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Binding of Independent Contexts in Source Memory

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BINDING OF INDEPENDENT CONTEXTS IN SOURCE MEMORY

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
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in

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by
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TABLE OF CONTENTS

ABSTRACT

Within the present study the binding between two independent source dimensions in a multidimensional source memory paradigm was investigated. Specifically, I examined stochastic dependence between the retrieval of each source dimension. Previous work has defined stochastic dependence as the higher probability of correct source retrieval for one dimension contingent on previous correct retrieval of a second source dimension, versus when contingent on incorrect retrieval of the second source dimension. Evidence is mixed as to whether item information within source dimensions must be encoded simultaneously in order to demonstrate eventual stochastic dependence. The present study tested the binding of two cross-modal source attributes (visual [left or right side of screen] and auditory [male or female voice]) over time by manipulating the lag between each independently-encoded source dimension. Source dimensions were encoded simultaneously or separately by two intervening encoding trials (separate condition). Based on the behavioral measures of binding, source dimensions presented more closely in time resulted in stochastic dependence in the context of remembering and not knowing. However, a multinomial model of response frequencies produced evidence of joint retrieval in the context of remembering for both the simultaneous and separate conditions. Because source dimensions were presented over time in some conditions, working memory capacity was measured as a potential predictor of stochastic dependence. However, working memory measures did not correlate with source memory performance. Future directions in examining this separate condition, stochastic dependence and individual differences in working memory capacity are discussed.

CHAPTER 1. INTRODUCTION

Source memory is information associated with an event or item that indicates where and how one acquired that specific memory (Johnson, Hashtroudi, & Lindsay, 1993; Otani, Libkuman, Goernert, Kato, Migita, Freehafer, & Landow, 2012) and has been a topic of importance in memory research for the past few decades (Vogt & Broder, 2007). The term *source* references the characteristics of a remembered event that collectively specify how and when the original event was experienced (e.g., spatial, temporal and social context of the event; Johnson et al., 1993; Tulving, 1985). Source memory involves episodic memory due to a person remembering where and how a specific memory occurred (Bröder & Meiser, 2007). Moreover, source memory is different than recognition memory. In the context of source memory, a person is identifying an overarching (or sometimes detailed) context of a learned event, whereas in standard recognition a person is determining whether or not they recognize an item as previously being experienced without specifying the manner in which it was presented. For example, deciding if you locked your car door when you arrived at work last Monday is an event; you are judging the context of you locking your car door last Monday. This is in comparison to you saying you recognize having driven your car to work.

1.1 Source monitoring

A cognitive process involved in retrieving source memories is the concept of source *monitoring*, which involves discriminating amongst different contender sources as being associated with the original event (Bayen, Murnane, & Erdfelder, 1996). This process of discriminating between different sources and determining which source is correct is a source-monitoring judgment (Johnson et al., 1993). Source monitoring is also a process that involves making attributions about various types of information in relation to the origin of memories (Hashtroudi, Johnson, & Chrosniak, 1989). This information can be perceptual (e.g., sound and color), contextual (spatial and temporal), affective (emotion), semantic detail, and cognitive operations (e.g., organization and elaboration; Johnson et al., 1993). Each type of information is helping the source monitoring process of making attributions about where a memory originated and how it occurred. Johnson and colleagues (1993) took this a step further and developed the source-monitoring framework.

The source-monitoring framework involves a person taking an active role in reconstructing the context of the original episode when retrieving memories (Johnson et al., 1993). Thus, a person is using different types of information (e.g., perceptual and affective) to reconstruct the context of a memory. The overarching source monitoring framework involves a set of cognitive processes that help people reinstate the contextual details of a memory trace, retrieve the memory and evaluate it (Ball, Marsh, Meeks, & Hicks, 2011; Johnson et al., 1993). The process of actually retrieving and evaluating the memory trace within this framework allows the rememberer to judge if the memory seems to be accurate or not (Johnson et al., 1993). A person can determine other aspects of a memory trace, such as whether the memory was externally or internally generated. For example, memory traces that involve a lot of perceptual details (e.g., location, color, sound) should be judged as more likely to have been generated externally than memory traces that have less perceptual details that might be inferred to be an internal thought.

When determining the accuracy of the memory trace, a spectrum of how accurate the memory trace feels to a person occurs. This is similar to Tulving’s (1983) position that the recollective experience can range from being clear to vague and fuzzy. Tulving (1985) developed the Remember-Know paradigm to measure a person's subjective experience when evaluating a memory trace. The feeling of remembering or recollection involves recognizing an item or event as previously presented and this recognition is accompanied by conscious recollection of the item or event, such as what you were thinking when the event occurred. In comparison, knowing or a feeling of familiarity still involves recognizing an item or event as previously presented, but now this recognition is accompanied by mere familiarity.

1.2 Multidimensional source memory

Investigating source memory typically involves a word being presented with a particular source or context. After a delay, these same words are presented along with new words and old/new recognition decisions are made. If the word is recognized as old, whether this recognition is in the feeling of recollection versus the feeling of familiarity (Tulving, 1985) is queried. Then the context associated with the word is queried. For example, if words are presented on the left or right side of a computer screen and a word is recognized as old, one must then decide if this is in the feeling of recollection or familiarity and then judge if the word was presented on the left or right side of the screen. If the word is not recognized (is called new), the test typically goes onto to the next item. However, source memory involves episodic memory, which is naturally multidimensional. Therefore, source memory paradigms in the lab need to measure multidimensional components.

Recently, multidimensional source contexts in which items are studied with two independent sources have been investigated (Hicks & Starns, 2015; Meiser & Bröder, 2002). Therefore, a word might be studied in one of two font sizes in addition to being studied on the left or right side of the computer screen (Meiser & Bröder, 2002; Starns & Hicks, 2005). Thus, in the most basic version of the paradigm, different items are encoded in a factorial crossing of the two source dimensions (e.g., font size and location) where a word is presented in one of two font colors and on the left or right side of the screen. Participants then typically provide old/new responses followed by feelings of recollection or familiarity followed by yes/no decisions on both source dimensions (font color and location). One of the benefits of multidimensional source paradigms is that the experimental encoding of information is more like the real-world multidimensional contexts in which items, objects, and actions are encoded. That is to say, in the real world it is difficult to imagine an event where only one aspect of the context (e.g., location) is associated with the item. This is because source memory entails retrieval of episodic memories, which are naturally multidimensional, often involving more than one source retrieved at a time (Boywitt & Meiser, 2012b). Tulving (1983) proposed that episodic memory representations are event engrams, which represent bound representations of multiple event elements (Horner & Burgess, 2013, 2014). Thus, a second benefit of the multidimensional paradigm is it allows us to examine these bound representations of multiple event elements.

1.3 Stochastic dependence

A third benefit of multidimensional paradigms is that they afford a unique way to understand the interplay between encoding and retrieval of multiple sources of information. Through multidimensional paradigms one can learn how source information or contexts are associated—or bound—to item information and also to other source information in a coherent memory. One can also learn how retrieval of independent contexts or bound contexts occurs. An intriguing aspect of retrieval processes in these paradigms was identified by Meiser and Bröder (2002) as *stochastic dependence*. The most basic operational definition of such dependence is that the likelihood of retrieving one source (e.g., location) is dependent on the likelihood of retrieving the second source (e.g., font size). Meiser and Bröder demonstrated such dependence as people having better memory for font size associated with words when a decision about encoded location was correct versus incorrect. Thus, stochastic dependence involves having one context be correctly remembered with a greater probability due to the second context being correctly remembered.

Boywitt and Meiser (2012a) concluded that this theoretical retrieval process of stochastic dependence is the result of direct binding between the two contexts, or “context-context” binding. In other words, stochastic dependence occurs when retrieving two contexts in a multidimensional source memory paradigm due to the binding between context one being correct (e.g., font size) and source two being correct (e.g., location). Such dependence should not occur if the context dimensions are not directly bound, such as when each is bound only to item information. One important qualification of this finding is that such dependence was significant only in the context of people also having a vivid recollection that words were old using a variant of the Remember-Know paradigm (cf. Tulving, 1985). When people felt that recognized words were only familiar (i.e., “Known”), as opposed to having vivid recollection (i.e., “Remembered”), dependence between the size and location sources was not significant.

