4-2016

The Effect of Emotional Words and Sounds in Multidimensional Source Memory

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by

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Undergraduate honors thesis under the direction of

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Submitted to the LSU Roger Hadfield Ogden Honors College in partial fulfillment of
the Upper Division Honors Program.

April, 2016

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Baton Rouge, Louisiana

Abstract

Enhanced memory in source memory studies involving emotion has been shown to exist under the condition that source (background) information is given the same priority as item (foreground) information. When source information is given high priority item-source binding seems to be more likely for emotional stimuli. The goal of the present study was to see whether this extends to context-context binding as operationalized by stochastic dependence within a multidimensional source memory framework. Two experiments were conducted, one involving emotional versus neutral word stimuli and one involving emotional versus neutral sounds, in order to test the hypothesis that emotional arousal at encoding will produce higher stochastic dependence (source-to-source binding) than will no emotional arousal. Results showed that emotional arousal in either experiment did not produce significantly higher stochastic dependence than did no emotional arousal. In addition, emotional arousal was sometimes detrimental to memory for individual sources. From this, it was concluded that emotion at encoding did not significantly affect source-to-source binding, even when participants were told to give equal priority to the item and sources prior to learning them. Further research is needed to investigate the roles of emotion, attention, and priority in multidimensional source memory.

Keywords: source memory, emotion, stochastic dependence

The Effect of Emotional Words and Sounds in Multidimensional Source Memory

The role of emotion on memory has long been established in the modern literature. For example, memory experiments involving emotional stimuli tend to yield stronger results than do experiments involving neutral stimuli, and it has been speculated that the reason for that involves the relationship between emotion and information priority (Mather & Sutherland, 2011). Furthermore, the triggering of emotional arousal in response to stimuli tends to serve as a signal to pay better attention to stimulus information (e.g., Cahill & McGaugh, 1998; Hamann, Ely, Grafton, & Kilts, 1999; Kensinger & Corkin, 2003). The results of such experiments show memory enhancement from emotion in tests where the participant's priority and attention are focused on a single emotional versus neutral item, like a picture or word, but the results are not so clear in studies that involve memory for the context in which the item was learned. Some of such studies involve a specific type of contextual memory called source memory, and the effects of emotion in those studies are somewhat ambiguous (Chiu, Dolcos, Gonsalves, & Cohen, 2013).

Source memory refers generally to memory for the manner in which information was presented (Johnson, Hashtroudi, & Lindsay, 1993). Information encoded about an item or event tends to covary with its source of presentation. In a real world context, source memory represents situations such as the location where a person encountered certain information, what time of day they encountered it, or who presented the information. Source decisions are often made in conjunction with memory retrieval to provide useful information, such as knowing whether a joke was told by one or another friend so that one can avoid repeating the joke to the original teller. By definition, source memory experiments address a more complex memory representation than do studies of item recognition or recall by requiring retrieval of more detailed information in order to make an effective decision, and the effect of emotion on source memory is also more complex. Likewise, studies on the influence of emotion on source memory have yielded contradicting results. For example, Jurica and Shimamura (1999) observed an "item-source memory tradeoff" effect, which showed that memory for the item (i.e., recognition memory) was enhanced by emotion while memory for item source was degraded. In this case, it can be said that source memory was impaired by emotion. However, a later study by Doerksen and Shimamura (2001) did not produce the same effect. In the latter study, both source memory and item memory were enhanced by emotion. More recent studies have also shown this controversy, with some demonstrating enhancing effects of emotion on source memory, some showing degrading effects, and some showing no effect, all while item memory is generally enhanced (for a review, see Chiu et. al., 2013).

Source memory experiments which show enhancement from emotional manipulation often involve temporal information or visual-perceptual features. Enhancing effects have been shown in studies involving the locations of pictures (Mather and Nesmith, 2008; Nashiro and Mather, 2011), locations of words (MacKay and Ahmetzanov, 2005), and locations of pictures within the temporal context of a list order (Schmidt, Patnaik, and Kensinger, 2011). There have also been many affirmative studies involving the color of items as a source, starting with the study done by Doerksen and Shimamura (2001) that manipulated colors of words and the color of a frame surrounding the word. A later study found the enhancing effect for both word color and word location (D'Argembeau and Van der Linden, 2004).

An explanation for these characteristics in successful source memory studies involving emotion can be drawn from "arousal-biased competition" (ABC) theory, which is based on the concept of competing mental representations during encoding or "memory trade-off" effects (Kensinger, Garoff-Eaton, & Schacter, 2007). The theory claims that arousal modulates the strength of competing mental representations, which improves memory for the items that win the contest for selective attention at the expense of the items that lose (Mather & Sutherland, 2011). For example, in a recent study by Ponzio and Mather (2014), emotional arousal at consolidation was shown to improve memory for information the subjects gave priority to, while memory for background information, which was not given priority, was degraded. This emotional trade-off effect can explain why some studies, like those involving complex contextual or relational information, may not show an improvement or may even show a decrement to source memory from emotional arousal (Chiu et al., 2013). Past studies of memory for scenes that accompany emotional items (Kensinger et al., 2007), memory for pairing between objects on scenes (Rimmele, Davachi, Petrov, Dougal, & Phelps, 2011) and memory for item pairs (Mather & Knight, 2008) have consistently shown a memory decrement to non-prioritized background information. This seems to demonstrate that the items in these studies are automatically prioritized over background information, which leads to their memory enhancement over contextual or source information.

In contrast, the studies that have shown source memory enhancement may benefit from a mutual high priority, where both the items and their sources are perceptually proximal enough to be considered on the same level of priority. This concept is supported by Mather's (2007) "object-based framework", which holds that emotional arousal enhances binding between the item and contextual information about the item, like its color or location. In this case, the information serving as a source is no longer treated as background or context but as source information that is intrinsic to the item being prioritized. Because the item and its sources are all considered equally relevant during encoding, memory for both the item and the sources are enhanced by emotional arousal.

The present study aims to incorporate past research on emotion and source memory to investigate the effects of emotional arousal within a multidimensional source memory framework. Within this framework, participants typically study items that vary on two source dimensions rather than just one, which allows for the analysis of stochastic dependence in retrieval between two source dimensions. For example, a participant might be asked to learn items that appear in either of two different locations and either of two different font sizes (e.g. Boywitt, Kuhlmann, & Meiser, 2012; Starns & Hicks, 2008). Across the list of encoded items, an equal number are learned in each combination of location-size conditions. Moreover, people in such studies are asked to retrieve both source dimensions. Source memory is considered stochastically dependent if the retrieval of one source feature is made more likely by the retrieval of the other source feature. In the example above, if the participant is better able to remember font size after correctly remembering the location for the same item as opposed to incorrectly remembering the location, then the source retrieval is considered stochastically dependent, which is generally taken as an indication for what has been called "context-context" binding (Boywitt & Meiser, 2013).

