak associates. In Experiment 1b, where BAS was manipulated, all four strong associates produced the lure in free association with a higher probability than any of the four weak associates. Critically, the associative variable that was not manipulated in a given experiment (BAS in Experiment 1a, FAS in Experiment 1b) was

similar across the strong and weak associates within each stimulus set, such that, on average, BAS did not differ between strong and weak FAS stimuli in Experiment 1a ($t(478) = .499, p = .618$), and FAS did not differ between strong and weak BAS stimuli in Experiment 1b ($t(478) = .073, p = .941$). For example, one theme used in Experiment 1a was built around the lure item *task*. The four strong FAS associates of *task* that participants studied were *job* (FAS = .370; BAS = .016), *chore* (FAS = .145; BAS = .038), *force* (FAS = .055; BAS = .012), and *duty* (FAS = .055; BAS = .027), while the four weak FAS associates that participants studied were *do* (FAS = .018; BAS = .011), *burden* (FAS = .012; BAS = .020), *mission* (FAS = .012; BAS = .027), and *assignment* (FAS = .012; BAS = .048). The average FAS of the strong associates was thus .156, while the average FAS of the weak associates was .014, a difference of .142 in mean FAS between the strong and weak associates. In contrast, the BAS for the strong FAS associates was .023 and the BAS for the weak FAS associates was .027, such that BAS was slightly *greater* for the weak FAS associates compared to the strong FAS associates for the theme built around the lure *task*. We generally sought to construct themes that maximized the differences between the strong and weak associates for the manipulated variable (FAS in Experiment 1a and BAS in Experiment 1b) while simultaneously minimizing the differences between the strong and weak associates for the controlled variable (BAS in Experiment 1a and FAS in Experiment 1b). Mean FAS and BAS for the strong and weak associate conditions, as well as the range of mean FAS and BAS for themes for each experiment are reported in Table 1.²

Forty of the 60 themes for each experiment were assigned to be study items, with the remaining 20 themes reserved to be unstudied items on the memory test. Eighty unusual-looking fonts (Arndt, 2006; 2010) were used to present stimuli. For the forty themes that were presented during encoding, two fonts were randomly assigned to present the themes' strong and weak associates, such that each theme's strong associates were presented in a different font than the theme's weak associates, and the fonts used to present a theme's associates were unique across themes. Study items were divided into two study lists, with 20 themes per study list. Thus, because presenting each theme during encoding involved presenting eight associates (four strong associates and four weak associates), each of the two study lists was 160 words in length.

Prior to the first study list, participants were informed that they would see a series of words one at a time on the computer screen, and that the words would appear in a variety of unusual-looking fonts. They were asked to rate the appropriateness of the font for the meaning of the word (Arndt, 2006; 2010; Arndt & Reder, 2003; Reder, Donavos, & Erickson, 2002) on a scale ranging from 1 (*not very appropriate*) to 4 (*very appropriate*). Participants were informed that there were no correct or incorrect answers for this task, but that we were interested in their perceptions of font-word correspondence. Finally, participants were instructed to do their best to remember the words that they were presented with because their memory for those words would be tested later in the experiment.

Participants were given a series of practice trials to acclimate them to the font-word correspondence task, after which study list presentation began. Study items were presented

²Complete stimuli for both of these studies are available from Jason Arndt.

serially on the computer screen blocked by theme, with the strong and weak associates within a theme also presented blocked. There were no breaks between themes or presentation of the strong and weak halves of themes – each study list was presented as a continuous series of words. Half of the themes in each study list were presented with their weak associates first, and half were presented with their strong associates first. The order of associate presentation for a theme (strong vs. weak associates first), as well as whether themes were studied or unstudied was counterbalanced across participants. The order of themes within a study list and the assignment of fonts to themes' strong and weak items was randomly determined anew for each participant.

Following each of the two study lists, participants were given a five-alternative forced-choice source memory task for the items that were presented on the immediately-preceding study list. Each test item was presented in four fonts that were shown during encoding. Studied items were tested in the font used to present them during encoding, as well as three other fonts that were presented during encoding (*distractor fonts*). Lure items were tested in the font used to show their strong associates during encoding, the font used to show their weak associates during encoding, and two distractor fonts that were studied, but were not used to show the lure's associates during encoding. In addition to the four font source options, participants were given the option to respond that a test item was new.

Test lists were composed of twenty items that were randomly chosen from the ten unstudied themes assigned to each test list (one strong and one weak FAS/BAS associate per theme), forty items that were studied associates of lure items (one strong and one weak FAS/BAS associate per theme, chosen randomly), the lures items related to the ten unstudied themes, and the lure items related to the twenty studied themes. Thus, each test list was 90 words long. The assignment of distractor fonts to test items was randomly determined with the constraint that each font served equally often as a distractor font for each participant. Further, the location of each test font (first-fourth) was randomly determined for each test item with the constraint that studied and distractor fonts occurred equally often in each of the four test positions for studied items and with the constraint that strong FAS/BAS, weak FAS/BAS, and distractor fonts occurred equally often in each of the four test positions for lure items.

