Psicothema

Psicothema 2017, Vol. 29, No. 3, 358-363
doi: 10.7334/psicothema2016.248

ISSN 0214 - 9915 CODEN PSOTEG

www.psicothema.com

The role of backward associative strength in false recognition of DRM lists with multiple critical words

María Soledad Beato[1] and Jason Arndt[2]
[1] University of Salamanca and [2] Middlebury College (USA)

Abstract

Background: Memory is a reconstruction of the past and is prone to errors. One of the most widely-used paradigms to examine false memory is the Deese/Roediger-McDermott (DRM) paradigm. In this paradigm, participants studied words associatively related to a non-presented critical word. In a subsequent memory test critical words are often falsely recalled and/or recognized. **Method:** In the present study, we examined the influence of backward associative strength (BAS) on false recognition using DRM lists with multiple critical words. In forty-eight English DRM lists, we manipulated BAS while controlling forward associative strength (FAS). Lists included four words (e.g., prison, convict, suspect, fugitive) simultaneously associated with two critical words (e.g., CRIMINAL, JAIL). **Results:** The results indicated that true recognition was similar in high-BAS and low-BAS lists, while false recognition was greater in high-BAS lists than in low-BAS lists. Furthermore, there was a positive correlation between false recognition and the probability of a resonant connection between the studied words and their associates. **Conclusions:** These findings suggest that BAS and resonant connections influence false recognition, and extend prior research using DRM lists associated with a single critical word to studies of DRM lists associated with multiple critical words.

Keywords: False memory, DRM paradigm, multiple critical words per list, Backward Associative Strength (BAS).

Resumen

Papel de la fuerza asociativa inversa en el reconocimiento falso empleando listas DRM con múltiples palabras críticas. **Antecedentes:** la memoria es reconstructiva y puede estar sujeta a errores. El paradigma más ampliamente utilizado para estudiar las memorias falsas es el paradigma Deese/Roediger-McDermott (DRM). En este paradigma se estudian palabras relacionadas con una palabra crítica no presentada, posteriormente recordándose y/o reconociéndose falsamente esta palabra crítica. **Método:** se analizó la influencia de la fuerza asociativa inversa (Backward Associative Strength, BAS) sobre el reconocimiento falso utilizando listas DRM con múltiples palabras críticas. Para ello se construyeron 48 listas DRM en inglés, manipulando el BAS mientras se controlaba la fuerza asociativa directa (Forward Associative Strength, FAS). Las listas incluían cuatro palabras (e.g., prison, convict, suspect, fugitive) asociadas simultáneamente con dos palabras críticas (e.g., CRIMINAL, JAIL). **Resultados:** el reconocimiento correcto era similar en las listas con alto y bajo BAS, mientras que el reconocimiento falso era mayor en las listas con alto BAS. Además, había una correlación positiva entre reconocimiento falso y la probabilidad de conexión resonante entre las palabras estudiadas y sus asociados. **Conclusiones:** los resultados confirman que el BAS y las conexiones resonantes afectan al reconocimiento falso, y amplían las conclusiones de anteriores estudios que empleaban listas con una palabra crítica al estudio de listas DRM con múltiples palabras críticas.

Palabras clave: memoria falsa, paradigma DRM, múltiples palabras críticas por lista, fuerza asociativa inversa.

Over recent years, the Deese/Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995) has been one of the most frequently used paradigms to study false memories. In this paradigm, participants study lists of words (e.g., hot, heat, pipe, cook, warm, etc) semantically related to a single non-presented critical word (e.g., STOVE). On a later memory test, participants frequently falsely recall and recognize the critical words (e.g., Arndt, 2015; Beato, Cadavid, Pulido, & Pinho, 2013; Cadavid & Beato, 2016; Carneiro, Albuquerque, Fernández, & Esteves, 2007; Coane, Huff, & Hutchison, 2016; Tempel, Frings, & Mecklenbräuker, 2015; for a review, see Gallo, 2006, 2010).

A general characteristic of DRM lists is that there is a high degree of variability in the probability they will produce false memory (e.g., Gallo & Roediger, 2002), despite the fact that the same criteria were used to build the lists (e.g., Anastasi, De Leon, & Rhodes, 2005; Beato & Arndt, 2014; Beato & Díez, 2011; Cadavid & Beato, 2017; Stadler, Roediger, & McDermott, 1999).