Previous research suggests that context-context binding occurs in the presence of two conditions. The first has to do with the retrieval process and Tulving's (1985) remember/know paradigm used to subjectively separate retrieval based on episodic recollection versus familiarity. Recent studies show that evidence of context-context binding or stochastic dependence is more likely to be observed under a subjective retrieval experience of recollection, meaning that the participant consciously remembers the item's presentation with some memorial detail (Boywitt & Meiser, 2012a, 2012b; Meiser, Sattler, & Weisser, 2008; Meiser & Broder, 2002; Starns & Hicks, 2005). A joint retrieval of source information has been strongly associated with "remember" responses on memory tests rather than "know" (i.e., familiarity) responses, which is why that paradigm was incorporated into the memory test for the current study.

The second condition has to do with the encoding process. Similar to the "memory trade-off" effects that Mather's arousal-biased competition theory is based on, Uncapher, Otten, & Rugg (2006) have suggested that allocation of attention during encoding affects the likelihood of establishing binding in item-to-source and source-to-source memory representations. In other words, giving higher attention or priority to certain source information during encoding increases the likelihood of that information being bound to the item or to another source. In a situation where the participant is not told what to focus attention on, stochastic dependence is generally observed only if source information is intrinsic to the item being studied, like the color of an item, rather than extrinsic, like a border surrounding the item or a background scene (Ecker, Zimmer, & Groh-Bordin, 2007). When participants were given explicit instructions during encoding to pay attention to certain source memory features that accompany the item, stochastic dependence was observed for both intrinsic and extrinsic source information, which suggests that multidimensional binding is mediated by attention (Boywitt & Meiser, 2012b).

The primary goal of the present study was to test whether emotional/arousing stimuli or conditions produce stronger stochastic dependence, or context-context binding, as opposed to neutral stimuli or conditions. As reviewed earlier, when source or context information is given high priority, item-source binding seems to be more likely for emotional stimuli. The present goal was to see whether this extends to source-to-source binding as operationalized by stochastic dependence. Because of the aforementioned effect and the object-based framework utilized in successful emotion and source memory studies, the two sources chosen for the current experiments were visual-perceptual in nature and intrinsic to the item (word) that was presented in the learning phase. Location of the word on a screen and size of the word were manipulated as source information in Experiment 1 and Experiment 2, and explicit instructions were given in both experiments to prioritize the item and both of its sources during the learning phase. Drawing from that, it was hypothesized that in both Experiment 1 and Experiment 2, emotional arousal would not only have an enhancing effect on item and source memory, but it would also increase the likelihood of context-context binding and the observation of stochastic dependence in retrieval of both sources.

Experiment 1 and Experiment 2 differed only in the manipulation of emotional arousal applied. In Experiment 1, participants were exposed to an emotionally arousing versus neutral sound before each of several neutral words. Emotional, rather than neutral, sounds were expected to be more arousing and would therefore enhance attention during subsequent encoding of a word. Experiment 2 utilized a more traditional method of inducing arousal from past experiments on memory by incorporating emotionally valenced words as compared to neutral words. The two experiments served to compare the two methods used in the event that one method of arousal was more effective than the other. With reference to past contextual memory studies, it was possible that emotional words would be more arousing to participants than emotional sounds, and because of that, it was also hypothesized that the strength of stochastic dependence in the second experiment would be higher than that of the first (Ponzio & Mather, 2014; Schmidt et. al., 2011; Doerkson & Shimamura, 2001, Experiment 1).

Methods

Experiment 1

In Experiment 1, we manipulated arousal by playing either a negatively valenced, highly arousing sound or a neutral sound before displaying the target item.

Participants. We tested 39 undergraduate students from Louisiana State University. The experiment lasted no longer than 45 minutes, and students received extra credit in a psychology course of their choice in exchange for participation.

Materials. From a set of 128 neutral English words, 64 were assigned as target items and the other 64 were used as new items in the testing phase. The words were taken from the Affective Norms for English Words (ANEW) pool (Bradley & Lang, 1999). Whether words served as targets or lures was counterbalanced across participants. During the learning phase, 64 words appeared on either the right or left side of the screen in either 10-point font or 48-point font. Those words were divided into sets of eight and assigned to one of the eight conditions created by the factorial combination of font size, location, and sound. The order in which the different encoding conditions were associated with the sets was then counterbalanced across participants.

All sounds, neutral and negative, were chosen from the International Affective Digital Sounds database (IADS; Bradley and Lang 2007). Sixteen negative sounds and sixteen neutral sounds were repeated throughout the experiment, and participants were exposed to the same sound no more than twice to preserve the arousing effect of the negative sounds. Examples of the negative sounds used are people screaming and animals growling, while neutral sounds included people yawning and water running.

A post-questionnaire given after the experiment's completion asked simple questions regarding participants' understanding of the remember/know paradigm used to distinguish between words they recalled in detail and words they recognized or were familiar with from the learning phase of the experiment. An example of a request that was on the post questionnaire is, "What specific details or thought processes did you associate with the word that made you think you ‘remembered’ it rather than ‘knew’ it?” The post questionnaire used in this experiment can be found in Appendix B.

Design and Procedure. The design was a 2 (source: font size and location) × 2 (sound: neutral or negative) × 2 (remember or know) within-subjects factorial. All experimental materials were displayed on a computer screen with the exception of the consent form and post-questionnaire. At the beginning of the experimental trial, participants were informed that they would be presented with a series of words that would appear in two different locations on the screen and in two different sizes. They were told to memorize each word, its location, and its size for a later memory test. Participants were also warned prior to the start of the experiment that sounds would be played before each word was displayed and that they would not be required to remember the sound for the memory test. During the learning phase, an asterisk was displayed on the screen for one second to mark the start of each new condition. The sound was then played for four seconds, and each word appeared on the screen immediately after for three seconds. After the complete study list was presented, participants were asked to solve a series of simple math problems as a distractor test lasting about five minutes.