Stochastic dependence has been replicated in further work by Meiser and colleagues (e.g., Boywitt & Meiser, 2012b), as well as others (e.g., Starns & Hicks, 2005; Vogt and Bröder, 2007), with different source dimensions. Research surrounding this phenomenon of binding in multidimensional source memory was reviewed recently by Hicks and Starns (2015). One strong conclusion adopted by Hicks and Starns was that stochastic dependence reflects the degree to which source information and item information is successfully bound at encoding. Well-attended event memories are more likely to have both source dimensions successfully bound to the item, as opposed to only one or the other source bound to the item. As was found with Boywitt and

Meiser (2012a), binding was found to only occur in the feelings of recollection, not familiarity. Thus, dependence was viewed by Hicks and Starns as an encoding phenomenon where items that are fully attended to result in better binding of context(s) to item than items that are not well attended to (Starns & Hicks, 2005).

This is in comparison to Meiser and Bröder (2002) who claimed binding could be the result of retrieval processes. A second important distinction is that Hicks and Starns adopted the view that stochastic dependence could be the result of separate context to item binding. For example, the font size and location for a studied word is bound during encoding because the font size is bound to the word and the location is separately bound to the word. In this sense, stochastic dependence can be viewed as a measure of the completeness of item-source bindings in a multidimensional setting and can vary from item to item. Boywitt and Meiser (2012a) however argued that "context-context" binding is happening instead. Therefore, the font size and location for a word are directly bound together. But, Hicks and Starns argued that very little evidence demonstrates direct context-to-context associations independent of item-to-context associations. Regardless, there is overwhelming evidence that the encoding of both source dimensions in the presence of the item is a very good predictor of later stochastic dependence. As one illustrative example, Meiser and Sattler (2007) showed that being asked to attend specifically to the perceptual/spatial nature of font size and location source dimensions of items manipulated at encoding created greater stochastic dependence than being asked to consider more semantic aspects of the items at encoding. The question remains if binding of two or more contexts is an encoding phenomena or the result of the retrieval process used when retrieving an episode.

Boywitt and Meiser (2012a) manipulated the encoding of two contexts associated to a word over time. They argued that if binding is an encoding phenomenon, presenting two contexts (location and font color) in two separate word lists, as opposed to presenting in conjunction with a common stimulus, should not find binding of contexts. Boywitt and Meiser (2012a) showed that encoding an item once with one of the source dimensions (font color) and later with the other dimension (location) did not produce stochastic dependence. Stochastic dependence was not found when the two source dimensions were cross-modal and presented separately (location and male or female voice) either. Presumably this was because these encoding conditions were unfavorable for allowing the two source dimensions to be bound with the item—and possibly to each other— due to being presented separately in two different word lists. However, the presentation of two source dimensions this far a part in time is extreme, thus it is not surprising that binding was not found.

Boywitt and Meiser (2012a) found evidence of stochastic dependence in the feeling of recollection using multinomial modeling as well. Multinomial processing trees (MPT) propose hypothetical cognitive states that underlie performance on a source memory test, with each parameter in the model estimating the probability of experiencing a discrete cognitive state (Moshagen, 2010). This modeling is an alternative way of explaining behavioral data for a multidimensional source memory test. Within the source monitoring paradigm items are studied with two different sources (e.g., source A [font size] and source B [location]). At test participants perform a recognition memory test by identifying each word as being presented before (old), deciding if this recognition is accompanied by a feeling of conscious recollection or mere familiarity, and then the correct context for source A and for source B, or identifying the item as new (Moshagen, 2010). The multiple cognitive processes engaged during this task – recognizing an item, discriminating amongst contender sources and response biases – are represented by the different parameters in the model. Boywitt and Meiser (2012a) found evidence of stochastic dependence through a parameter that reflects direct context-to-context binding in the feeling of recollection when visual modality contexts and cross-modal contexts were presented simultaneously. Thus, they found evidence of stochastic dependence in both behavioral data and in multinomial modeling, but only when sources were presented with items simultaneously and not separately.

1.4 Current study

The present study was an attempt to partially reconcile the different results in the Boywitt and Meiser (2012a) and Hicks and Starns (2015) review. Specifically, the present study was an attempt to establish the separate item-source binding of two source attributes over time, but not as extreme as Boywitt and Meiser's (2012a) manipulation. In this sense, the proposed study can be viewed more or less as a conceptual replication and extension of Boywitt and Meiser (2012a). By assessing the binding of two source attributes over a shorter lag of intervening encoding trials, the extent to which binding or stochastic dependence occurs between multiple sources can be measured. Boywitt and Meiser (2012a) presented the separate item-source information for each item after all other items were encoded at least once. Therefore, the lag between the encoding of each item-source dimension was long and with many intervening items. In the present study, a shorter lag of only two intervening items provided a means to establish whether a lag within one's focus of attention is critical to binding the different source dimensions.

Moreover, other methodological issues were addressed by including cross-modal sources (visual and auditory; Meiser, Sattler, & Weiβer, 2008). Lastly, because each source was presented over a lag, measures of working memory capacity (an operation span task and a change detection task) were included as an individual difference assessment. To the extent that people can successfully bind two item-source pairings across separate encoding experiences, one's capacity to encode a new pairing while also holding in working memory the prior pairing (or while concurrently retrieving the prior pairing from long-term memory) should moderate this effect. In addition, working memory capacity measures may demonstrate individual differences in the extent of binding ability even in the best-case encoding context (i.e., the simultaneous encoding of both source dimensions).

1.5 Theoretical outcomes

The present experiment expects to follow the trend of Boywitt and Meiser's (2012a) results for the simultaneous condition. That is, I predict stochastic dependence for the simultaneous condition. Whether stochastic dependence is found for the separate condition was the primary question. Furthermore, the well-founded result for recollected and familiar ratings was expected in terms of stochastic dependence, such that stochastic dependence would be found for words rated as recollected, but not for those rated as familiar. Lastly, a main effect of working memory capacity was predicted, such that those with a higher working memory capacity will perform significantly better on the source retrieval task than those with a low working memory capacity. Whether working memory capacity interacts with the separate manipulation was also of interest. Presumably people with higher capacity, as compared to those with lower capacity, will be better able to consistently bind both source dimensions in the simultaneous and separate conditions. Thus, planned comparisons were undertaken to test for stochastic dependence based on recollection, based on familiarity, separately for the simultaneous and separate conditions.

CHAPTER 2. METHOD

2.1 Participants

One-hundred and forty students took part in the present experiment in exchange for course or extra credit and were randomly assigned to either the simultaneous or separate condition. Participants were recruited from a subject pool of undergraduate psychology students at Louisiana State University.

2.2 Measures

2.2.1 Working memory measures. Operation Span Task. An automated computerized brief version of the operation span task (OSPAN) (Turner & Engle, 1989; Unsworth et al., 2005; Foster et al., 2014) was used as one working memory measure for the present experiment. On each trial, participants are given a basic mathematical operation to verify as either true or false (e.g., addition, subtraction, multiplication, division) and then are presented with a letter to encode. Between 2 and 7 problem-letter trials are presented in a set and, after each set, the letters must be recalled in the order in which they were learned. The task ranged in number of trials (at most 56 trials) for each participant depending on their performance. Scores are calculated by summing the number of letters correctly recalled in the correct order, resulting in a partial score. This partial score ranges from 0 to 56. There are three blocks in this task. Foster and colleagues (2014) examined how much more variance of fluid intelligence was measurable with each successive block of the OSPAN task. They found a predicted alpha of .817 when a sample of participants completed blocks 1 and 2. Using hierarchical regression models, Foster et al., (2014) found that the third block of trials only accounted for an additional 1.4% of the variance of fluid intelligence factors, and only 3.2% of the variance for WMC. This is a non-significant addition of variance of WMC and fluid intelligence factors. As a result, participants only completed blocks 1 and 2 in the present experiment due to this being a good predictor of general fluid intelligence and WMC. See Figure 1 for an example of the OSPAN.