Previous research has attempted to understand the bases of this variability by examining the role of Forward Associative Strength (FAS, the associative strength from non-studied critical words to studied items) and Backward Associative Strength (BAS, the associative strength from studied items to non-studied critical words) in producing false memory (for an alternative explanation

Received: August 9, 2016 • Accepted: April 20, 2017
Corresponding author: María Soledad Beato
Faculty of Psychology
University of Salamanca
37005 Salamanca (Spain)
e-mail: msol@usal.es

of this variability, see Cann, McRae, & Katz, 2011). These studies have found that BAS was an important factor in determining false memory rates (e.g., Arndt, 2006; Arndt & Gould, 2006; Gallo & Roediger, 2002; Howe, Wimmer, & Blease, 2009; Knott, Dewhurst, & Howe, 2012; McEvoy, Nelson, & Komatsu, 1999; Roediger, Watson, McDermott, & Gallo, 2001). However, there is less consistency in the results of studies examining FAS's role, such that no significant correlations between FAS and false recall or false recognition have been found in some studies, (e.g., Beato & Arndt, 2014; Gallo & Roediger, 2002; Roediger et al., 2001), while other studies have found that both FAS and BAS had a significant effect on false recognition (e.g., Arndt, 2012a; Brainerd & Wright, 2005).

One factor that makes it hard to study the individual roles of BAS and FAS on false memories is that they are correlated (Brainerd, Yang, Reyna, Howe, & Mills, 2008). Thus, it is important to separate the contributions of BAS and FAS to false memory in order to understand the specific role that each one plays. To accomplish this goal, we built DRM lists with high and low BAS, while keeping FAS values extremely low (almost zero). Further, it is well known that there are properties of words that can affect false memory (e.g., word length, word frequency, familiarity, typicality, concreteness, etc; e.g., Roediger et al., 2001). To ensure that such characteristics cannot explain variability in false recognition, we built high and low BAS lists for exactly the same critical words.

False memories have been explained using several theoretical approaches (for a review, see Arndt, 2012b). First, according to activation-monitoring theory (e.g., McDermott & Watson, 2001; Roediger et al., 2001), spreading activation from studied words to related words (critical words) is responsible for increasing false memory. However, people may use monitoring processes in an effort to determine whether each word that comes to mind in recall or that is tested on a recognition test was previously studied (Koriat, Goldsmith, & Pansky, 2000). Thus, false memory occurs when critical word activation is high and source monitoring fails. Second, fuzzy-trace theory (e.g., Brainerd & Reyna, 1990; Reyna & Brainerd, 1995) proposes that memory traces are stored on a *verbatim* to *gist* continuum. Verbatim traces contain the perceptual details and surface structure of experiences, while gist traces contain the general meaning or theme of a series of events (e.g., a study list). True memory is often mediated by verbatim traces, while false memory occurs when critical words match gist traces. Third, global-matching models suggest that critical word false memory arises because critical words match the traces of their studied associates (Arndt & Hirshman, 1998). Thus, like fuzzy-trace theory, global-matching models view false memory as arising from shared similarity between studied items and critical words. Important for the present study is that, despite their differences, all three theories predict that increasing BAS should increase false memories. The present study will test this core prediction of these theories, and, in contrast to prior studies (e.g., Knott et al., 2012; Roediger et al., 2001), we will test the individual role that BAS plays in false memory, while explicitly controlling FAS across our manipulation of BAS, and keeping FAS values almost zero. Thus, any false memory effects we observe should be BAS-based effects.

The majority of studies employing the Deese/Roediger-McDermott paradigm have used lists of words associated with a single critical word. However, there are also DRM normative studies employing lists associated with multiple critical words (Beato & Arndt, 2014; Beato & Díez, 2011; Cadavid & Beato, 2017). Importantly, lists associated with multiple critical words have not been used to study the standard effect of BAS on false memories.

In the present study, we built DRM lists associated with two-critical words that manipulated BAS while virtually eliminating FAS in order to examine the effect of BAS without the potentially-confounding effects of FAS. With these specific lists we attempted to achieve the following objectives: (1) to confirm that BAS, by itself, is an important factor producing false recognition; (2) to extend the role of BAS to lists with multiple critical words; and, finally, (3) to provide a new pool of 48 DRM lists with multiple critical words that are useful for false memory studies with an English-speaking population.

Method

Participants

Forty undergraduate students, native English speakers, participated in this study as part of a research appreciation requirement for an introductory psychology course (M_{age} = 18.81 years, SD = 0.91, 58% women).

Instruments

A total of 48 four-word DRM lists were constructed from English free-association norms (Nelson, McEvoy, & Schreiber, 1998, 2004). Specifically, there were 24 pairs of lists, each of which produced the same two critical words in free association (i.e., they were related via backward associative strength, or BAS), one list that was strongly related to the critical words (high-BAS list), and one list that was weakly related to the critical words (low-BAS list) (see Table 1).