During the testing phase, participants were exposed to the 64 words they saw during the learning phase in addition to 64 new words. All 128 words appeared in the center of the screen in 24-point font and were presented in random order. Before the test began, subjects were informed about the series of memory questions that would be asked about each word. No sounds were played during the testing phase, and participants gave their responses by selecting the key on the keyboard that corresponded with their answer shown on the screen beneath each word. In order to make this task easier for participants, each key that corresponded with an answer shown on the screen was labeled with the corresponding answer. For example, the key (b) that corresponded with a word they thought was "new" was labeled as "new" on the keyboard.

Participants were first asked to give a recognition response for each word by selecting if it was "old" or "new". It was explicitly stated in the instructions before the test began and throughout the test that the choice "old" meant that they had seen the word before in the experimental context, while the choice "new" meant that it was a new word that they had not encountered during the learning phase. If the response "new" was selected, no follow up questions were asked. If the response "old" was selected, the participants were then asked to make a judgment about if they "remember" the word, meaning they specifically recalled seeing it in the learning phase, or if they "know" the word, meaning they recognized it but did not recall any details of the word's presentation during the learning phase. The definitions for "remember" and "know" were described in the testing phase instructions, and participants were required to consult the experimenter with any questions about the paradigm before continuing on to the memory test.

After the remember/know test for each word identified as "old", participants were asked to make a judgment regarding the word's sources. Two source memory questions were asked for this part of the test, one regarding location and one size. The first source memory question asked if the participant saw the word on the left or right side of the screen, and the second asked if the word had been in a small or large font size. An asterisk was shown on the screen for one second between each word condition to signify to the participant that they were moving on to a new word.

At the conclusion of the experiment, participants were debriefed, and then they were asked to complete the post-questionnaire.

Experiment 2

In Experiment 2, emotional arousal was manipulated through the stimuli themselves instead of sounds. The words used were either negatively valenced or neutrally valenced, in order to test the effects of a more traditional route to producing emotional arousal.

Participants. Thirty-eight students from Louisiana State University who did not participate in the first experiment were tested in Experiment 2. This experiment lasted no longer than 45 minutes, and participants received extra credit points in a psychology course of their choice as compensation.

Materials. Another 128 words were pulled from the ANEW pool (Bradley & Lang, 1999). Half were negatively valenced, highly arousing words, while the other half were neutral words. In the learning phase, 32 negative and 32 positive words were distributed across the same two source conditions of location (left or right) and font size (large or small). The words were divided into groups of eight and assigned to one of four conditions based on the factorial combination of the two sources. The conditions were then counterbalanced in sets of eight across participants. Additionally, whether words served as targets in the learning phase or lures in the testing phase was counterbalanced across participants. An asterisk preceded each word, and the words were displayed on the screen for three seconds. During the testing phase, the 64 learned words were displayed with 64 new words in the center of the screen, in the same medium font size and in random order.

The post-questionnaire from Experiment 1 was also used in Experiment 2 (Appendix B).

Design and Procedure. The design was a 2 (source: font size and location) × 2 (word: negative or neutral) × 2 (remember or know) within-subjects factorial. Like Experiment 1, all materials were displayed on a computer screen except the consent form and post-questionnaire.

Participants were given similar instructions to Experiment 1 before the learning phase began. They were told to memorize each word, its location, and its size for a later memory test. After the study list was presented, the participants were asked to solve a series of math problems as a distractor test for approximately five minutes.

During the testing phase, participants were exposed to all 128 words. They were given explicit instructions regarding the questions and answers on the memory test, including definitions of the answer choices of “new”, “old”, “remember”, and “know”. The memory test was exactly the same procedure as in Experiment 1.

At the conclusion of the experiment, participants were debriefed and asked to complete the post-questionnaire.

Results

An alpha level of 0.05 was used as the criterion for significance in all analyses. The two experiments were analyzed in the same way by first testing the behavioral data using traditional statistical methods and then by using multinomial modeling.

Behavioral Data Analysis

Recognition Memory. Analysis of hit and false alarms rates was conducted to investigate overall recognition memory. “Hits” were measured as all of the times a participant correctly identified stimuli they had studied before in the learning phase. In other words, a participant’s recognition of the word was considered a hit if the word was old, and he or she called it old. “False alarms” were measured as all of the times a participant mistakenly identified new stimuli as an item they had studied in the learning phase. In other words, false alarms occurred when a participant called a new word old. These rates were tested first to assess individual participant performance. Participants were removed from analyses if their false alarm rates were more than three standard deviations from the mean or if their recognition discriminability was near chance levels. As a result, two participants were excluded from both analyses, resulting in a total of 37 participants for Experiment 1 and 36 participants for Experiment 2.

Mean proportion hits and false alarm rates for the negative and neutral conditions in Experiment 1 and Experiment 2 are shown in Table 1. Analysis of how these differed between the negative and neutral conditions in each experiment revealed that in Experiment 1, hits and false alarms did not differ depending on neutral or negative sounds. In Experiment 2, hits for negative words ($M = .79$) were significantly higher than for the neutral words ($M = .67$), $t(35) = 5.39$, $p < .01$. However, false alarms were also significantly higher for negative ($M = .29$) rather than neutral ($M = .20$) words, $t(35) = 3.33$, $p < .01$.

Independent Source Memory. For both experiments, independent source memory performance was tested as the proportion of recognized words correctly attributed to a source, regardless of which one it was. In other words, we calculated average conditional source identification measure scores (ACSIM; Murnane & Bayden, 1996). These scores were used to evaluate whether source recognition differed between emotion and neutral conditions and if memory for sources was above chance level (.50). In both experiments, all ACSIM scores were above chance for both "remember" and "know" responses. Therefore, to investigate the influence of emotional arousal on individual source memory accuracy, an analysis of variance (ANOVA) was performed separately for "remember" and "know" responses with repeated measure factors of source (location and size) and emotion condition (neutral and negative). Values of independent source memory for both experiments are shown in Table 2.

Experiment 1. Experiment 1, the sound manipulation, revealed no significant main effects or interactions for "remember" responses. However, there was a main effect of emotional valence for "know" responses, such that negative sounds (M = .64) rather than neutral sounds (M = .59) produced stronger overall source memory scores, $F(1, 35) = 4.95$, $p = .03$, partial eta-squared = .12. This result differed from memory scores for "remember" responses, wherein overall source memory scores were slightly improved for stimuli presented with neutral sounds rather than negative sounds. However, the effect of emotional valence on memory for those responses was not significant.