Results

For each study, I report four primary dependent measures. First, I present the probability that participants chose the font a studied item was presented in during encoding. Second, I present the conditional probability that a studied item was attributed to the source in which it was encoded, given the item was judged to have been studied (*conditional source* hereafter). Third, I present the probability that lure items were attributed to the source used to study their strong and weak FAS (Experiment 1a) or BAS (Experiment 1b) associates or a distractor font. Fourth, I present the conditional probability that lure items were attributed to the source used to study their strong and weak FAS/BAS associates or a distractor font, given the lure was judged to have been studied (*lure conditional source* hereafter). For completeness, I present the probability that studied items, lure items, new items and lures items related to new items were judged "old" in Table 2.

Experiment 1a (FAS manipulated, BAS controlled)

Studied items—Figure 1 presents the probability that studied associates were attributed to the font in which they were studied (top panel), as well as conditional source accuracy (bottom panel), as a function of whether the studied associates were lures' strong or weak FAS associates. As is evident from inspection of Figure 1, neither measure differed as a function of studied associates' FAS (both $t(107) < 0.60$, $p > .50$, $d = .006$ for source attributions and $d = .057$ for conditional source accuracy). Further, the probability that strong FAS associates were attributed to a distractor font was .22, and the probability that weak FAS associates were attributed to a distractor font was also .22. Finally, the probability that new items were attributed to one of the four sources was generally low (between .057 and .066) and did not differ across the four source response options, $F(3,321) = 1.07$, $MSE = .002$, $p = .362$.

Lure items—Figure 2 presents the probability that lure items were attributed to the font in which their strong FAS associates were studied, the font in which their weak FAS associates were studied, or a distractor font (top panel), as well as lure conditional source for each of the three types of lure source attributions (bottom panel). Both measures documented that there were differences across the three types of source attributions (both $F(2,214) > 160.55$, $p < .001$). Bonferroni-adjusted t-tests ($\alpha = .008$) indicated that participants were more likely to attribute a lure to one of the fonts in which its associates were studied than to a distractor font (all $t(107) > 14.18$, $p < .001$, $d = 1.76$ for source attributions to high FAS fonts; $d = 1.36$ for source attributions to low FAS fonts; $d = 1.79$ for high FAS font lure conditional source and $d = 1.41$ for low FAS lure conditional source). Importantly, both measures also documented that participants were more likely to attribute lure items to the font in which their strong FAS associates were studied compared to the font in which their weak FAS associates were studied (both $t(107) = 3.19$, $p < .002$, $d = .31$ for source attributions and $d = .32$ for lure conditional source). Thus, people disproportionately attributed lure items to the sources used to study lures' associates, particularly lures' strong FAS associates.³ Finally, the probability that lure items related to unstudied associates were attributed to one of the four sources was generally low (between .065 and .081) and did not differ across the four source response options, $F(3,321) = 1.73$, $MSE = .003$, $p = .161$.

Experiment 1b (BAS manipulated, FAS controlled)

Studied items—Figure 3 presents the probability that studied associates were attributed to the font in which they were studied (top panel), as well as conditional source accuracy (bottom panel), as a function of whether the studied associates were lures' strong or weak BAS associates. Both measures showed that participants had better source memory for lures' strong BAS associates than lures' weak BAS associates (both $t(71) > 4.02$, $p < .001$; $d = .47$ for source attributions and $d = .36$ for conditional source accuracy). The probability that

³I also analyzed the high vs. low FAS source attribution probabilities for order effects, since some stimulus sets were studied such that weak FAS associates occurred first, while others were studied such that strong FAS associates occurred first. I used a 2 (order: weak FAS associates first vs. strong FAS associates first) $\times$ 2 (FAS: weak vs. strong) ANOVA. This analysis produced only a main effect of FAS, $F(1,107) = 8.82$, $MSE = .016$, $p = .004$. The main effect of order ($F < 1$) and the interaction ($F(1,107) = 1.02$) did not approach significance. The main effect of FAS, coupled with the lack of an interaction, indicates that the effects of FAS on lure source attributions (strong > weak) occurred regardless of whether a lure's strong or weak FAS associates were presented first during encoding.

strong BAS associates were attributed to a distractor font was .23, and the probability that weak BAS associates were attributed to a distractor font was .26. Finally, the probability that new items were attributed to one of the four sources was generally low (between .047 and .061) and did not differ across the four source response options, $F(3,213) = 2.27$, $MSE = .001$, $p = .082$.