The BAS values for each critical word (*critical word BAS* hereafter) were determined by the mean of the associative strengths between the four associated words and each critical word. Similarly, the BAS values of each list (*BAS list strength* hereafter) were calculated as the mean of the BAS values for the two critical words (Beato & Díez, 2011; Robinson & Roediger, 1997). BAS for the two critical words of each list was almost identical ($M_{difference}$ = .001).

For example, for the critical words FOOD and EAT, the high BAS associates were *restaurant*, *dine*, *feast*, *diner* (BAS_{FOOD} = .268; BAS_{EAT} = .267), while the low BAS associates were *plates, dishes, chip*, *eggs* (BAS_{FOOD} = .024; BAS_{EAT} = .023). Thus, the high BAS associates had a BAS list strength of .268, while the low BAS associates had a BAS list strength of .024 (see Figure 1).

Across the corpus, critical words had a mean BAS list strength of .182 (SD = .04, range: .131-.293) in the high-BAS condition, and a mean BAS list strength of .036 (SD = .02, range: .016-.061) in the low-BAS condition. The high-BAS and low-BAS list strengths differed significantly, $t(46) = 15.95$, $p < .001$, Cohen's $d = 4.60$, 95% CI [.13, .16].

Forward associative strength (FAS) was calculated similarly to BAS. As we intended to examine the unique contribution of BAS to false memory, lists were explicitly constructed such that FAS list strength was extremely low, almost zero (M = .01, SD = .01). Note that, although high and low BAS lists differed in FAS (.018

Table 1
Forty-eight lists with two critical words, the backward associative strength (BAS) values per critical word, the mean percentages of true recognition (TR list), and false recognition (FR list) were included

Critical words: associated words	BAS Critical 1	BAS Critical 2	TR list	FR list
BEER, DRINK: bartender, pub, alcohol, bottle	.236	.240	91.67	36.67
BEER, DRINK: bottle, flask, pour, quench	.042	.040	71.67	10.00
PAIN, SAD: hurt, sorrow, grief, misery	.217	.218	65.00	20.00
PAIN, SAD: misery, trauma, failure, terrible	.059	.063	71.67	20.00
ANIMAL, CAT: stray, vet, furry, wolf	.150	.149	81.67	10.00
ANIMAL, CAT: tail, breed, rabbit, bird	.046	.045	66.67	10.00
ANSWER, QUESTION: response, ask, statement, explain	.157	.159	65.00	53.33
ANSWER, QUESTION: statement, remark, explain, suggest	.052	.050	55.00	26.67
SCHOOL, TEACHER: education, faculty, class, learner	.158	.157	68.33	46.67
SCHOOL, TEACHER: lesson, desk, profession, union	.028	.023	68.33	20.00
MONEY, BUY: purchase, expense, receipt, shopping	.172	.176	73.33	13.33
MONEY, BUY: customer, sales, bargain, market	.042	.045	63.33	16.67
DRESS, CLOTHES: outfit, skirt, hem, suit	.164	.169	81.67	36.67
DRESS, CLOTHES: pants, button, torn, sleeve	.016	.020	68.33	36.67
HOT, WARM: heater, cool, climate, fireplace	.168	.167	60.00	30.00
HOT, WARM: sunshine, dryer, radiator, shorts	.033	.032	71.67	6.67
CRIMINAL, JAIL: prison, convict, suspect, fugitive	.167	.170	88.33	50.00
CRIMINAL, JAIL: robbery, perjury, corrupt, steal	.016	.016	83.33	30.00
FALSE, LIE: true, untruthful, disbelieve, truthful	.158	.160	66.67	3.33
FALSE, LIE: myth, liar, superstition, pretend	.029	.031	81.67	20.00
FOOD, EAT: restaurant, dine, feast, diner	.268	.267	83.33	20.00
FOOD, EAT: plates, dishes, chip, eggs	.024	.023	91.67	13.33
FRIEND, NICE: neighbor, kind, friendly, friendship	.167	.170	66.67	43.33
FRIEND, NICE: understanding, concern, like, compassion	.020	.021	60.00	10.00
GOD, CHURCH: cathedral, prayer, lord, pray	.292	.294	83.33	36.67
GOD, CHURCH: shrine, sacred, rejoice, believe	.028	.032	70.00	6.67
LAUGH, JOKE: giggle, pun, gag, serious	.213	.209	71.67	23.33
LAUGH, JOKE: gag, comedian, hilarious, entertain	.058	.063	76.67	3.33
STUPID, DUMB: ignorant, smart, wisdom, brilliant	.151	.156	71.67	30.00
STUPID, DUMB: wisdom, gifted, brilliant, clever	.016	.017	65.00	3.33
MUSIC, HORN: trumpet, bugle, flute, oboe	.146	.150	90.00	20.00
MUSIC, HORN: trombone, oboe, drum, brass	.055	.055	83.33	30.00
WEIRD, STRANGE: bizarre, unusual, freak, uncommon	.163	.164	78.33	40.00
WEIRD, STRANGE: unnatural, obscure, different, irregular	.034	.039	76.67	33.33
PAPER, NEWSPAPER: newsstand, ad, times, daily	.164	.163	83.33	53.33
PAPER, NEWSPAPER: daily, issue, weekly, media	.036	.037	61.67	20.00
RAIN, WET: drench, puddle, sprinkle, mist	.162	.163	71.67	26.67
RAIN, WET: waterfall, shower, flood, drip	.025	.029	78.33	16.67
SHIP, BOAT: anchor, captain, sailing, sailor	.236	.239	81.67	46.67
SHIP, BOAT: submarine, sink, gully, steam	.032	.037	73.33	33.33
SOAP, CLEAN: detergent, dishwasher, washcloth, shower	.148	.152	83.33	30.00
SOAP, CLEAN: washcloth, laundry, bathroom, cleaning	.054	.058	60.00	46.67
BASEBALL, FOOTBALL: sports, softball, player, referee	.131	.130	81.67	3.33
BASEBALL, FOOTBALL: player, pro,ball, bench	.057	.054	66.67	6.67
BAD, GROSS: disgusting, awful, unpleasant, smoking	.140	.138	73.33	20.00
BAD, GROSS: vulgar, smoking, crude, slum	.033	.032	70.00	6.67
WORK, JOB: task, chore, duty, function	.216	.213	68.33	33.33
WORK, JOB: management, secretary, technician, union	.017	.016	66.67	26.67