Experiment 2. Data from Experiment 2 revealed a significant emotion vs. source condition interaction for "remember" responses, $F(1, 35) = 5.57$, $p = .02$, partial eta-squared = .14. There was also a main effect of emotional valence, $F(1, 35) = 6.30$, $p = .02$, partial eta-squared = .15. These results showed a significant detriment to overall source memory scores for negative words (M = .71) rather than neutral words (M = .76), but memory scores for the location of negative words appeared to suffer most. To investigate the interaction, post-hoc comparisons were performed using a Bonferroni adjustment to the overall alpha level. The t-tests revealed that the mean score for the location of negative words (M = .67) differed significantly from the mean score for the location of neutral words (M = .76), $t(35) = 3.70$, $p < .01$. However, the difference between negative and neutral scores for the size of the words was not significant, $t(35) = .45$, $p = .66$. For "know" responses, no significant main effects or interaction were found.

Stochastic Dependence. To investigate context-context binding in each experiment, two within subjects ANOVAs with factors of emotion condition (neutral and negative) and conditional source accuracy scores (correct and incorrect) were performed separately for "remember" and "know" responses. In contrast to the overall source memory results presented earlier, in this case conditional source accuracy scores were a calculation of memory scores for the second source condition following correct or incorrect responses for the first condition. The difference in whether or not the subject correctly recalled the second source dimension after correctly recalling (versus incorrectly recalling) the first represented stochastic dependence.

Because participants demonstrate this type of memory less often in each possible cell of the design, missing data from participants resulted in lower degrees of freedom for each of the four ANOVAs. For example, in order to produce a recorded score available to assess stochastic dependence, a participant would have had to first identify an item as “old”, then make a remember/know decision, then complete the first source memory question (and get at least one wrong and one right), and then finally complete the second source memory question (following at least one right first source decision). If the participant marked the item as “new”, no source memory questions were asked, and therefore, no source memory data was recorded for that item. It follows that some participants did not provide source memory data at all for certain learned words, so some never demonstrated selecting one source correctly after correctly selecting the other source. As a result, for Experiment 1 “remember” responses, the data of 23 participants were included in the analysis, and for “know” responses, the data of 30 participants were included. For Experiment 2, the data of 28 participants were included in the analysis for both “remember” and “know” responses. Joint retrieval scores in the “remember” and “know” conditions for Experiment 1 are shown in Figure 1, and for Experiment 2 in Figure 2.

Experiment 1. After running the 2 x 2 ANOVAs, Experiment 1 showed a significant main effect of conditional source accuracy scores for both “remember” and “know” responses. However, there were no main effects or interactions beyond that. In other words, for “remember” responses, a significant main effect representing stochastic dependence was found, $F(1, 22) =$

6.70, $p = .02$, partial eta-squared = .23. This was also true for "know" responses, $F(1, 29) = 7.73$, $p = .01$, partial eta-squared = .21. These results indicate that memory for location was better when the size decision was correct versus incorrect, for "remember" and "know" responses. However, the lack of an interaction indicates the presence of negative or neutral sounds did not significantly affect the amount of stochastic dependence one way or the other.

Experiment 2. Experiment 2 showed a significant main effect of conditional source accuracy scores where memory for the second source was higher when the first source was remembered accurately ($M = .72$) rather than inaccurately ($M = .56$) for "remember" responses, $F(1, 27)= 7.93$, $p = .01$, partial eta-squared = .23. Again, this demonstrates stochastic dependence. There was also a main effect of emotional valence for "remember" responses such that neutral words produced higher conditional source memory scores ($M = .69$) than negative words did ($M = .59$), whether the first source was recalled accurately or not, $F(1, 27) = 7.00$, $p = .01$, partial eta-squared = .21. No significant interaction was found, which indicates stochastic dependence was not more likely to be found for negative words, as originally predicted. For "know" responses, there were no main effects, and there was no interaction.

Multinomial Modeling

Data was also analyzed using the re-parameterized version of Meiser and Broder's (2002) multinomial processing tree (MPT) for two crossed source dimensions (new parameters; Meiser, 2009). The model estimates parameters for independent and stochastically dependent source retrieval simultaneously and separately for "remember" versus "know" responses. In general, the parameters of the model give probabilities of cognitive states produced by studied and new words during the memory test. Parameter estimates represent a pure measure of underlying cognitive processes that, when assessed by behavioral measures alone, might be affected by indefinite memory decisions such as guessing (Batchelder & Riefer, 1999).

For the following explanation of the parameters of the model of most interest to the present experiments, refer to Figure 3 for a processing tree diagram. At the left of the diagram is the stimulus, which is either a target item (old word) or a distractor item (new word) as presented to the participants, and these stimuli are connected via the cognitive processes described by each parameter to the participant's memory decision at the right side of the diagram. Because participants were given the studied word with the source dimensions *i,j* (i.e., font size, location), each parameter is described in terms of *i,j*. The probability that the participant will recognize an item as "old" is represented with parameter D_{ij}, and the complementary parameter $1\text{-}D_{ij}$ represents the probability that the item is not detected but could be called "old" or "new" based on guessing processes. In terms of the distractor item, parameter D_N represents the probability that a participant identifies a "new" item correctly, and parameter *b* represents the probability that a participant will identify a "new" item as "old" based on guessing. Parameter R_{ij} is the probability that an already recognized item is judged as "remembered", and $1\text{-}R_{ij}$ is the probability that it is judged as "known". The resulting parameters then are described in terms of both *i,j* and *R*, *K*, "remember" or "know". *R** represents the probability that a new item is first classified as "old" and then further classified as "remembered".

Regarding source dimensions, if an item is considered "old" and "remembered", source dimensions that are retrieved jointly are described with probability d^{R}_{ij}. If dimensions are not retrieved jointly ($1\text{-}d^{R}_{ij}$), then sources can still be retrieved separately with probabilities $e^{\text{Dim1 R}}$ and $e^{\text{Dim2 R}}$. Similarly, if the item is considered "old" and "known", source dimensions that are retrieved jointly are described with probability d^{K}_{ij}. If dimensions are not retrieved jointly under the "know" condition, then sources can still be retrieved separately with probabilities $e^{\text{Dim1 K}}$ and $e^{\text{Dim2 K}}$. The source of the item may also be guessed even after being classified correctly as "old" (*a* parameters), and the source may also be guessed after a new item is incorrectly classified as "old" (*g* parameters). The purpose of the model is to fit the empirical data by allowing parameter estimates to adjust and predict the observed probabilities with the best fit possible.