Lure items—Figure 4 presents the probability that lure items were attributed to 1) the font in which their strong BAS associates were studied, 2) the font in which their weak BAS associates were studied, or 3) a distractor font (top panel), as well as lure conditional source for each of the three types of lure source attributions (bottom panel). Both measures documented that there were differences across the three types of source attributions (both $F(2,142) > 30.64$, $p < .001$). Bonferroni-adjusted t-tests ($\alpha = .008$) indicated that lures were attributed to the font in which their strong BAS associates were studied more often compared to the font in which their weak BAS associates were studied (both $t(71) > 6.44$, $p < .001$; $d = .90$ for source attributions and $d = .76$ for lure conditional source), and compared to a distractor font (both $t(71) > 6.43$, $p < .001$; $d = .83$ for source attributions and $d = .76$ for lure conditional source). However, participants were not more likely to attribute lures to the font in which their weak BAS associates were studied compared to a distractor font (both $t(71) < 1.49$, $p > .10$; $d = .17$ for source attributions and $d = .18$ for lure conditional source). Thus, people disproportionately attributed lure items to the source used to study lures' strong BAS associates in comparison to both lures' weak BAS associates and studied sources that were not used to present tested lures' associates during encoding.⁴ Finally, the probability that lure items related to unstudied associates were attributed to one of the four sources was generally low (between .056 and .075) and did not differ across the four source response options, $F(3,213) = 1.41$, $MSE = .004$, $p = .242$.

Discussion

The results of these studies replicate prior research showing that BAS plays a role in producing false recollection (Arndt, 2006; Hicks & Hancock, 2002; Hicks & Starns, 2006a), and extends those results to show that BAS increases false recollection when it is not confounded with FAS. Additionally, these results show that FAS increases false recollection, even when it is not confounded with BAS. Thus, the results of these studies build on prior work showing that both BAS and FAS increase false memory (Arndt, 2012b; Brainerd & Wright, 2005; Howe, et al., 2009) by showing that they also increase false recollection. Importantly, and in contrast to prior results (Arndt, 2012b; Brainerd & Wright, 2005), the results of the present studies provide strong evidence that BAS and FAS influence false recollection, and cannot be explained by familiarity-based processes. Thus, like variables

⁴I also analyzed the strong vs. weak BAS source attribution probabilities for order effects, since some stimulus sets were studied such that weak BAS associates occurred first, while others were studied such that strong BAS associates occurred first. I used a 2 (order: weak BAS associates first vs. strong BAS associates first) x 2 (BAS: weak vs. strong) ANOVA. This analysis produced a main effect of BAS, $F(1,71) = 54.60$, $MSE = .007$, $p < .001$, as well as a main effect of order, $F(1,71) = 7.35$, $MSE = .006$, $p = .008$, but no interaction, $F < 1$. The main effect of order indicates that participants were slightly (~2.5%) more likely to attribute lure items to a studied source when strong BAS associates were studied first. However, the most important finding is that there was no hint of an interaction, indicating that the main effect of BAS was similarly-sized for both orders of theme presentation (weak BAS first, strong BAS first).

such as the number of associates of a lure that are studied (Arndt, 2010), BAS and FAS influence false memory in general *and* false recollection in particular.

On a theoretical level, these results support global-matching models' explanation of false recollection over spreading activation theories' explanation of false recollection. Specifically, global-matching models explain lure item false memory and false recollection as a result of lure items being similar to traces in memory. Thus, they expect any variable that indexes the similarity between a memory probe and traces in memory, such as FAS and BAS, to influence false memory. Further, because global-matching models suggest that memory for context, and therefore false recollection, is driven by the same basic processes as memory for items, they also expect variables that increase the similarity between a memory probe and traces in memory to increase false recollection.

In contrast, spreading activation theories expect BAS alone to increase false recollection. This prediction results from the claim that lure errors, as well as lure false recollection, are increased by factors that influence the spread of activation from study items to lure representations, such as the strength of the directional association from study items to lure representations (i.e., BAS). Thus, because FAS indexes the strength of the association emanating from a lure item to studied items in a semantic network, it should not have effects on lure activation, and therefore should not influence the probability that a lure representation is associated with encoding context. As a result, spreading activation theories would not expect changes in FAS to impact false recollection.