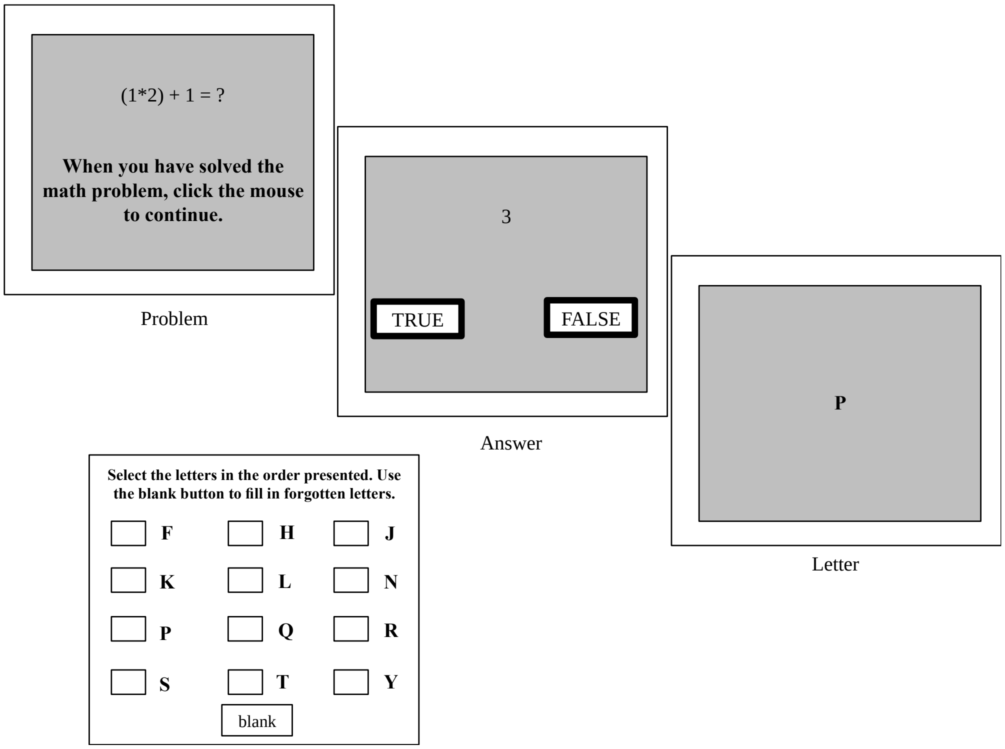

Figure 1. Operation Span Task trial example.

2.2.2 Visual Working Memory. Change Detection Task. In addition, a visual short-term working memory task was assessed. A change detection task (Luck & Vogel, 1997; Phillips, 1974) was used to estimate visual working memory capacity. Study arrays of 4, 6, or 8 colored squares were displayed for 500 msec at a time, followed by a 500 msec blank inter-stimulus interval. A test array was then displayed with all of the squares again but with one of them probed by a surrounding circle. On half of the test trials the probed square's color was different from the presentation phase and on the other half it was the same color. People had to decide either "same" or "different" as to whether the probed test square has changed. The proportion of correct trials was used as an index of a person's visual short-term memory ability. This change detection task has been used successfully to predict source memory performance in a separate laboratory task (Hicks & DeWitt, 2012) and has also been argued to reflect a measure of one's ability to bind information together during encoding (Wheeler & Treisman, 2002). The change detection task consisted of 72 trials, with 24 trials for each set size (4, 6, or 8 colored squares) and each different type of trials was randomly presented.

2.2.3 Sources. There were two source dimensions, visual (location on the left/right side of computer screen) and auditory (male or female voice) (Boywitt & Meiser, 2012a; Meiser et al., 2008). Digitized versions of each word spoken in a male and a female voice were used. Words were obtained from the ANEW database (Bradley & Lang, 1999).

2.3 Design

A 2 (Working memory: Low vs. High span) [between] x 2 (Spatial Source vs. Gender Source) [within] x 2 (Location: Simultaneous vs. Separate) x 2 (Recollection vs. Knowing) [within] mixed factorial design was represented in the present study.

2.4 Procedure

The procedure for the present experiment was adapted from Boywitt and Meiser's (2012a) and the Meiser et al. (2008) procedures. All instructions and presentation of materials were presented via the computer and completed individually. Participants first completed the shortened OSPAN measure. The OSPAN task took approximately 10 minutes. Then, participants were instructed to study a list of words presented one at a time for a later memory test. From a set of 165 words of four to nine letters, 64 words were used as study items, and 40 words as distractors. Words were presented in the same size, with half presented in the vertical center on the left hand side of the screen and the other half presented in the vertical center on the right hand side of the screen. Words were presented for 3 seconds with a 500 ms inter-stimulus interval. One second after visual presentation of the words, participants heard via headphones an acoustic presentation of the words. Half of the words were presented in a male voice, the other half in a female voice. One of the two different lag presentation conditions (simultaneous or separate) was randomly assigned to participants. Presentation of the words in each source dimension for the simultaneous presentation group commenced as described above. For the separate condition, the words were presented once associated with one of the source dimensions (e.g., on the left) and the second time associated with the other source dimension (e.g., accompanied by a female voice). The difference between these groups was two intervening trials for a different word in the separate condition. This encoding phase had 64 trials.

Following a two-minute filler task of math problems, participants completed the source-monitoring task administered via the computer. Target and distractor words were randomly presented one at a time. Participants were instructed in accordance with Meiser and Bröder's (2002) methodology. Participants first decided if the word was presented before (old) or not (new). If a word was claimed as "new," the next test word was presented. For an old response, participants decided if the judgment was accompanied by recollection or familiarity. Thus, the first decision was among a claim of recollection (old), familiarity (old), or new. In the instructions, recollection (or Remembering) was described as a conscious, vivid recollection of the word being presented before, while familiarity (or Knowing) means recognizing the word without a recollective experience (but not guessing) See Appendix A for R and K descriptions. Following either a "Remember" or "Know" response, participants decided if the word was presented on the left or right hand side of the screen. Then participants decided if the word was presented with a male or female voice. The test phase of the source memory test consisted of 104 trials (64 old trials, 40 new trials) and lasted approximately 30 minutes. See Figure 2 for an example of a simultaneous encoding and Figure 3 for an example of separate encoding.

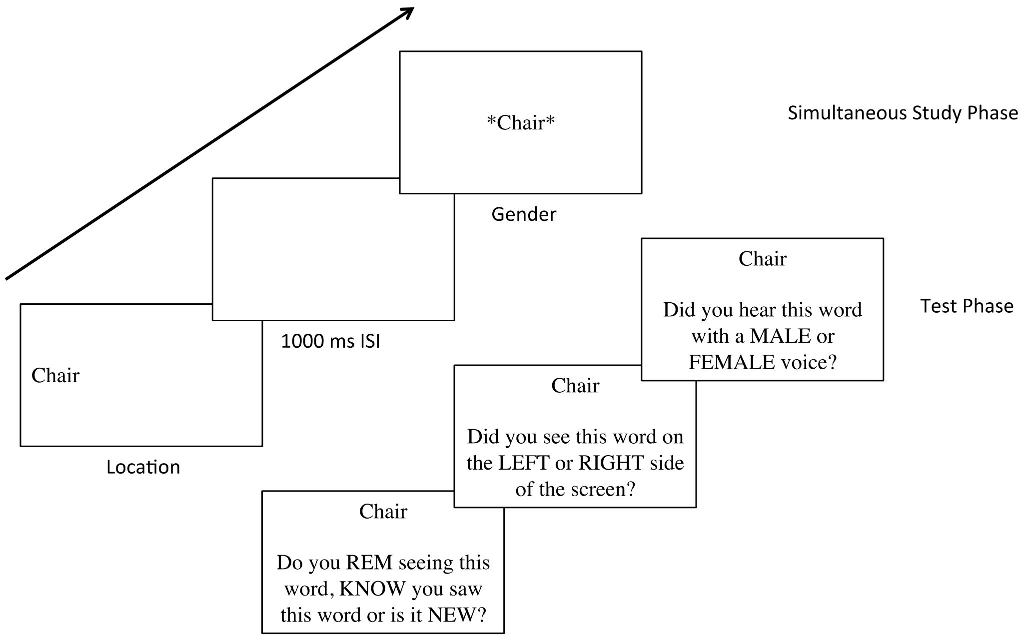

Figure 2. Simultaneous encoding and test phase

Upon completion of the source-monitoring task, participants completed the change detection task on the computer. The change detection task lasted approximately 10 minutes. The whole experiment took approximately one hour. Following completion of this third task, participants were debriefed.