vs. .003, respectively), these values are so extremely low that they can not be responsible for the effects found in this study.

Since each pair of lists shared the same critical words, we distributed the 48 associated lists into two groups of 24 lists (12 high-BAS and 12 low-BAS lists) to ensure that neither associated nor critical words were repeated within each group. Participants were randomly assigned to a stimulus sets, and studied 18 of the 24 lists (9 high-BAS and 9 low-BAS lists). The other 6 lists (3 high-BAS and 3 low-BAS lists) were employed as distractors on the recognition test. Lists were assigned to be studied and distractors equally often across participants.

The recognition memory test included 144 words, randomly presented: 72 studied words (4 associates per list), 36 critical words, 12 unrelated critical-distractors and 24 unrelated distractors.

Procedure

Participants were informed that they would be presented with words one at a time on the computer screen and their task was to remember the words as best they could, because they would be given a memory test for these words later on in the experiment. Participants were tested individually using a PC computer. Study items were presented blocked by DRM list, and in decreasing order of BAS. The order of list presentation was randomized.

At the conclusion of the study phase, participants completed a self-paced recognition memory test.

Data analysis

The results are presented as the mean percentage of true recognition, false recognition, false alarms to unrelated critical-distractors and false alarms to unrelated distractors. A one-way repeated-measures analysis of variance (ANOVA) was carried out to establish that there were differences in the percentage of "old" responses across the four types of words. Subsequently, Bonferroni-adjusted post-hoc analyses were used to examine which types of words received old responses at different rates, and thus to document that there was a false memory effect. Furthermore, to analyze differences in true recognition and false recognition as a function of high and low BAS, we used a t-test. Finally, correlational analysis was used to examine if there was a relationship between false recognition and some properties of studied words. A value of $p < .05$ was considered statistically significant. Partial eta squared (η^2_p) indicates effect size. Confidence intervals and Cohen's *d* have also been included. Statistical analysis was carried out using SPSS Statistics 23.0.

Results

The results are presented as the mean percentage of true recognition, false recognition, false alarms to unrelated critical-distractors and false alarms to unrelated distractors.