Evaluation of Other Associative Variables and Alternative Explanations

One concern readers may have regarding the present studies is that examining the effects of BAS and FAS is necessarily correlational since both variables are the product of one's life experience.⁵ Thus, although the stimuli were rigorously controlled to vary either BAS or FAS while controlling the other associative variable, there may be other semantic memory factors that varied across the levels of strong and weak BAS or FAS in these experiments, which in turn may be able to explain the present results. As a way of assessing the extent to which semantic memory variables other than BAS or FAS may have impacted the present results, I evaluated how each of the semantic memory variables that are contained within the University of South Florida free association norms (Nelson, et al., 1998) varied across lures' strong and weak associates for the stimuli used in these studies. Means and simple comparisons (*t*-tests) across lures' weak and strong FAS associates are presented in Table 3, while means and simple comparisons across lures' weak and strong BAS associates are presented in Table 4.

For the stimuli used in Experiment 1a (FAS manipulation), the analyses generally suggested that item characteristics such as concreteness (*CONC*) and word frequency (*WF*) did not differ across lures' weak and strong FAS associates. Second, of the associative variables in the Nelson, et al (1998) norms, lures' weak and strong FAS associates did not differ in terms of the number (*#O*) or summed strength (*OSG*) of the overlapping associates they shared with lure items. Similarly, lures' weak and strong associates did not differ in the density of

⁵I thank Keith Hutchison for raising this point.

connections among study items' associates (connectivity, or *CONN*). Third, lures' weak and strong associates had a similar number of associations in semantic memory (set size, or *SS*). Thus, none of these variables offers a plausible alternative explanation for the effects of FAS on lure false recollection.

However, lures' strong FAS associates had more (*#M*) mediated connections between lures and studied items than lures' weak FAS associates, and the summed strength of those mediated connections (*MSG*) was greater for lures' strong FAS associates than their weak FAS associates. This difference in mediated association strength between strong and weak FAS associates does not seem to compromise the theoretical conclusion that global-matching models explain the effects of FAS, while spreading activation theories do not. Specifically, greater strength of mediated connections between a lure and its studied associates for strong FAS associates would be viewed by global-matching models as further evidence that lures and their strong FAS associates have more featural overlap in semantic memory compared to lures and their weak FAS associates – exactly the factor that the models use to explain the effects of direct FAS-based connections. In comparison, spreading activation theories would claim that stronger mediated connections between a lure and its studied associates simply allows more activation to flow, via mediated connections, from the lure to its associates when the lure is experienced. Thus, although there would be both direct and indirect connections between a lure and its associates, the basic prediction that spreading activation theories make – that FAS should not influence false recollection – is not altered by mediated associations being stronger for lures' strong FAS associates relative to their weak FAS associates.

In addition, lures' strong FAS associates were more likely to possess resonant, or bi-directional, connections with their non-lure associates (*PRC*) than lures' weak FAS associates, and the summed strength of those resonant connections (*RCSG*) was greater for lures' strong FAS associates compared to their weak FAS associates. It is possible to argue that summed strength differences in resonant connections provides an explanation for the present results that does not rest on the direct influence of FAS on false memory, although that explanation is fairly complex. Specifically, spreading activation theories could claim that resonant connections between study items and their associates lead to more overall activation of lures' strong FAS associates, which in turn produces greater activation of lure representations during encoding of the lures' strong FAS associates. This explanation would claim that activation spreads from study items to their non-lure associates, which then spreads back to study items, via resonant connections, from their non-lure associates. Since the summed strength of the resonant connections for strong FAS associates is greater than the summed strength of the resonant connections for weak FAS associates, the activation of lures' strong FAS associates could then become greater than the activation of lures' weak FAS associates, strictly due to the effects of spreading activation from their resonant connections. Finally, even though the associative strength between strong and weak FAS associates and lure items (i.e., *BAS*) was controlled, if the representations of lures' strong FAS associates become more active than the representations of lures' weak FAS associates, it could produce greater activation flowing from lures' strong FAS associates to lure representations. This would, in turn, activate lure items more when their high FAS associates were studied compared to when their low FAS associates were studied, potentially

producing a greater likelihood that the lure's associative network will be episodically marked with the context (font) in which its strong FAS associates were studied or that the lure will be associated with the encoding context of its strong FAS associates.