2.5 Statistical analyses

A 2 (simultaneous vs. separate) [between-subjects] x 2 (low WMC/change detection performance vs. high WMC/change detection performance) [between-subjects] x 2 (recollection vs. knowing) [within-subjects] x 2 (Stochastic dependence, with side correct: Gender correct vs. gender incorrect) [within-subjects] mixed factorial design was used to measure stochastic

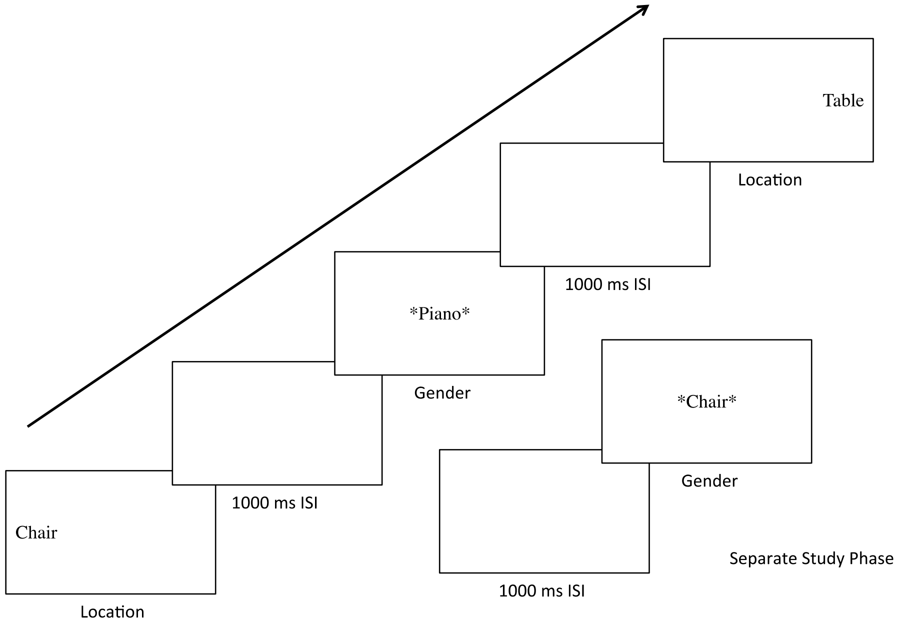

Figure 3. Separate encoding with the word CHAIR presented in a location, followed by a different word in a location and a different word in a male or female voice, then presented CHAIR in a male or female voice

dependence of cross-modal sources in the feeling of recollection versus knowing in the simultaneous and separate conditions in a multidimensional source memory paradigm. Low versus high WMC and change detection task performance was created using a median split of the partial score for the OSPAN measure and the overall performance on the change detection task. By doing so, we measured how WMC and change detection task performance correlates with source memory performance, as well as how low versus high span and task performance correlates with source memory performance. To examine binding between sources for the simultaneous and separate conditions, planned comparisons were conducted to analyze stochastic dependence in the feeling of recollection and knowing in the simultaneous and separate conditions. Paired samples t-tests were conducted based on the robust finding that stochastic dependence only occurs in the feeling of recollection and when each source is presented simultaneously (Boywitt & Meiser, 2012a). The present study examined whether presenting each source separately with two intervening trials resulted in stochastic dependence in the feeling of recollection as has been found when each source is presented simultaneously.

2.6 Power analysis

A power analysis was conducted using G*Power 3 (Faul et al., 2007) to determine the sample size needed to detect an effect of spacing of items and working memory capacity on stochastic dependence and multidimensional source memory in a between-subject manipulation for two groups (simultaneous and separate conditions). Cohen's **d** and effect size *r* were calculated based on Boywitt and Meiser's (2012a) correct source judgment in the simultaneous presentation with the feeling of recollection. Experiment 1 used a between subjects manipulation, resulting in mean conditional context accuracy for location, given that font color was correct (*M* = .69, *SE* = .02) versus incorrect (*M* = .62, *SE* = .03). Standard deviations were calculated for font color correct (*SD* = .13) versus font color incorrect (*SD* = .20). The difference between the means for font colors being correct and incorrect was calculated (*M* = .07). This results in a Cohen's **d** of .42. Experiment 2 used a within-subjects manipulation, resulting in mean conditional context accuracy for location, given that gender is correct (*M* = .77, *SE* = .02, and gender is incorrect (*M* = .71, *SE* = .02). Standard deviation was also calculated here, resulting in gender correct and incorrect (*SD* = .19). Using an estimated correlation between the samples of .50, this results in treating these analyses as a between-subjects manipulation. Thus, using the mean between these samples (*M* = .74) and an average of these standard deviations (*SD* = .19), this results in a Cohen's **d** of .32. Using these estimates, a statistical power of at least .80, and Type I error rate of .05, an estimated sample size of 60 subjects per condition is required (i.e., 120 subjects total).

CHAPTER 3. RESULTS

3.1 Recognition memory and confounding variables

We set an alpha level of .05 for all analyses. Participants were removed from analyses if they had zero recollection responses or zero know responses on the source test. Moreover, those with false alarm rates more than 2 standard deviations above the mean, or whose overall recognition discriminability was near chance levels, were removed. This data screening resulted in thirteen people removed (10 from the simultaneous condition and 3 from the separate condition) leaving 61 participants in the simultaneous condition and 66 participants in the separate condition.

For mean proportion hits and false alarms rates for R (Remembering) and K (Knowing) responses, please refer to Table 1. Mean proportion hits for R responses ($M = .41$) were significantly higher than K responses ($M = .33$), and mean proportion false alarms were significantly higher for K responses ($M = .12$) than R responses ($M = .03$), regardless of condition, $F(1,125) = 29.89$, $p < .05$, partial eta-squared = .19.

Table 1. Mean proportions of remember and know responses to target items and distractors. Standard error of the mean is presented in parentheses.

Response	Simultaneous Presentation ($n = 61$)	Separate Presentations ($n = 66$)
Remember		
Hits	.41 (.03)	.41 (.03)
False alarms	.04 (.01)	.03 (.01)
Know		
Hits	.33 (.02)	.34 (.02)
False alarms	.14 (.02)	.11 (.01)

3.2 Overall context memory

To analyze overall context memory, average conditional source identification measures (ACSIM) were calculated for each combination of context dimension (side or gender), condition (separate or simultaneous) and level of experience (recollected vs. known). These data are presented in Table 2. ACSIM scores represent the overall ability for people to correctly retrieve the source along a single dimension (i.e., for side or for gender), conditional on that item also being judged as "old." Separate ACSIM scores were produced for old items called "old" and based on Remembering versus those based on Knowing. For example, the ACSIM score for side judgments accompanied by Remembering was calculated by taking all correct side judgments previously called "Remembered" and dividing them by the quantity of these correct judgments plus all incorrect side judgments previously called "Remembered." A similar score was calculated for side performance based on items called "Known." For the side ACSIM scores, performance on the gender decision was irrelevant. The same process was undertaken for gender ACSIM scores, with side performance ignored accordingly.

Table 2. Mean context memory (ACSIM) scores. Standard error of the mean is presented in parentheses.