The overall fit of the model was assessed with the asymptotically chi-squared distributed likelihood-ratio statistic G^2 (Batchelder & Riefer, 1999). For the present experiments, a program called MultiTree was used to import equations needed to represent the model. The same model was used to analyze data separately for neutral stimuli or stimuli accompanying a neutral sound and data for negative stimuli or stimuli accompanying a negative sound. This resulted in four model analyses: two (negative and neutral) for Experiment 1 and two (negative and neutral) for Experiment 2. Summed frequencies for each decision-making scenario were collected and imported to the MultiTree file and fit to the model. These summed frequencies were the total amount of times all of the participants in either experiment made a certain decision represented by the model. For example, in Experiment 1 in the neutral condition, all 37 participants correctly called words old, remembered, on the left, and big a total of 55 times. These response frequencies were then fit to the model, and the analysis was run. For the following results, see Table 3 for the parameter values in each condition of Experiment 1 and Experiment 2.

Experiment 1. Thirty-seven participants were included in the analyses for negative and neutral sounds. The model did not provide a good fit to the data for words presented with neutral sounds, $G^2(21) = 35.36$, $p = .03$, but it did provide a good fit for words presented with negative sounds, $G^2(21) = 28.13$, $p = .14$. Unfortunately, because of the lack of fit, it was not plausible to make comparisons between the neutral and negative conditions using the models, but the results, particularly for the negative condition, were nevertheless compared to the analyses of the behavioral data to help draw tentative conclusions.

The most relevant parameter to the current study was the joint retrieval parameter for "remember" (d_r) and "know" (d_k) responses. In both the neutral and negative models, joint retrieval was higher for remembered words than for familiar ones. In contrast to the behavioral data, the negative sounds model showed no significance for joint retrieval for either response. The neutral sounds model showed joint retrieval for remembered responses to be significant; however, because of the low fit of this model, joint retrieval could not be compared between the two emotion conditions.

Additionally, memory for the individual sources of location and size were not comparable across the models. Because of this, the behavioral analyses seemed to give a better explanation, and they were used to draw conclusions.

Experiment 2. Thirty-six participants were included in the analyses for neutral and negative words. Again, the model did not provide a good fit to the data for neutral words, $G^2(21) = 39.20$, $p = .01$, but it did provide a good fit for negative words, $G^2(21) = 23.84$, $p = .30$. Same as the first experiment, comparisons could not be made between the neutral and negative data, but interpretations of the models were tentatively used to compare with the behavioral data analyses.

Joint retrieval was shown to be higher for remembered negative words rather than familiar negative words, and for the remembered words, the model also showed a significant effect. Conversely, for neutral words, joint retrieval was both higher and significant for familiar words rather than remembered ones. No comparisons could be made about the difference in effects between the negative and neutral models.

As in Experiment 1, the behavior analyses seemed to give a better representation of what conclusions could be drawn from the data, especially with reference to the individual source memory scores.

Discussion and Conclusions

The present study investigated the effect of emotional arousal in a multidimensional source memory paradigm. Because it was the first of its kind, the hypotheses were based on theories concerning emotion in basic source memory studies, which have produced varying results (Chiu et. al., 2013). We hypothesized that in both experiments, as long as participants were told to give equal attention to the word and both sources, emotional arousal would not only have an enhancing effect on item and source memory, but it would also increase the likelihood of context-context binding and the observation of stochastic dependence in retrieval of both sources. In addition, we hypothesized that the second experiment, which utilized words rather than sounds to manipulate emotional arousal, would produce a stronger effect of stochastic dependence overall.

Because the multinomial model did not provide fit for the neutral conditions in both experiments, discussion and conclusions made were based mostly on the behavioral data analyses, with reference to how emotion influenced item memory, individual source memory, and joint retrieval, or stochastic dependence.

Item Memory

Analysis of memory for the individual words in the current experiments revealed interesting results. Particularly, the differences in hit rates and false alarms between the two experiments reinforce suggestions made by Dougal and Rotello in 2007 that enhanced item memory in experiments involving emotional arousal may be due to a categorical response bias rather than an improvement in recollection memory. In the study, the authors tested participants' memory for negative, neutral, and positive words, and they asked participants to report their subjective feelings of memory by reporting "remember" and "know" judgments as well. Their results showed that participants responded more liberally in their remember/know judgments to negative words, rather than neutral or positive ones, but actual memory accuracy for those words was not improved. This showed participants were more likely to report they remembered or were familiar with most negative words, not because they had actually seen the words before but because they fit into the category of being negative.

The current experiments revealed what seems to be a similar occurrence: the experiment involving emotional sounds did not produce the same effect on memory for the individual words as the experiment in which the words themselves were neutral or negative. This means in the words experiment (Experiment 2), improved memory for negative items could be due to a response bias. In the testing phase participants were asked to identify both negative and positive words, some new and some old, and this differed from the sounds experiment (Experiment 1) in which participants were asked to identify only neutral words, some new and some old. When looking at the data from Experiment 2, it is clear from the proportions of hits and false alarms that participants were significantly more likely to remember words correctly if they were negative, but they were also significantly more likely to report they remembered negative words when the words had not been presented in the learning phase. However, in Experiment 1, neither difference was found.

The lack of improvement for words paired with negative sounds in Experiment 1 could be the result of the sounds being ineffective for producing emotional arousal. However, the inflated hits and false alarm rates for negative words in Experiment 2 seem to point towards a categorical response bias rather than a difference in the effectiveness of the sounds or words to produce better memory. The bias, as observed in Experiment 2, could also further explain why in some source memory studies, the inclusion of emotional stimuli seems to improve memory for the individual items but does not have the same effect on source information, which cannot be placed into the same categories (i.e. Jurica and Shimamura, 1999).

Source Memory

Contrary to our hypothesis, the effects of the emotional manipulations employed in both of the present experiments revealed no improvement in individual source memory as a result of negative emotional arousal. In fact, in Experiment 2, negative emotion was shown to be a detriment to memory for the location of words, a direct contrast to what has been found in at least one other study in the past involving emotion where memory for the location of words was enhanced (MacKay and Ahmetzanov, 2005). In Experiment 1, an enhancement effect was found in memory for the size and location of words paired with negative sounds; however, overall, the results seem to show very little to no improvement in independent source memory as a result of the emotion manipulation.