Although this is a plausible explanation for the effects of FAS found in Experiment 1a, there are three reasons global-matching models' explanation is preferable to that offered by spreading activation theories for the effects of FAS on false recognition. First, parsimony considerations clearly favor the explanation offered by global-matching models, where BAS and FAS are viewed in the same manner – as reflections of the similarity between studied items and lure items. Thus, either variable is capable of producing increases in lure false memory, as well as lure false recollection, and the exact same mechanism – the match between memory traces and lure items – is the basis for the variables' effects on false memory and false recollection. In contrast, although spreading activation theories view the effects of BAS and FAS to be due to the influence of spreading activation on memory networks, the effects of BAS are a *direct* influence of spreading activation, while the influence of FAS is exceedingly *indirect*, requiring activation to spread from studied items to their associates, back to studied items, and then finally to lure items in order to produce the differential activation of lure items that explains FAS's effects on false recollection. Second, the explanation of FAS's effects on false memory and false recollection offered by spreading activation theories suggests the effects should be exceedingly small, similar to the those found when priming is mediated by two interim associates (McNamara, 1992). However, all of the studies that have examined FAS's effects on false memory using a categorical manipulation of the variable (Experiment 1a, Arndt, 2012b, Brainerd & Wright, 2005; Howe, et al., 2009) have found robust effects of FAS on false memory. In contrast, the only published study that has failed to find effects of FAS on false memory examined FAS over a very small range – .01 to .06 (Roediger, et al., 2001), such that the failure to find evidence that FAS predicted false memory may have been due to restricted range (Brainerd & Wright, 2005). Indeed, although the effects of FAS on false recollection ($d = .32$) in the data reported in this paper was smaller than the effect of BAS on false recollection ($d = .76$), the strength of the two manipulations was not specifically equated, such that it is likely the BAS manipulation (mean difference of .21 between strong and weak BAS associates) was stronger than the FAS manipulation (mean difference of .09 between strong and weak FAS associates). Thus, the difference between the size of the FAS and BAS effects was likely due to a difference in how strongly each variable was manipulated rather than inherent differences in the magnitude of the effects of these two associative variables. Third, and finally, studies that have examined mediated false memory, where people study lists of words that are only connected to a lure item via an interim associate, have generally found that mediated false recognition only occurs when the study of mediated DRM lists is followed immediately by recall or explicit attempts to guess the lure item based upon the list items (Huff & Hutchison, 2011; Huff, Coane, Hutchison, Grasser, & Blais, 2012). Thus, using procedures such as those in the present studies, where the study of DRM lists was not followed by a recall attempt, prior work has shown that elevated false memory for lure items does not occur when there is a single mediator association across which activation must flow. As a consequence, an explanation of FAS's effects on false recollection that rests on activation flowing across two associative links – the mechanism spreading activation

theories could offer to explain FAS's effects on false recollection – seems implausible. Taken together, these three considerations favor global-matching models' explanation of the effects of FAS on false recollection over that offered by spreading activation theories.

Table 4 reports an analysis of these same semantic memory variables for the stimuli used in Experiment 1b (BAS manipulation). These analyses demonstrated that lures' weak and strong associates did not differ in word frequency (*WF*), concreteness (*CONC*), connectivity (*CONN*), and the summed strength (*OSG*) of their overlapping associates. Thus, although lures' weak and strong BAS associates differed in the number of overlapping associates (*#O*), the summed strength of those associations was not sufficiently different between lures' weak and strong associates to produce fundamentally different levels of overlapping associative strength to complicate the interpretation of BAS's direct effects on false recollection.

However, there were several variables that differed between lures' strong and weak associates. Specifically, lures' weak and strong BAS associates differed in set size (*SS*), such that lures' strong associates had slightly smaller set sizes on average than lures' weak associates. This result suggests that strong BAS associates have less interference in semantic memory in terms of their relationship to lure items in addition to stronger direct connections with lure items. Importantly, this difference does not fundamentally undermine the conclusion that BAS differences influence false recollection. Indeed, it may simply suggest that lures were slightly more likely to overlap with their strong BAS associates than the most straightforward interpretation of BAS in terms of associative activation (spreading activation theories) or similarity (global-matching models). Thus, even if set size explains some of the effect of BAS on false recollection, the general conclusion that BAS influences false recollection is valid, whether it is through direct connection strength, similarity between studied items and lure items, reduced semantic interference, or (most likely) some combination of the three. Finally, and similar to the results for the stimuli that manipulated FAS, lures' weak and strong BAS associates differed in the number (*#M*) and strength of the mediated connections between lures and studied items (*MSG*), as well as the summed strength of their resonant connections (*RCSG*) with associates, but not in the probability they possessed a resonant connection (*PRC*). The finding that lures' weak associates had a lower mediated strength than lures' strong associates does not critically undermine the conclusion that BAS plays a role in producing false recollection, since such mediated connections simply reinforce the strength of the relationship between lure items and their studied associates. Thus, in the view of spreading activation theories, such mediated connections provide an additional boost to lure representation activation, furthering the disparity in activation that lures receive from their weak and strong associates, respectively. Similarly, in the view of global-matching models, such mediated connections simply reflect an additional source of similarity between lure items and their studied associates. Thus, mediated association strength does not fundamentally undermine the conclusion that BAS influences false memory or false recollection. Finally, with regard to the summed strength of the resonant connections, this associative strength for lures' weak BAS associates was *higher* than the summed strength of the resonant connections for lures' strong BAS associates. Thus, differences in the summed strength of resonant connections would work

against BAS increasing false recollection rather than provide an alternate explanation of BAS's effects on false recollection.