Context	Simultaneous Presentation	Separate Presentations
Remember		
Side	.75 (.02)	.69 (.02)
Gender	.76 (.02)	.65 (.02)
Know		
Side	.64 (.02)	.54 (.02)
Gender	.62 (.02)	.56 (.02)

All of the ACSIM measures in Table 2 were above chance level performance (e.g., higher than .5). Therefore, a 2 (condition: separate vs. simultaneous) [between-subjects] x 2 (experience: remember vs. know) [within-subjects] x 2 (source context: gender vs. side) [within-subjects] mixed subjects ANOVA was conducted with ACSIM scores to analyze overall context memory across both conditions in terms of experience and each source context. This resulted in a non-significant three-way interaction, $F(1,123) = 2.87$, $p = .09$, partial eta-squared = .02.

However, there was a significant main effect was found for the source context, $F(1,123) = 89.61$, $p < .05$, partial eta-squared = .42. This is due to performance being significantly better for side judgments ($M = .72$) than gender judgments ($M = .59$). There was also a significant main effect of condition, $F(1,123) = 16.26$, $p < .05$, partial eta-squared = .12, with memory for overall context memory being significantly higher in the simultaneous than the separate condition.

3.3 Stochastic dependence

Recall that stochastic dependence reflects the likelihood that performance on one source dimension might depend on performance on the other source dimension being correct versus incorrect. For the following analyses, I computed a measure of side dimension performance contingent on gender source decisions being correct or incorrect. To the extent that performance is greater for side decisions following correct gender decisions as compared to following incorrect side decisions, the interpretation would be that stochastic dependence exists. Based on the prior literature, such dependence has only been found in the context of recollection (i.e., Remembering), but not in the context of Knowing. This pattern is predicted for the simultaneous encoding condition. Whether this pattern follows in the separate condition is of particular interest. If dependence only arises following the simultaneous (joint) presentation of source dimensions with items, then dependence should not be greater than chance in the separate condition either for decisions based on Remembering or for those based on Knowing. Therefore, although an overall factorial ANOVA is presented next, planned comparisons addressing these predictions are presented after the ANOVA. Conditional context accuracy scores for correct recognition of context dimension B (gender) given that context dimension A (side) was correct, as well as when context dimension B (gender) is incorrect when context dimension A (side) is correct are displayed in Table 3.

Table 3. Mean conditional context accuracy scores for Context Dimension A (Side) being recognized, given that Context Dimension B (Gender) was recognized and given that Context Dimension B was not recognized.

Context	Simultaneous Presentation	Separate Presentations
Remember		
Gender Correct	.76 (.02)	.70 (.03)
Gender Incorrect	.65 (.03)	.69 (.03)
Know		
Gender Correct	.64 (.03)	.53 (.02)
Gender Incorrect	.58 (.04)	.55 (.03)

A 2 x 2 x 2 mixed subjects ANOVA on side dimension proportion correct was conducted with condition (separate vs. simultaneous) [between-subjects], feeling of recollection either remembering or knowing (experience) [within-subjects] and correct vs. incorrect performance on the gender dimension [within-subjects]. A two-way interaction between gender performance (correct vs. incorrect) and condition was significant, $F(1,114) = 6.94$, $p < .05$, partial eta-squared = .06. In the separate condition, side performance did not differ significantly when contingent on correct gender source decision versus incorrect gender source decisions, but this difference was significant in the simultaneous condition. In addition, a significant main effect of subjective experience was found, $F(1,114) = 38.42$, $p < .05$, partial eta-squared = .25, which confirms that source performance was better overall in the context of Remembering as opposed to Knowing. A significant main effect of gender performance was found, $F(1,114) = 4.20$, $p < .05$, partial eta-squared = .04, demonstrating that side judgments were overall better following correct versus incorrect gender decisions. Finally, condition did not result in a significant main effect, $F(1,114) = 2.47$, $p = .12$, partial eta-squared = .02, showing that overall performance on the source memory test did not differ between the simultaneous presentation or separate presentation. Importantly, note that these main effects should be interpreted cautiously, because they produced the interaction presented earlier.

To further analyze the condition by gender decision interaction for side judgment performance, paired-samples t-tests were performed as a series of one-tailed planned comparisons. Note that although the three-way interaction among gender correct/incorrect based on side being correct, condition, and subjective experience in the 3-way ANOVA was not significant, the planned comparisons call for a distinction between performance based on Remembering versus Knowing based on the wealth of prior findings (e.g., Meiser & Bröder, 2002; Starns & Hicks, 2005) showing that stochastic dependence is typically significant only in the context of Remembering. Recall that these means are displayed in Table 3. Of these four comparisons, the only significant difference was for side decisions in the simultaneous condition in the context of Remembering, in which performance was greater following correct gender decisions as compared to incorrect gender decisions, $t(55) = 2.48$, $p < .05$, Cohen's **d** = 0.43. Significant differences were not found with recollected responses in the separate condition, $t(61) = 0.10$, $p > .92$, or for Know responses in either the simultaneous condition, $t(58) = 1.59$, $p > .12$, or the separate condition, $t(65) = -0.50$, $p > .62$. Figure 4 displays these planned comparisons.

An alternative way to view these stochastic dependence results is to analyze gender decision performance contingent on side decisions as correct versus incorrect. See Table 4 for these values. In fact, one prediction is that the pattern of data should not depend on which source dimension is analyzed as being contingent on the other. Therefore, a 2 x 2 x 2 mixed subjects ANOVA on gender dimension proportion correct was conducted with condition (separate vs. simultaneous) [between-subjects], feeling of recollection either remembering or knowing (experience) [within-subjects] and correct vs. incorrect performance on the side dimension [within-subjects]. The two-way interaction between condition and side performance was found to be significant, $F(1,113) = 6.11$, $p < .05$, partial eta-squared = .05. This is due to side performance based on being correct versus incorrect being significantly different in the simultaneous condition and not in the separate condition. The main effect of subjective experience was found, *F*(1,113) = 27.80, *p* < .05, partial eta-squared = .20, due to recollection (*M* = .68) being significantly higher than in the feeling of knowing (*M* = .57). The main effect of side performance was significant, *F*(1,113) = 4.53, *p* < .05, partial eta-squared = .04. This was due to correct side performance being significantly higher than incorrect side performance when gender performance was correct. As with the previous analyses with side performance being correct, the condition main effect was not significant, *F*(1,113) = 2.97, *p* > .08, partial eta-squared = .03.

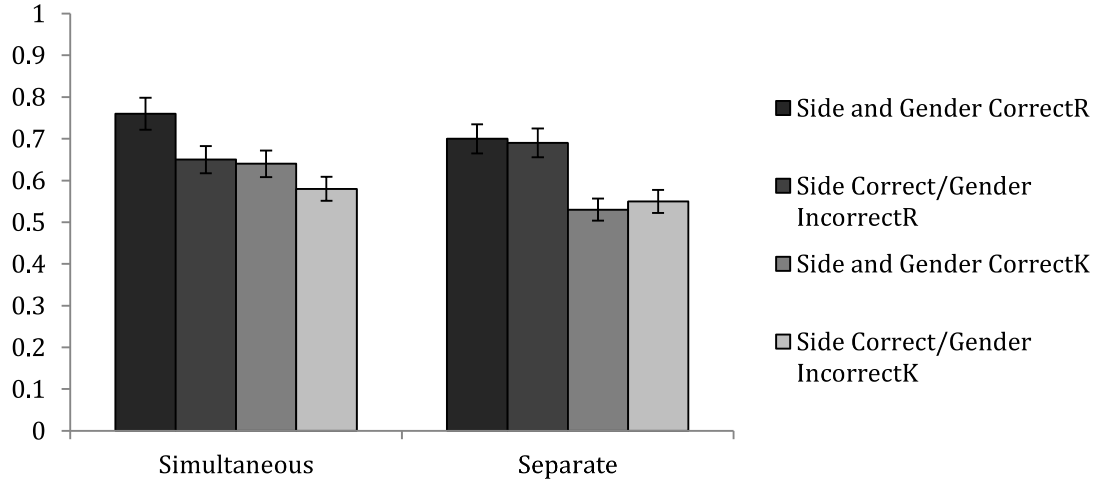

Figure 4. Condition x Gender performance contingencies paired-sample t-tests with the subjective feeling of remembering versus knowing.