The lack of enhancement, along with varied results, leads to further discussion concerning the nature of attention and priority for emotion in source memory studies. On the one hand, the variation in how emotion affected source memory in the present study directly reflects current ambiguity in the source memory literature (Chiu et al., 2013). However, the lack of improvement in memory for individual sources, after explicit instructions were given to pay equal attention to the words provided, their location, and their size, leads to two observations. The first is even after being told what to pay attention to, the data still showed Mather and Sutherland's (2011) memory trade-off effect, particularly in Experiment 2. This could mean the instructions in our experiment were not enough to remedy participants assigning priority to item information over source information. The second is, although we based our experimental design in Mather's "object-based" framework (2007), memory for source information was only improved for familiar items, but not remembered items, in the first experiment. Both of these observations suggest the two theories may not have been good explanations for how emotion affected participants' attention when encoding source information in the current experiment. However, further research is needed to address limitations with the current project and to further investigate the effect of the two theories in multidimensional source memory.

Stochastic Dependence

Similar to what was revealed about individual source memory, stochastic dependence in both experiments was found, and although there were slightly enhanced effects in the emotion conditions of each experiment, they did not differ significantly. However, when it came to stochastic dependence rather than emotional arousal, our emphasis on attention for both sources equally in the experimental instructions and the inclusion of two sources intrinsic to the item in our experimental design seems to have reinforced theories by Boywitt and Meiser (2012b) and Ecker, et. al. (2007) that stochastic dependence is mediated by attention. In addition, our results revealed a significant effect representing stochastic dependence in a state of familiarity ("know" response) as well as in a more concrete state of memory ("remember" response) in Experiment 1, but not in Experiment 2. Past research has shown stochastic dependence is strongly associated with a state of "remembering" rather than "knowing", so the current study has produced an nontraditional effect. However, caution should be used when evaluating this result, as in the current study, the participant pool was small and, judging from the post-questionnaires that evaluated understanding of the remember/know paradigm from Experiment 2, there were a few participants who did not fully grasp the difference between a "remember" and "know" response.

Limitations and Suggestions for Future Studies

As previously stated, the current study was limited by small sample sizes and confusion on the remember/know part of the memory test. A continuation of the study will address this by collecting more data to be analyzed and also by placing a simplified version of the remember/know instructions on the computer where participants can easily see them. Additionally, a further analysis of the data will exclude those participants who very clearly did not understand the instructions, in order to investigate the effect of these misunderstandings on the behavioral data analyses as well as its impact on the fit of data to the multinomial model.

Other than addressing the limitations of the current study, future research may be useful for investigating the differences in effects found in studies which employ emotional stimuli versus a differentiated mode of emotional arousal, like the sounds used in the current study. In particular, it would be interesting to investigate source memory, or to further investigate multidimensional source memory, with a special focus on the categorical response bias observed in the present study as well as in similar past studies. Additionally, further research is needed to address the theoretical foundations of the impact of emotion on context-context binding. As the current study was the first to employ emotion in a multidimensional source memory paradigm, future research could further investigate this relationship by utilizing different emotion manipulations as well as having participants study differing sources for the target information.

References

Batchelder, W. H., & Riefer, D. M. (1999). Theoretical and empirical review of multinomial process tree modeling. *Psychonomic Bulletin & Review, 6*, 57–86.

Boywitt, C. D., Kuhlmann, B. G., & Meiser, T. (2012). The role of source memory in older adults' recollective experience. *Psychology and Aging, 27*, 484–497.

Boywitt, C. D., & Meiser, T. (2012a). Bound context features are integrated at encoding. *The Quarterly Journal of Experimental Psychology*, 1484–1501.

Boywitt, C. D., & Meiser, T. (2012b). The role of attention for context–context binding of intrinsic and extrinsic features. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*, 1099–1107.

Boywitt, C. D., & Meiser, T. (2013). Conscious recollection and binding among context features. *Consciousness and Cognition, 22*, 875-886.

Bradley, M. M., & Lang, P. J. (1999). Affective norms for English words (ANEW): Stimuli, instruction manual and affective ratings (Tech. Rep. C-1) *Gainsville: University of Florida, Center for Research in Psychophysiology*.

Cahill, L., & McGaugh, J. L. (1998). Mechanisms of emotional arousal and lasting declarative memory. *Trends in Neuroscience*, *21*, 294-299.

Chiu, Y., Dolcos, F., Gonsalves, B. D., & Cohen, N. J. (2013). On opposing effects of emotion on contextual or relational memory. *Frontiers In Psychology, 4*(103), 1-4.

D'Argembeau, A., & Van der Linden, M. (2004). Influence of affective meaning on memory for contextual information. *Emotion, 4*, 173–188.

Doerksen, S., & Shimamura, A. P. (2001). Source memory enhancement for emotional words. *Emotion, 1*, 5-11.

Dougal, S., & Rotello, C. M. (2007). “Remembering” emotional words is based on response bias, not recollection. *Psychonomic Bulletin & Review, 14* (3), 423-429.

Ecker, U. K. H., Zimmer, H. D., & Groh-Bordin, C. (2007). Color and context: An ERP study on intrinsic and extrinsic feature binding in episodic memory. *Memory & Cognition, 35*, 1483–1501.

Hamann, S. B., Ely, T. D., Grafton, S. T., & Kilts, C. D. (1999). Amygdala activity related to enhanced memory for pleasant and aversive stimuli. *Nature Neuroscience, 2*, 289-293.

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological Bulletin, 114*(1), 3-28.

Jurica, P. J., & Shimamura, A. P. (1999). Monitoring item and source information: Evidence for a negative generation effect in source memory. *Memory & Cognition, 27*, 648-656.

Kensinger, E. A., & Corkin, S. (2003). Memory enhancement for emotional words: Are emotional words more vividly remembered than neutral words? *Memory and Cognition, 31*, 1169-1180.

Kensinger, E. A., Garoff-Eaton, R. J., & Schacter, D. L. (2007). Effects of emotion on memory specificity: memory trade-offs elicited by negative visually arousing stimuli. *Journal of Memory and Language, 56*, 575–591.

MacKay, D. G., & Ahmetzanov, M. V. (2005). Emotion, memory, and attention in the taboo stroop paradigm an experimental analogue of flashbulb memories. *Psychological Science, 16*, 25–32.

Mather, M. (2007). Emotional arousal and memory binding: an object-based framework. *Perspectives on Psychological Science, 2*, 33-52.

Mather, M., & Knight, M. (2008). The emotional harbinger effect: poor context memory for cues that previously predicted something arousing. *Emotion, 8*, 850-860.

Mather, M., & Nesmith, K. (2008). Arousal-enhanced location memory for pictures. *Journal of Memory and Language, 58*, 449–464.

Mather, M., & Sutherland, M. R. (2011). Arousal-biased competition in perception and memory. *Perspectives on Psychological Science, 6* (2), 114-133.

Meiser, T. (2009, October). Multinomial analysis of multidimensional source memory: Overview and new extensions. Paper presented at the Winer Lectures, Purdue University, West Lafayette, IN.