In summary, evaluating a large corpus of alternate semantic variables that could have differed across the strong and weak associates used in these two studies suggests that BAS and FAS have direct, reliable influences on false recollection. Further, evaluating the semantic memory variables in the Nelson, et al (1998) corpus did not undermine the primary theoretical conclusion reached based upon interpretation of the direct effects of FAS and BAS on false recollection, that the present results favor global-matching models' explanation of false recollection.

Spreading-activation theories and Forward Associative Strength (FAS)

To this point, I have compared general predictions from spreading activation views to general predictions from global-matching models for these two studies. Implicit in this approach is that *all* theories with spreading activation at the heart of their explanation of false memory in the DRM paradigm, such as associative activation theory (Howe, 2006) and activation-monitoring theory (Roediger, et al., 2001), will need to make relatively complex, and likely implausible, assumptions to explain these results. However, it may be useful to consider more detailed assumptions of one variant of spreading-activation theory that has been suggested to explain the effects of FAS on false memory, associative activation theory (Howe, 2006; Howe, et al., 2009). As discussed in the introduction, Howe, et al. (2009) examined the influence of both BAS and FAS on false recall. While Howe and colleagues were primarily interested in developmental changes in false recall, their study's 18 year old age group produced data that are relevant for present purposes, since those data come from an age group that is similar to the participants in these studies.

The primary finding from this age group was that both BAS and FAS influenced false recall, with BAS differences producing a larger effect on false recall than FAS differences. Associative activation theory's explanation of developmental changes in false recall, as well as its general explanation of why both BAS and FAS influenced false recall is that overall associative activation is the key factor that produces false memories (Howe, et al., 2009). In this sense, associative activation theory has the potential to explain the current results. Specifically, if FAS is capable of producing overall greater levels of lure activation within the spreading activation framework that underlies associative activation theory, it would in turn have the potential to influence false recollection. However, associative-activation theory currently lacks a clearly-articulated mechanism, based in the spreading activation principles that underlie its explanation of lure false memory, by which FAS can influence lure activation. Indeed, the most straightforward explanation that spreading-activation theories seem to provide to explain how FAS influences lure activation, and thus lure false memory, involves activation spreading across three associative links. First, activation would have to spread from studied items to lure representations based upon their BAS when the lure's associates are studied. As long as BAS is controlled, as it was in Experiment 1a, this would not produce differential activation of the lure's representation based upon study of its strong and weak FAS associates. Second, activation would have to spread from lure representations back to studied items based upon how much the lure was activated by the study of its

associates. When FAS differs, as it did in Experiment 1a, this would potentially produce differential activation of a lure's studied associates, such that its strong FAS associates would be activated more than its weak FAS associates. Third, and finally, activation would have to again spread from the lure's associates to the lure's representation a second time, based upon how much they were activated by resonant activation from the lure's representation. As noted above when evaluating alternative semantic/associative variables that differed across the strong and weak FAS associates (PRC and PRSG), an explanation of false memory involving activation spreading over three associations seems implausible given the results of studies of mediated priming (McNamara, 1992) and studies of mediated false memory (Huff & Hutchison, 2011; Huff, et al., 2012). Specifically, studies of mediated priming document that activation spreading over two interim associations produces exceedingly small effects. Similarly, studies of mediated false memory have shown that that false memory can only be mediated by a single associate (Huff & Hutchison, 2011; Huff, et al., 2012), and only when recall or an attempt to guess the lure item follows immediately after each study list, and neither procedure was employed in these studies. Thus, a spreading-activation based explanation of FAS's effects on false memory seems highly implausible.

A second possibility that spreading-activation theories could use to explain the effects of FAS on false recollection that were documented in these studies would be to invoke mechanisms at retrieval. In particular, one of the mechanisms that spreading-activation theories use to explain false recollection is that activation during encoding can produce "marking" of associative pathways that link studied items to lure representations (Anderson & Bower, 1973; Howe, et al., 2006; Hutchison & Balota, 2005). In cases where BAS is above floor, but equal, across levels of FAS (e.g., Experiment 1a), this would lead to equal levels of associative pathway marking during encoding for a lure's strong and weak FAS associates. Then, during retrieval, when a lure is tested, the lure's stronger association with its strong FAS associates would lead to a greater probability those marked pathways are accessed when the lure is tested, resulting in a greater probability people will believe the lure was experienced in the encoding context that was linked to the lure's strong FAS associates. Critically, this mechanism could be readily embedded within any spreading-activation based that seeks to explain false memory. Indeed, this explanation favors the current instantiation of associative-activation theory (Howe, 2006; Howe, et al., 2009), which adheres to this view of why false memories are often treated as if they were episodically experienced (see also Hutchison & Balota, 2005) over other spreading activation-based frameworks that seek to explain false memory, such as activation-monitoring theory (Roediger, et al., 2001), which argues that false recollection reflects the strength of associations between lure items and encoding context that were formed during encoding.