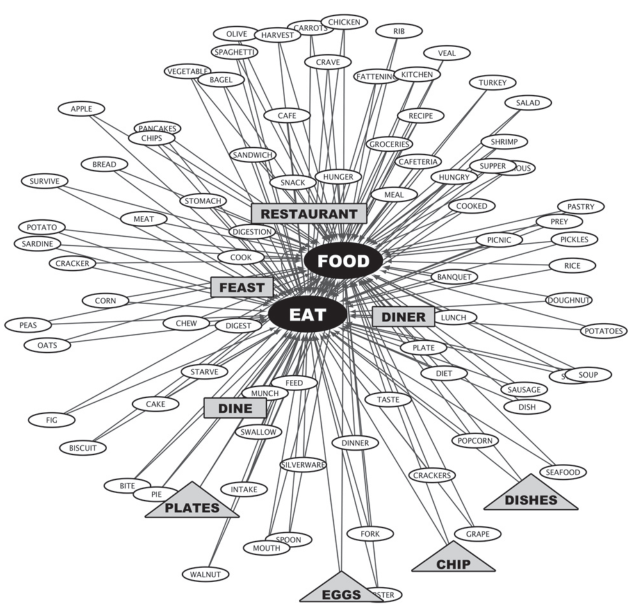

Figure 1. Graphical representation of the associative network for FOOD-EAT critical words. Black ovals: critical words. Rectangles: words included in high-BAS list. Triangles: words included in low-BAS list

False memory effect

A one-way repeated-measures analysis of variance (ANOVA) was used to evaluate the probability of "old" judgments across the four levels of the Type of Word variable (studied word, critical word, unrelated critical-distractor and unrelated distractor). This analysis revealed a significant main effect of Type of Word, $F(3, 117) = 335.18$, $p < .001$, $\eta^2_p = .90$. Bonferroni post-hoc analysis showed that hits to studied words (true recognition) ($M = 73.96$, $SD = 13.46$) were higher than false alarms to critical words (false recognition) ($M = 24.58$, $SD = 12.85$), $p < .001$, 95% CI [42.47, 56.28], false alarms to unrelated critical-distractors ($M = 11.46$, $SD = 13.17$), $p < .001$, 95% CI [53.70, 71.30], and false alarms to unrelated distractors ($M = 8.02$, $SD = 8.87$), $p < .001$, 95% CI [58.55, 73.32]. There were also differences between false alarms to critical words and both unrelated critical-distractor and unrelated distractor items, both *ps* < .001, 95% CIs [7.30, 18.95], and [12.10, 21.02] respectively. There was not a significant difference between the two types of unrelated distractors, $p = .34$, 95% CI [-1.42, 8.29]. These results indicate that these stimuli produced the typical false memory effect, where critical false alarms were higher than unrelated false alarms, and thus are appropriate stimuli to study false memory with an English-speaking population.

True recognition (TR)

Participants' memory for study items in high-BAS and low-BAS lists did not reliably differ ($M = 76.25$ vs. 71.67, respectively), $t(39) = 1.97$, $p = .056$, Cohen's $d = 0.30$, 95% CI [-0.13, 9.30] (see Table 2).

False recognition (FR)

Examining false recognition (FR) at the level of each list allowed us to observe that there were wide differences between lists. For example, some lists had high FR (e.g., 53%, ANSWER-QUESTION: *response, ask, statement, explain*), whereas other lists yielded very low FR (e.g., 3%, STUPID-DUMB: *wisdom, gifted, brilliant, clever*). When we analyzed FR at the level of each critical word we found that some critical words were never falsely recognized (BAD, BEER, DUMB, FOOTBALL, LAUGH and LIE), while critical words like NEWSPAPER (80%), FRIEND (67%), and SHIP (67%) showed the highest FR levels. This high variability in FR rates was also observed in previous DRM studies with BAS lists with multiple critical words in Spanish (Beato & Díez, 2011; Cadavid & Beato, 2017). Overall, FR for the 48 lists was 25% ($SD = 12.85$).

Table 2
Mean percentage of true and false recognition as a function of high and low backward associative strength (BAS)

BAS	True recognition	False recognition
High-BAS	76.25 (13.37)	30.27 (15.66)
Low-BAS	71.67 (17.09)	18.89 (13.94)
Average	73.96 (13.46)	24.58 (12.85)

Note: Standard deviations are in parentheses

Importantly, high-BAS lists produced higher FR (M = 30.27, SD = 15.66) than low-BAS lists (M = 18.89, SD = 13.94), $t(39)$ = 4.88, p < .001, Cohen's d = 0.77, 95% CI [6.66, 16.11] (see Table 2). Although low-BAS lists produced lower levels of FR, they still showed above-baseline levels of FR, $t(39) = 3.73$, $p = .001$, Cohen's $d = 0.55$, 95% CI [3.40, 11.46] for the comparison with false alarms to unrelated critical-distractors.