Meiser, T., & Broder, A. (2002). Memory for multidimensional source information. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*, 116–137.

Meiser, T., Sattler, C., & Weisser, K. (2008). Binding of multidimensional context information as a distinctive characteristic of remember judgments. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*, 32–49.

Murnane, K., & Bayen, U. J. (1996). An evaluation of empirical measures of source identification. *Memory & Cognition, 24*, 417–428.

Nashiro, K., & Mather, M. (2011). How arousal affects younger and older adults' memory binding. *Experimental Aging Research, 37*, 108–128.

Ponzio, A., & Mather, M. (2014). Hearing something emotional influences memory for what was just seen: How arousal amplifies effects of competition in memory consolidation. *Emotion, 14*(6), 1137-1142.

Rimmele, U., Davachi, L., Petrov, R., Dougal, S., & Phelps, E. A. (2011). Emotion enhances the subjective feeling of remembering, despite lower accuracy for contextual details. *Emotion, 11*, 553-562.

Schmidt, K., Patnaik, P., & Kensinger, E. A. (2011). Emotion's influence on memory for spatial and temporal context. *Cognition & Emotion, 25*, 229–243.

Starns, J. J., & Hicks, J. L. (2005). Source dimensions are retrieved independently in multidimensional monitoring tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*(6), 1213-1220.

Starns, J. J., & Hicks, J. L. (2008). Context attributes in memory are bound to item information, but not to one another. *Psychonomic Bulletin & Review, 15*, 309–314.

Tulving, E. (1985). Memory and consciousness. *Canadian Psychology, 26*, 1–12.

Uncapher, M. R., Otten, L. J., & Rugg, M. D. (2006). Episodic encoding is more than the sum of its parts: An fMRI investigation of multifeatural contextual encoding. *Neuron, 52*, 547–556.

Appendix A

Table 1. Hits and False Alarms for Experiment 1 and Experiment 2

Response	Experiment 1 (Sounds)		Experiment 2 (Words)	
	Neutral	Negative	Neutral	Negative
Hits	.67 (.03)	.68 (.03)	.67 (.04)	.79 (.02)
False alarms	.22 (.03)	.20 (.03)	.20 (.03)	.29 (.04)

Note: Standard errors are shown in parentheses.

Table 2. Mean Context Memory (ACSIM) Scores in Experiments 1 and 2

	Experiment 1		Experiment 2	
Source	*Negative Sound*	*Neutral Sound*	*Negative Word*	*Neutral Word*
Remember				
Source 1	73.94%	76.00%	74.52%	75.88%
Source 2	74.49%	76.14%	66.50%	76.35%
Know				
Source 1	66.58%	62.05%	53.38%	62.29%
Source 2	61.89%	56.77%	54.92%	57.68%

Note: For Experiments 1 and 2, Source 1 is font size and Source 2 is location.

Table 3. Parameter Values Estimated With the Multinomial Model of Multidimensional Source Memory

	Experiment 1		Experiment 2	
Parameter	*Negative Sound*	*Neutral Sound*	*Negative Word*	*Neutral Word*
D_{lb}	.53 [.44-.62]	.48 [.39-.58]	.49 [.38-.60]	.48 [.40-.57]
D_{ls}	.56 [.47-.65]	.43 [.34-.52]	.63 [.54-.74]	.47 [.36-.57]
D_{rb}	.39 [.29-.48]	.45 [.36-.55]	.44 [.33-.54]	.43 [.33-.52]
D_{rs}	.46 [.40-.52]	.42 [.36-.48]	.49 [.43-.54]	.48 [.42-.53]
R	.32 [.24-.41]	.29 [.21-.37]	.33 [.26-.40]	.29 [.20-.37]
b	.38 [.33-.43]	.38 [.33-.43]	.57 [.51-.62]	.39 [.34-.45]
d^R	.31 [-.00-.62]	.40 [.15-.64]	.42 [.26-.57]	.28 [-.00-.57]
d^K	.22 [-.08-.52]	.13 [-.23-.49]	.00 [-.43-.43]	.36 [.10-.62]
e^{1R}	.63 [.35-.90]	.51 [.09-.91]	.00 [-.69-.69]	.53 [.16-.90]
e^{1K}	.00 [-.71-.71]	.00 [-.81-.81]	.00 [-.53-.53]	.00 [-.83-.83]
e^{2R}	.37 [.02-.72]	.29 [-.07-.65]	.35 [.13-.57]	.45 [.18-.71]
e^{2K}	.41 [.11-.71]	.43 [.13-.74]	.40 [.03-.77]	.02 [-.43-.46]

Note: The four recognition parameters (D) are for each of the four combinations of source conditions (left, big; left, small; right, big; right, small). For individual source memory scores (e), source dimension one was location and source dimension two was size.

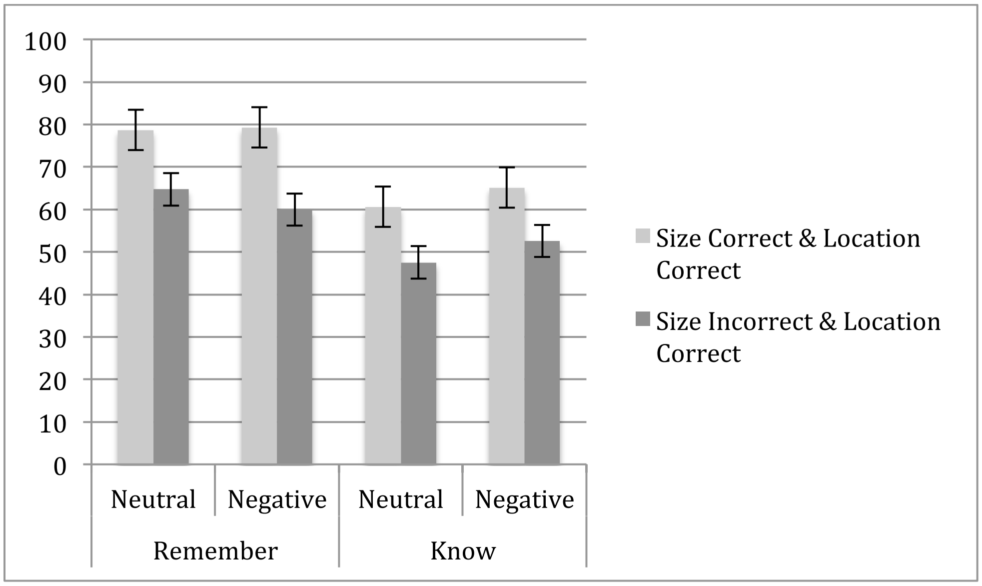

Figure 1. *Experiment 1: Proportion of correct responses for Location when Size was identified correctly versus incorrectly in the state of "Remembering" as well as in a state of "Knowing." Error bars represent the standard error for each score.*