Although this retrieval-based explanation succeeds at explaining the present data, there are two considerations that weigh against it being the best explanation for the present data. First, parsimony considerations again favor the explanation offered by global-matching models, which explains the effects of FAS and BAS using the same basic underlying process – the similarity of lure items to traces in memory. In contrast, this explanation argues that the effects of BAS and FAS on false memory arise at different stages of the memory process (encoding and retrieval, respectively). Thus, this explanation suggests that the core

mechanism spreading-activation theories use to explain false memory, lure representation activation, does not account for the effects of FAS on false memory, in contrast to prior theorizing about the basis of FAS's (and BAS's) effects on false memory from the perspective of associative-activation theory (Howe, et al., 2009). Second, and most important, existing data argue against the view that BAS and FAS arise from different stages of memory processing. Specifically, Arndt (2012b) examined the influence of a retrieval-time manipulation on false recognition while factorially manipulating BAS and FAS. The results of this study documented that 1) both BAS and FAS influenced false memory when retrieval was speeded as well as when it was self-paced, and 2) that the effects of BAS and FAS on false recognition were similar in magnitude when retrieval was speeded and when retrieval was self-paced. The fact that both BAS and FAS influenced false recognition when retrieval was speeded argues that the same basic process, available early in retrieval, underlies at least some of the effects of both variables. Thus, complex, time-consuming processes at retrieval, such as the retrieval of episodic markers on associations, do not seem to be plausible explanations of the effects of FAS on false memory. Similarly, the fact that the effects of BAS and FAS were of similar magnitude when retrieval was speeded and when retrieval was self-paced further argues against the view that the two variables having fundamentally different underlying bases for their effects on false memory. Thus, the explanation that the effects of BAS are due to lure representation activation and the effects of FAS are due to complex, time-consuming processes at retrieval does not adequately account for the full range of these variables' effects on false memory. In summary, while spreading-activation theories offer several potential explanations of the effects of FAS on false recollection, none of the currently-available explanations derived from this viewpoint appear to be able to explain the available data on how BAS and FAS influence false memory. In contrast, global-matching models readily explain the similarity in the effects of BAS and FAS found by Arndt (2012b) and in the current studies because these models suggest that the two variables' effects on false memory have a common cause – the similarity between lure representations and the memory traces of their studied associates.

Concluding Remarks

In closing, there are two important issues that the results of these studies highlight. First, these studies provide further evidence for the importance of separating the contributions of different semantic/associative variables to false memory production (Brainerd, et al., 2008). In particular, these results qualify prior findings suggesting that BAS is the sole driving factor behind lures' ability to retrieve encoding context (Arndt, 2006; Hicks & Hancock, 2002) by suggesting that the effects found in prior studies may have been driven by FAS in addition to BAS. Thus, future research should take care to separate the effects of BAS and FAS on false memory, particularly because understanding their separate effects on false memory has important implications for evaluating theoretical views of the bases of false memory, as illustrated by the present studies. Second, understanding false memory is likely to benefit from a thorough examination of the semantic variables that underlie false memory, both in the DRM paradigm, and more generally. Thus, while the present research examined two major variables that have been confounded in most prior work, there are a number of other semantic memory variables that may predict the occurrence of false recognition and recollection, and those variables' influences on false memory have not been extensively

explored (Brainerd, et al, 2008). Indeed, as documented in the general discussion, these variables are important for future studies to evaluate while controlling other, potentially-confounding, variables in order to examine the influence of naturally-occurring semantic variables on false memory with appropriate methodological rigor.

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Figure 1.

The proportion of correct source judgments (top panel) and conditional source accuracy (bottom panel) for studied items in the weak and strong FAS conditions in Experiment 1a. Error bars depict the standard error of the mean.

Figure 2.

The proportion of lure items attributed to the source of the lure's weak FAS associates, strong FAS associates, or a distractor font (top panel), and the conditional probability that a lure was attributed to the source of the lure's weak FAS associates, strong FAS associates, or a distractor font (bottom panel). Error bars depict the standard error of the mean.

Figure 3.

The proportion of correct source judgments (top panel) and conditional source accuracy (bottom panel) for studied items in the weak and strong BAS conditions in Experiment 1b. Error bars depict the standard error of the mean.

Figure 4.