Therefore, similar to McEvoy et al. (1999), who manipulated BAS while controlling FAS, our results showed that BAS increased FR independently of FAS since our FAS values were almost zero. In addition, even low-BAS lists produced a false memory effect (for another example with extremely low-BAS lists, see Cadavid & Beato, 2017).

Figure 2 shows FR in the 24 pairs of lists we used in this study. With few exceptions, the high-BAS lists produced higher FR. Further, there was a high degree of variability in FR for both high-BAS lists (range: 3.33-53.33) and low-BAS lists (range: 3.33-46.67).

We sought to understand this variability by analyzing study words' characteristics because critical words were constant across the high/low BAS conditions. Specifically, we recorded study words' set size, frequency, concreteness, mean connectivity among its associates, probability of a resonant connection, and resonant strength (Nelson et al., 1998), and evaluated whether there was a correlation between FR by list and the characteristics of the studied words included in those lists. As expected from the results presented above, there was a significant correlation between FR and BAS, $r(46)$ = .41, p = .004, but, furthermore, and more importantly, there was a significant correlation between FR and the probability of a resonant connection involving the studied words and its associates (PR), $r(46)$ = .30, p = .037. PR is an estimate of the probability that each associate produced by a studied word also produces the studied word as an associate (e.g., Nelson, McEvoy, & Pointer, 2003). None of the other list variables were correlated with FR, all ps > .05. Further, there was not a reliable correlation between PR and BAS, $r(46)$ = .24, p = .106, showing that PR and BAS contribute independently to FR variability.

Discussion

The aim of this research was to analyze, for the first time, the effect of BAS on false recognition (FR) in DRM lists with multiple critical words and with FAS values almost zero. The methodology used in the design of the lists was similar to that used in previous normative studies in Spanish that have examined the bases of false memory by using multiple critical words, both lists based on BAS (Beato & Díez, 2011; Cadavid & Beato, 2017) and FAS (Beato & Arndt, 2014). This methodology has never before been used to create DRM lists in English. For this purpose, we carried out an experiment to determine the amount of FR produced by DRM lists in English with two critical words, as well as if FR varied with BAS.

The results showed that there was wide variability in FR, with mean critical word false alarms ranging from 3% to 53% across lists. High variability was also found in other prior normative DRM studies (e.g., Anastasi et al., 2005; Roediger et al., 2001; Stadler et al., 1999), all of them using a single critical word per list. Previous Spanish normative studies that included multiple critical words per list found similar variability in FR (e.g., 4%-65%, in Beato & Díez, 2011; 10%-62%, in Cadavid & Beato, 2017).

Previous research has found that BAS could explain the wide FR variability across DRM lists with a single critical word (e.g., Arndt, 2006; Arndt & Gould, 2006; Gallo & Roediger, 2002; Knott et al., 2012; Roediger et al., 2001). Continuing with this line of research, and for the first time in the literature, we documented that BAS is associated with FR in DRM lists related to multiple critical words and extended those results to stimuli where BAS was manipulated while FAS values were close to zero. Finally, it is important to note that our results not only support the conclusion that BAS plays an important role in false memory, but also showed that even low BAS levels were sufficient to produce FR.

At a theoretical level, our data support a central prediction of activation-monitoring theory, fuzzy-trace theory and global-matching models (for a discussion, see Arndt, 2012a), all of which predict that increasing BAS will increase FR.

In addition to BAS, we found that the probability of a resonant connection (PR) between the studied words and their associates also helps explain variability in FR. Thus, the positive correlation between FR and PR, together with the absence of a correlation between PR and BAS, seems to indicate that the number of bi-directional associates (i.e., resonant connections), but not their associative strength, should be taken into account when studying FR variability across DRM lists. This could be a promising direction for future research.

Returning to major theories of false memories, all three appear to be able to explain why increasing PR increases FR. According to activation-monitoring theory, when activation spreads from studied words to their associates, and then back to the studied words via resonant connections, it should increase studied words' activation. Further, the more such resonant connections a word has, the greater the studied words' activation. In turn, the greater the studied words' activation, the greater the activation that spreads to critical words, increasing FR. Alternatively, fuzzy-trace theory would interpret greater numbers of resonant connections as signifying greater similarity among a lures' associates, such that gist traces are strengthened by lists with more resonant connections. Then, at test, critical words will tend to match those strong gist traces more, increasing FR. Global-matching models would make a similar prediction, and for similar reasons as fuzzy-trace theory: The greater the similarity among the traces of the studied words, the more a critical word will match them, increasing FR.