Table 4. Mean conditional context accuracy scores for Context Dimension A (Gender) being recognized, given that Context Dimension B (Side) was recognized and given that Context Dimension B was not recognized.

Context	Simultaneous Presentation	Separate Presentations
Remember		
Side Correct	.76 (.02)	.66 (.03)
Side Incorrect	.66 (.03)	.64 (.03)
Know		
Side Correct	.62 (.03)	.55 (.02)
Side Incorrect	.55 (.04)	.58 (.03)

As was done with the condition by gender decision interaction for side judgment performance, one-tailed planned comparisons were made for gender performance contingent on correct versus incorrect side decisions, for each condition and for each type of subjective experience. Again, the only significant difference was in the simultaneous condition, for side decisions based on recollection when gender decisions were correct (*M* = .77) versus incorrect (*M* = .66), *t*(56) = 2.81, *p* < .007, Cohen's **d** = 0.53. For the simultaneous condition based on Knowing, the difference was larger here than when side decisions were contingent on correct versus incorrect gender decisions, with a difference of .07, but still non-significant, *t*(56) = 1.69, *p* > .10. And for the separate condition, these differences were also not significant, *t*(61) = 0.47, *p* > .64, in the context of Remembering and t(64) = -1.06, *p* > .29, in the context of Knowing. See Table 4 for conditional context accuracy scores for correct recognition of context dimension B (side) given that context dimension A (gender) was correct, as well as when context dimension B (side) is incorrect when context dimension A (gender). Please refer to Figure 5 for these one-tailed planned comparisons.

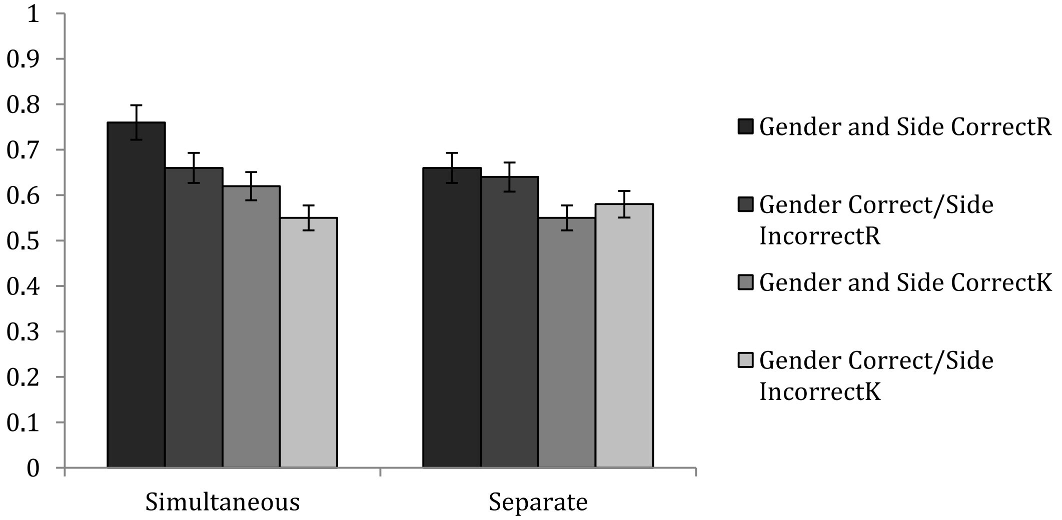

Figure 5. Condition x Side performance contingencies paired-sample t-tests with the subjective feeling of remembering versus knowing.

3.4 Multinomial modeling of stochastic dependence

The next step in analyzing source memory performance involved the multinomial processing tree (MPT) software called Multitree (Moshagen, 2010). See Figure 6 for an example of the model applied from Boywitt and Meiser (2012a). MPT is a group of stochastic models to analyze categorical data. In standard versions of this model, there are typically two sources, source A and source B, as well as new items, resulting in three possible outcomes (A, B, new). In the present study and in recent studies of multidimensional source monitoring, there are two such sources but for two independent dimensions. Location was dimension A (sources were left and right) and Gender was dimension B (sources were male and female). The MPT assumes that the decision processes in determining whether dimension A, dimension B or a new item is presented are reflected in the model. Specifically, dimension A is represented as parameter $D_{1\cdot}$ and dimension B is represented by $D_{\cdot 2}$. These two parameters represent when participants are able to correctly recognize an item as old, or in other words are item detection parameters. When the dimension conditions are represented, four combinations exist, such as D_{11} for the combination of left and male encoded items, D_{12} for the combination of left and female items, and so on. During the memory test, participant's first decision is irrespective of the source, and is represented by the parameter that participants recognize the item as old (*D*). Parameter *R* is the probability that a recognized study item is judged as being recollected or Remembered, and the parameter (1-*R*) represents an item being studied as Known (Boywitt & Meiser, 2012a). Following parameter *R*, participants retrieve context features jointly (i.e., stochastic dependence) with probability d^{R} and if both context features are not retrieved jointly $(1 - d^{\mathrm{R}})$, then each source can be retrieved independently with $e^{\mathrm{Source\ SideR}}$ and $e^{\mathrm{Source\ GenderR}}$. Alternatively, if the studied item is judged as known (1-*R*), participants can retrieve items jointly, d^{K}, or independently with $e^{\mathrm{Source\ SideK}}$ and $e^{\mathrm{Source\ GenderK}}$.

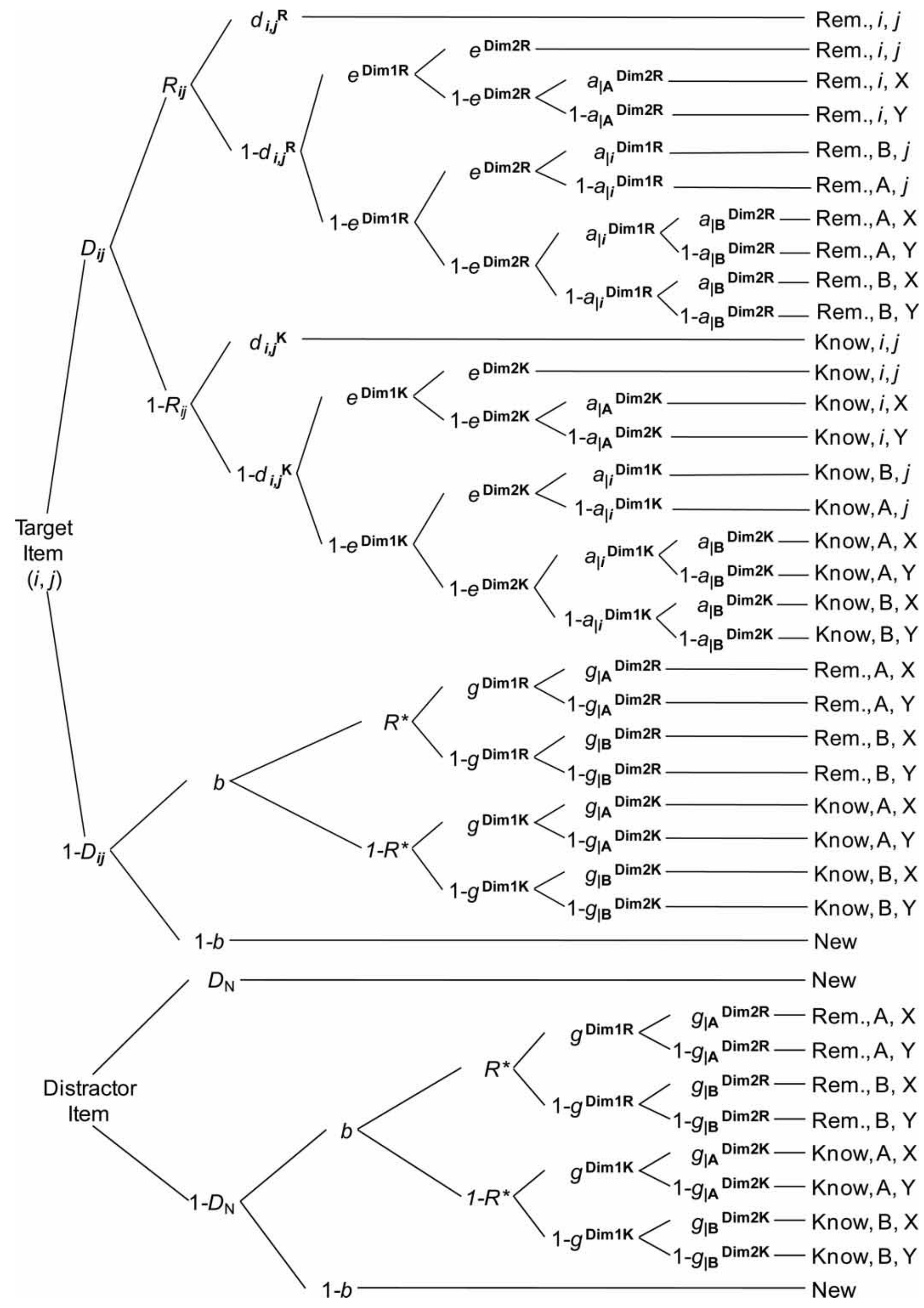

Figure 6. Processing-tree diagram of the multinomial model of multidimensional source memory in Boywitt and Meiser (2012a).