The proportion of lure items attributed to the source of the lure's weak BAS associates, strong BAS associates, or a distractor font (top panel), and the conditional probability that a lure was attributed to the source of the lure's weak BAS associates, strong BAS associates, or a distractor font (bottom panel). Error bars depict the standard error of the mean.

Table 1

Mean backward (BAS) and forward (FAS) associative strengths for stimulus sets in Experiment 1a (FAS manipulated, BAS controlled) and Experiment 1b (BAS manipulated, FAS controlled). The range of the mean FAS and BAS for themes in each condition are indicated in parenthesis.

Experiment 1a (FAS manipulated)

Mean Association Strength	FAS Condition	
	Low	High
FAS	.02 (.012–.045)	.11 (.062–.178)
BAS	.12 (.018–.423)	.12 (.014–.452)

Experiment 1b (BAS manipulated)

Mean Association Strength	BAS Condition	
	Low	High
FAS	.01 (.000–.127)	.01 (.000–.049)
BAS	.03 (.020–.235)	.24 (.048–.774)

Table 2

Probability “old” judgments for Low FAS/BAS, High FAS/BAS, and lure items in Experiment 1a (FAS manipulated, BAS controlled) and Experiment 1b (BAS manipulated, FAS controlled) as a function of whether the theme’s associates were studied (*old items*) or unstudied (*new items*). Standard error of the mean is in parenthesis.

<i>Experiment 1a (FAS manipulated)</i>			
	Item Type		
	Low FAS	High FAS	Lure
Old Items	.89 (.01)	.89 (.01)	.63 (.02)
New Items	.22 (.02)	.28 (.02)	.30 (.02)

<i>Experiment 1b (BAS manipulated)</i>			
	Item Type		
	Low BAS	High BAS	Lure
Old Items	.87 (.01)	.90 (.01)	.46 (.03)
New Items	.20 (.02)	.21 (.02)	.26 (.03)

Semantic memory characteristics of Experiment 1a's stimuli as a function of forward associative strength. Significant differences between weak and strong associates are indicated by bolded text.

Table 3

	Variable									
	MSG	#M	OSG	#O	SS	WF	CONC	CONN	PRC	RCSG
<i>Weak FAS Associates</i>	0.004	1.43	0.207	2.52	15.26	105.13	4.64	1.80	0.382	0.06
<i>Strong FAS Associates</i>	0.015	3.04	0.214	2.84	14.76	116.25	4.68	1.80	0.506	0.10
<i>t</i> (478)	7.12	8.86	0.28	1.88	1.14	0.44	0.28	0.03	6.85	4.79

Note: *MSG* = Mean summed strength of all of the mediated connections between lure items and their studied associates; *#M* = Mean number of mediated connections between lure items and their studied associates; *OSG* = Mean summed strength of the overlapping associates shared between study items and lure items; *#O* = Mean number of overlapping associates those associates that are shared between study items and lure items; *SS* = Mean set size, defined as the number of associates related to each studied item; *WF* = Mean Ku era-Francis (1967) word frequency of studied associates; *CONC* = Mean concreteness of studied associates; *CONN* = Mean connectivity among studied items' associates, defined as the number of associative connections among the items most closely related to study items; *PRC* = Mean probability of a resonant, or bi-directional, connection between study items and their associates in semantic memory; *RCSG* = Mean strength of the resonant connections between study items and their associates in semantic memory.

Semantic memory characteristics of Experiment 1b’s stimuli as a function of backward associative strength. Significant differences between weak and strong associates are indicated by bolded text.

Table 4

	Variable									
	MSG	#M	OSG	#O	SS	WF	CONC	CONN	PRC	RCSG
<i>Weak BAS Associates</i>	0.007	1.67	0.015	1.63	16.69	60.45	4.50	1.68	0.231	0.036
<i>Strong BAS Associates</i>	0.013	2.38	0.020	2.05	14.14	43.76	4.64	1.62	0.210	0.024
<i>t</i> (478)	4.52	4.54	1.62	3.49	11.55	0.81	0.71	1.02	1.45	2.50

Note: *MSG* = Mean summed strength of all of the mediated connections between lure items and their studied associates; *#M* = Mean number of mediated connections between lure items and their studied associates; *OSG* = Mean summed strength of the overlapping associates shared between study items and lure items; *#O* = Mean number of overlapping associates – those associates that are shared between study items and lure items; *SS* = Mean set size, defined as the number of associates related to each studied item; *WF* = Mean Ku era-Francis (1967) word frequency of studied associates; *CONC* = Mean concreteness of studied associates; *CONN* = Mean connectivity among studied items’ associates, defined as the number of associative connections among the items most closely related to study items; *PRC* = Mean probability of a resonant, or bi-directional, connection between study items and their associates in semantic memory; *RCSG* = Mean strength of the resonant connections between study items and their associates in semantic memory.