In summary, the data from this experiment suggest that both backward associative strength and the probability of a resonant connection between studied words and their associates play an

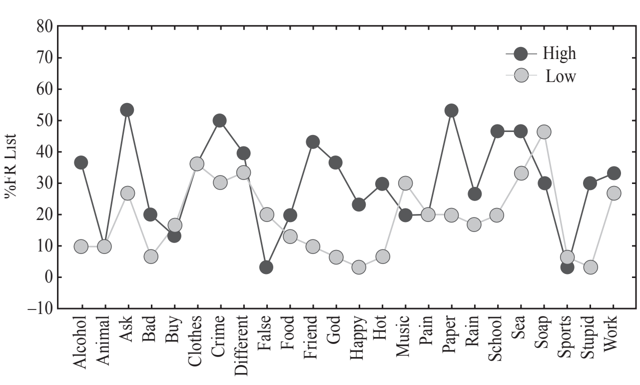

Figure 2. Percentage of false recognition per theme as a function of high and low backward associative strength

important role in false memory production in the DRM paradigm. This effect occurs even when multiple critical word lists are used, thus confirming predictions made by major theories of false memory. Finally, our study led to the construction of 48 new DRM lists with multiple critical words that will be useful for future research in this area.

References

Anastasi, J. S., De Leon, A., & Rhodes, M. G. (2005). Normative data for semantically associated Spanish word lists that create false memories. *Behavior Research Methods, 37*(4), 631-637. http://dx.doi.org/10.3758/BF03192733

Arndt, J. (2006). Distinctive information and false recognition: The role of encoding and retrieval processes. *Journal of Memory and Language, 54*(1), 113-130. http://dx.doi.org/10.1016/j.jml.2005.08.003

Arndt, J. (2012a). The influence of forward and backward associative strength on false recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*(3), 747-756. http://dx.doi.org/10.1037/a0026375

Arndt, J. (2012b). False recollection: Empirical findings and their theoretical implications. In B. H. Ross (Ed.), *Psychology of Learning and Motivation* (vol. 56, pp. 81-124). San Diego, US: Elsevier Academic Press.

Arndt, J. (2015). The influence of forward and backward associative strength on false memories for encoding context. *Memory, 23*(7), 1093-1111. http://dx.doi. org/10.1080/09658211.2014.959527

Arndt, J., & Gould, C. (2006). An examination of two process theories of false recognition. *Memory, 14*(7), 814-833. http://dx.doi.org/10.1080/09658210600 680749

Arndt, J., & Hirshman, E. (1998). True and false recognition in MINERVA2: Explanations from a global-matching perspective. *Journal of Memory and Language, 39*(3), 371-391. http://dx.doi.org/10.1006/jmla.1998.2581

Beato, M. S., & Arndt, J. (2014). False recognition production indexes in forward associative strength (FAS) lists with three critical words. *Psicothema, 26*(4), 457-463. http://dx.doi.org/10.7334/psicothema2014.79

Beato, M. S., Cadavid, S., Pulido, R. F., & Pinho, M. S. (2013). No effect of stress on false recognition. *Psicothema, 25*(1), 25-30. http://dx.doi.org/10.7334/psicothema2012.158

Beato, M. S., & Díez, E. (2011). False recognition production indexes in Spanish for 60 DRM lists with three critical words. *Behavior Research Methods, 43*(2), 499-507. http://dx.doi.org/10.3758/s13428-010-0045-9

Brainerd, C. J., & Reyna, V. F. (1990). Gist is the grist: Fuzzy-trace theory and the new intuitionism. *Developmental Review, 10*(1), 3-47. http://dx.doi.org/10.1016/0273-2297(90)90003-M

Brainerd, C. J., & Wright, R. (2005). Forward association, backward association, and the false-memory illusion. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*(3), 554-567. http://dx.doi.org/10.1037/0278-7393.31.3.554

Brainerd, C. J., Yang, Y., Reyna, V. F., Howe, M. L., & Mills, B. A. (2008). Semantic processing in "associative" false memory. *Psychonomic Bulletin & Review, 15*(6), 1035-1053. http://dx.doi.org/10.3758/PBR.15.6.1035

Cadavid, S., & Beato, M. S. (2016). Memory distortion and its avoidance: An event-related potentials study on false recognition and correct rejection. *PLoS ONE, 11*(10): e0164024. http://dx.doi.org/10.1371/journal.pone.0164024

Cadavid, S., & Beato, M. S. (2017). False recognition in DRM lists with low association: A normative study. *Psicológica, 38,* 133-147.