If participants cannot correctly recognize an item as old, the parameter $(1-D)$ reflects this. Moreover these items that are not correctly recognized as old can be categorized as remembered with the probability $R*$. Lastly, there are parameters in the model for correctly guessing the source of an item after participants already called the item old correctly with both remember responses for each source. Specifically, if source A is correctly recognized as old and remembered and source B is guessed correctly as old and Remembered, there are parameters: $a_{|\text{Side}}^{\text{GenderR}}$, $a_{|\text{Gender}}^{\text{SideR}}$, $(1-a_{|\text{Side}}^{\text{GenderR}})$, $(1-a_{|\text{Gender}}^{\text{SideR}})$. Also, for Know responses: $a_{|\text{Side}}^{\text{GenderK}}$, $a_{|\text{Gender}}^{\text{SideK}}$, $(1-a_{|\text{Side}}^{\text{GenderK}})$, $(1-a_{|\text{Gender}}^{\text{SideK}})$. There are also parameters when participants call an item old, but ultimately guess both sources incorrectly but still judged as remembered, $a_{|\text{Gender}}^{\text{GenderR}}$, $(1-a_{|\text{Gender}}^{\text{GenderR}})$, $a_{|\text{Side}}^{\text{SideR}}$, $(1-a_{|\text{Side}}^{\text{SideR}})$ or judged as know, $a_{|\text{Gender}}^{\text{GenderK}}$, $(1-a_{|\text{Gender}}^{\text{GenderK}})$, $a_{|\text{Side}}^{\text{SideK}}$, $(1-a_{|\text{Side}}^{\text{SideK}})$. If participants cannot correctly recognize an item as new, the parameter $(1-D_{\text{N}})$ reflects this. In this parameter, participants can still judge this item as old (parameter b). Lastly, there are parameters with 'g' where the sources of items are guessed as old even though the items are new ($g_{|\text{Side/Gender}}^{\text{SideR}}$, $g_{|\text{Side/Gender}}^{\text{GenderR}}$, $g_{|\text{Side/Gender}}^{\text{SideK}}$, or $g_{|\text{Side/Gender}}^{\text{GenderK}}$).

In the present study, I created a MultiTree input file and determined the frequencies for each parameter. This resulted in five different trees: Tree 1 is for decisions made on Left/Male items, tree 2 is for Left/Female items, tree 3 is for Right/Male items, tree 4 is for Right/Female items and tree 5 is for new items. Within each of the first 4 trees, each equation results in either a correct decision for both source contexts (joint retrieval) with or without guessing, correct independent retrieval of each source context, correct retrieval of only one source context (dimension A or dimension B), correct retrieval of only one source context with guessing and incorrect retrieval of both source contexts. See Appendix B for the equation for each parameter for each tree and the response frequencies for the simultaneous and separate conditions can be found in Table 5 and Table 6.

Table 5. Response Frequencies in the Source Monitoring Task for the Simultaneous Condition, Side and Gender With Remember-Know Judgments for "Old" Items.

	Remember Judgment				Know Judgment				
	Left		Right		Left		Right		
True Category	Female	Male	Female	Male	Female	Male	Female	Male	New
Left									
Female	211	58	76	35	108	71	78	74	265
Male	40	289	36	67	68	140	38	85	213
Right									
Female	49	30	262	57	60	45	128	65	280
Male	32	58	105	205	50	58	64	145	259
New	18	25	27	17	78	84	69	107	2,015

Table 6. Response Frequencies in the Source Monitoring Task for the Separate Condition, Side and Gender With Remember-Know Judgments for "Old" Items.

	Remember Judgment				Know Judgment				
	Left		Right		Left		Right		
True Category	Female	Male	Female	Male	Female	Male	Female	Male	New
Left									
Female	203	103	80	59	105	89	112	89	216
Male	79	215	45	95	69	121	70	96	266
Right									
Female	55	49	201	103	81	56	104	88	319
Male	42	80	95	216	56	85	82	118	282
New	21	18	25	19	55	86	60	87	2,269

In MultiTree, the Dn parameter was set equal to Dlm in order to constrain two of the item identification parameters. The *R* parameters for each source combination were also set equal to one another to make the model more identifiable (Moshagen, 2010). The *R* parameter is the probability that a recognized study item is judged as being recollected or remembered; the *d* parameters for each correct source combination were set equal to one another for recollected and know responses. The response frequencies for the 127 participants analyzed with the behavioral stochastic dependence measures for the simultaneous and separate conditions were entered into the model. See Table 7 for parameter values for the simultaneous and separate conditions. However, the model did not provide a good fit to the data for the simultaneously presented context features, $G^2(15) = 46.98$, $p < .01$, but the model did fit the data for the separately presented context features, $G^2(15) = 13.56$, $p = .56$.

We went a step further and re-entered the response frequencies with the ten participants that were removed (therefore, were not a part of the behavioral data). This resulted in 140 participants (71 participants in the simultaneous condition, 69 participants in the separate condition) and again, the model did not fit the data for the simultaneous condition, $G^2(15) = 33.84$, $p < .01$. However, by including the five participants in the separate condition, the model fit decreased slightly, $G^2(15) = 15.50$, $p = .42$. Therefore, participants that were removed from the sample due to near chance recognition discriminability did not significantly influence the fit of the model in the simultaneous condition or the separate condition. See Table 8 for the parameter values with all 140 participants included.

Table 7. Parameter values estimated with the reparameterized version of the multinomial model

Parameter	Simultaneous Presentation	Separate Presentation
Dlf	.53 [.48-.58]	.68 [.64-.72]
Dlm	.64 [.60-.69]	.62 [.58-.66]
Drf	.55 [.50-.59]	.55 [.51-.59]
Drm	.56 [.53-.59]	.59 [.56-.62]
R	.66 [.63-.69]	.62 [.59-.64]
$R*$	.21 [.17-.25]	.23 [.19-.27]
b	.39 [.36-.42]	.34 [.31-.37]
d^R	.30 [.20-.41]	.14 [.05-.23]
d^K	.12 [-.08-.33]	.00 [-.11-.11]
$e^{1\,R}$	.39 [.27-.50]	.36 [.27-.45]
$e^{1\,K}$	.33 [.12-.53]	.13 [.01-.25]
$e^{2\,R}$	.36 [.25-.48]	.25 [.16-.35]
$e^{2\,K}$	.36 [.16-.56]	.23 [.12-.34]

Table 8. Parameter values estimated with the reparameterized version of the multinomial model of multidimensional source memory with participants not removed from the sample.