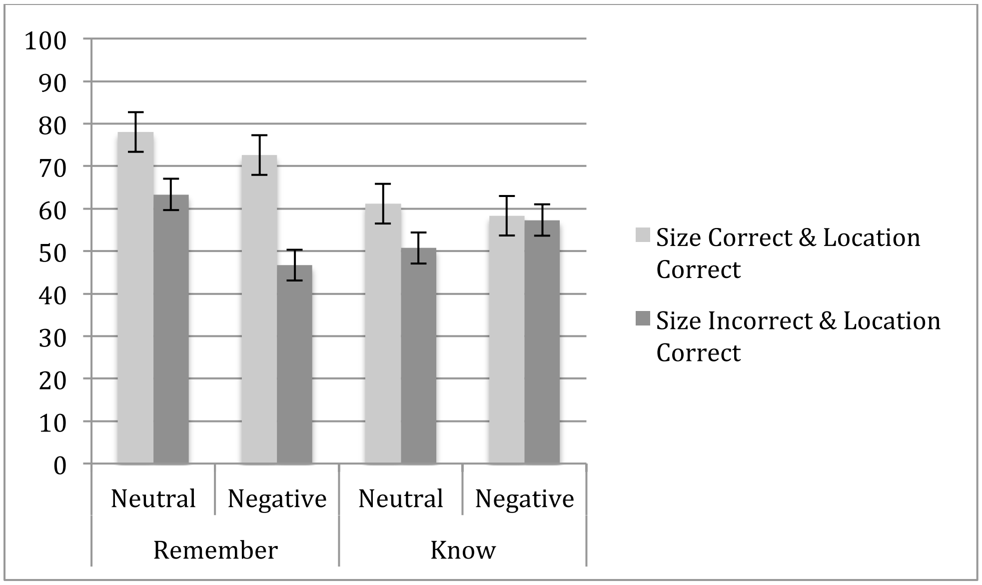

Figure 2. *Experiment 2: Proportion of correct responses for Location when Size was identified correctly versus incorrectly in the state of "Remembering" as well as in a state of "Knowing." Error bars represent the standard error for each score.*

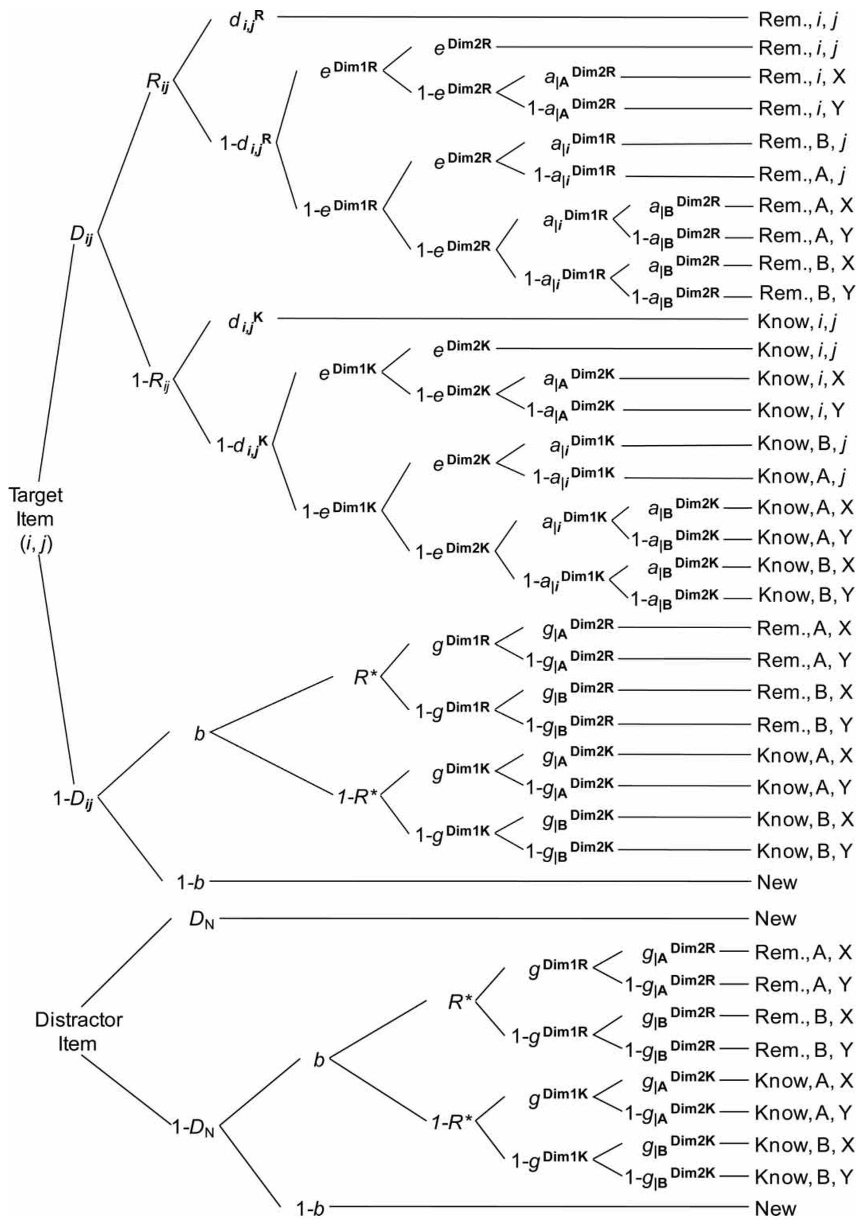

Figure 3. *Processing-tree diagram for re-parameterized version of the multinomial model of multidimensional source memory (Boywitt & Meiser, 2012a). Refer to text for a description of the parameters.*

Appendix B

Post-Questionnaire

Please answer the following questions to the best of your ability.

What is one word from the test that you claimed to “remember”?

What specific details or thought processes did you associate with the word that made you think you “remembered” it rather than “knew” it?

What is one word from the test that you claimed to “know”?

Why did you choose “know”, but not “remember”?

Thank you for your time and cooperation. Feel free to ask the experimenter if you have any questions about the tasks you completed. You are now finished with the experiment.