Cann, D. R., McRae, K., & Katz, A. N. (2011). False recall in the Deese–Roediger-McDermott paradigm: The roles of gist and associative strength. *The Quarterly Journal of Experimental Psychology, 64*(8), 1515-1542. http://dx.doi.org/10.1080/17470218.2011.560272

Carneiro, P., Albuquerque, P., Fernandez, A., & Esteves, F. (2007). Analyzing false memories in children with associative lists specific for their age. *Child Development, 78*(4), 1171-1185. http://dx.doi.org/10.1111/j.1467-8624.2007. 01059.x

Coane, J. H., Huff, M. J., & Hutchison, K. A. (2016). The ironic effect of guessing: Increased false memory for mediated lists in younger and older adults. *Aging, Neuropsychology, and Cognition, 23*(3), 282-303. http://dx.doi.org/10.1080/13825585.2015.1088506

Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of Experimental Psychology, 58*(1), 17-22. http://dx.doi. org/10.1037/h0046671

Gallo, D. A. (2006). *Associative illusions of memory: False memory research in DRM and related tasks*. New York: Psychology Press.

Gallo, D. A. (2010). False memories and fantastic beliefs: 15 years of the DRM illusion. *Memory & Cognition, 38*(7), 833-848. http://dx.doi.org/10.3758/MC.38.7.833

Gallo, D. A., & Roediger, H. L. (2002). Variability among word lists in eliciting memory illusions: Evidence for associative activation and monitoring. *Journal of Memory and Language, 47*(3), 469-497. http://dx.doi.org/10.1016/S0749-596X(02)00013-X

Howe, M. L., Wimmer, M. C., & Blease, K. (2009). The role of associative strength in children's false memory illusions. *Memory, 17*(1), 8-16. http://dx.doi.org/10.1080/09658210802438474

Knott, L. M., Dewhurst, S. A., & Howe, M. L. (2012). What factors underlie associative and categorical memory illusions? The roles of backward associative strength and inter-item connectivity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*(1), 229-239. http://dx.doi.org/10.1037/a0025201

Koriat, A., Goldsmith, M., & Pansky, A. (2000). Toward a psychology of memory accuracy. *Annual Review of Psychology, 51*, 481-537.

McDermott, K. B., & Watson, J. M. (2001). The rise and fall of false recall: The impact of presentation duration. *Journal of Memory and Language, 45*(1), 160-176. http://dx.doi.org/10.1006/jmla.2000.2771

McEvoy, C. L., Nelson, D. L., & Komatsu, T. (1999). What is the connection between true and false memories? The differential roles of interitem associations in recall and recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*(5), 1177-1194. http://dx.doi.org/10.1037/0278-7393.25.5.1177

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1998). *The University of South Florida word association rhyme and fragment norms* [On line]. http://w3.usf.edu/FreeAssociation/

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (2004). The University of South Florida free association, rhyme, and word fragment norms. *Behavior Research Methods, Instruments, & Computers, 36*(3), 402-407. http://dx.doi.org/10.3758/BF03195588

Nelson, D. L., McEvoy, C. L., & Pointer, L. (2003). Spreading activation or spooky action at a distance? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*(1), 42-52. http://dx.doi.org/10.1037/0278-7393.29.1.42

Reyna, V. F., & Brainerd, C. J. (1995). Fuzzy-trace theory: An interim synthesis. *Learning & Individual Differences, 7*(1), 1-75. http://dx.doi.org/10.1016/1041-6080(95)90031-4

Robinson, K. J., & Roediger, H. L. (1997). Associative processes in false recall and false recognition. *Psychological Science, 8*(3), 231-237. http://dx.doi.org/10.1111/j.1467-9280.1997.tb00417.x

Roediger, H. L., & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*(4), 803-814. http://dx.doi.org/10.1037/0278-7393.21.4.803

Roediger, H. L., Watson, J. M., McDermott, K. B., & Gallo, D. A. (2001). Factors that determine false recall: A multiple regression analysis. *Psychonomic Bulletin & Review, 8*(3), 385-407. http://dx.doi.org/10.3758/BF03196177

Stadler, M. A., Roediger, H. L., & McDermott, K. B. (1999). Norms for word lists that create false memories. *Memory & Cognition, 27*(3), 494-500. http://dx.doi.org/ 10.3758/BF03211543

Tempel, T., Frings, C., & Mecklenbräuker, S. (2015). Dual processes of false recognition in kindergarten children and elementary school pupils. *Journal of Experimental Child Psychology, 138,* 135-142. http://dx.doi.org/10.1016/j.jecp.2015.05.004