Parameter	Simultaneous Presentation	Separate Presentation
Dlf	.49 [.44-.54]	.66 [.62-.71]
Dlm	.61 [.56-.65]	.60 [.56-.64]
Drf	.50 [.45-.55]	.54 [.49-.58]
Drm	.50 [.48-.53]	.58 [.55-.61]
R	.67 [.63-.70]	.62 [.59-.64]
*R**	.35 [.32-.39]	.22 [.18-.26]
b	.49 [.47-.52]	.39 [.36-.42]
d^R	.34 [.22-.46]	.15 [.06-.24]
d^K	.05 [-.24-.34]	.00 [-.11-.11]
$e^{1\ R}$	.42 [.28-.56]	.35 [.26-.44]
$e^{1\ K}$	.45 [.23-.67]	.12 [-.01-.24]
$e^{2\ R}$	.38 [.24-.52]	.25 [.15-.34]
$e^{2\ K}$	.41 [.17-.64]	.24 [.13-.35]

It is important to note that the parameter estimates of greatest interest—those for joint recollection—were in line with previous research in the simultaneous condition. Looking at Table 8, joint source retrieval based on recollection (d^R) was estimated at .30 and joint retrieval based on familiarity or knowing (d^K) was very low at .12. In Table 7 in the separate condition, joint retrieval based on familiarity was low at .00, but joint retrieval based on recollection was estimated to be above chance at .14. This finding is intriguing, because it suggests an above-chance joint recollection for the separate condition that does not agree with the statistical results of the proportion-correct data presented earlier. Looking at Table 8, these parameters do not change significantly when all 140 participants were included. Unfortunately, whether one can put any stock into these patterns of model parameters is undercut by the model's overall bad fit to the response frequency data. While the parameter estimates for joint recollection in the subjective feeling of remembering in the separate condition is intriguing, due to the inconsistencies in the fit of the model with the present sample and the differences between the model parameters and the behavioral data, further hypothesis testing of model parameters across conditions could not be conducted using the multinomial model.

3.5 Working memory measures and source memory

Individual differences were explored with measures of working memory being a potential moderator of source memory performance in general and for stochastic dependence in particular. The source retrieval measures represent the ACSIM scores from Table 2 and also joint retrieval scores created by subtracting retrieval of side information contingent on incorrect gender performance from the analogous measure contingent on correct gender performance (i.e., this difference scores represents a measure of stochastic dependence). See Table 9 for mean OSPAN and change discrimination scores for the simultaneous and separate conditions, as well as range of scores. The partial score of the operation span task did not significantly correlate with the change discrimination measure. Moreover, ACSIM scores of each context source dimension for feelings of recollection and knowing did not significantly correlate with partial score or change discrimination. See Appendix C for correlations between operation span partial score, an average change discrimination score and measures of source retrieval (ACSIM scores and difference scores) for each source context dimension and for R and K responses for the simultaneous condition with only the 127 participants included.

Table 9. Mean partial score on OSPAN and change discrimination for each condition and the range of scores.

	Simultaneous Presentation	Separate Presentation
Partial Score	36.28	35.30
Partial Score Range	[7-50]	[12-48]
Change Discrimination	.37	.35
Change Discrimination Range	[.17-.50]	[.10-.49]

In the simultaneous condition, there were significant correlations between ACSIM Side Remember and Know (*r* = .44), between ACSIM Side and Gender Remember, (*r* = .65), between ACSIM Gender Remember and ACSIM Side Know (*r* = .39), between ACSIM Gender Know and ACSIM Side Remember (*r* = .34), ACSIM Gender and Side Know (*r* = .41) and ACSIM Gender Know and Remember (*r* = .45). There were also significant correlations between Gender and Side Remember difference scores (*r* = .93) and between Gender and Side Know difference scores (*r* = .94).

In the separate condition, the ACSIM Side Remember correlated significantly with the change discrimination measure (*r* = .28). Note that this is the only measure that correlated with any of the individual difference score measures. ACSIM Side Remember score significantly correlated with ACSIM Side Know (*r* = .29) and ACSIM Gender Remember significantly correlated with ACSIM Side Remember (*r* = .46). The Side Remember difference score negatively correlated with the ACSIM Gender Remember score (*r* = -.30). The Side and Gender Remember difference scores significantly correlated (*r* = .90), as well as the Side and Gender Know difference scores, (*r* = .98). The Side Know difference score correlated with ACSIM Side Know (*r* = -.34) and with ACSIM Gender Remember (*r* = .24). This indicates that feelings of Remembering and Knowing for each source dimension correlated. See Appendix D for these correlations in the separate condition.

Significant correlations were found (not reported in Appendices C or D) between the overall change discrimination score and change discrimination set size 4 (*r* = .70), set size 6 (*r* = .80) and set size 8 (*r* = .87). In addition, the different set sizes of the change discrimination task significantly correlated: Set size 4 and 6 (*r* = .30), set size 4 and 8 (*r* = .45) and between set size 6 and 8 (*r* = .56). These patterns remained when all 140 participants were included. Due to these inconsistent patterns showing mostly non-significant correlations between change discrimination, OSPAN scores and ACSIM scores, individual differences in performance based on the simultaneous or separate conditions were not explored any further.

CHAPTER 4. DISCUSSION

In the present study we explored whether making the separate manipulation of two separate word lists, as was done by Boywitt and Meiser (2012a), less extreme with a separation of two trials, would result in stochastic dependence. Previous research has found that presenting two source contexts simultaneously results in joint recollection in the feeling of remembering and not knowing, and not when the two sources are presented separately (Boywitt & Meiser, 2012a). The present study found stochastic dependence in the feeling of remembering in the simultaneous condition, and not in the feeling of knowing. Furthermore, stochastic dependence was not found in the separate condition, as was found by Boywitt and Meiser (2012a). However, using the multinomial model and taking into account the thirteen participants response frequencies that were removed from the behavioral data, the joint remembering retrieval parameter (d^R) in the separate condition was significantly above chance (.14) indicating a measurable amount of joint retrieval in the separate condition. Therefore, this is the first time stochastic dependence has been found in the context of remembering when two source contexts are not presented simultaneously. This was not found in Boywitt and Meiser's (2012a) multinomial modeling work with the more extreme separate manipulation. However, the model fit was questionable, due to the simultaneous model creating a bad fit to the data even though the parameter estimates for that condition were very much in line with previously-published data. In terms of the simultaneous condition, the present results replicated the typical pattern of stochastically dependent context features for recollected responses, but not for the K responses. Therefore, as Boywitt and Meiser (2012a) stated, stochastic dependence or context-context binding may occur based on the attention allocated to stimuli in the encoding phase. Information, whether uni-modal or cross modal, needs to be presented close in time and location to be bound during later memory retrieval due to some binding process occurring at encoding.

4.1 Stochastic dependence at encoding or retrieval

The present research did not address how exactly stochastic dependence occurs however. Starns and Hicks (2008) concluded that stochastic dependence is an encoding phenomenon due to the more attention allocated when source contexts are initially presented, the more likely stochastic dependence is to be found in the feeling of recollection. Specifically, stochastic dependence occurs due to each context being independently bound to the item. For example, the context being presented on the left or right side of the screen is bound to the word 'CHAIR' and this is independent of the context being presented in a male or female voice being bound to the word 'CHAIR.' Alternatively, Boywitt and Meiser (2012a) concluded that stochastic dependence occurs because of context-context binding. That is, the context of location is directly bound to the context of the gender of the voice the word was studied in. Future research needs to address the nature of stochastic dependence more closely to answer whether this binding is the result of encoding or retrieval in a multidimensional source memory paradigm.

4.2 Limitations, implications and future directions

In the present study, the only significant correlation between source memory performance and individual differences performance is between the change discrimination score and the ACSIM Side Remember score in the separate condition. The remaining correlations were not significant. In terms of WMC this is surprising due to the binding hypothesis of working memory (Wilhelm, Hildebrandt, & Oberauer, 2013). The binding hypothesis originated from the view that working memory is a system that builds and maintains rapidly updating binding of information (e.g., list position of items in an encoding phase or objects bound to a location in visual search).

Due to the limited nature of WM, as the number of bindings increase (in the present study, e.g., binding of words to a location and gender of a speaker), WM reaches capacity and harms performance on a later memory test of such context dimensions. Therefore, it is surprising that OSPAN did not correlate with source memory performance.

However, Foster et al., (2014) stated in their review of the shortened WMC measures that the best approach in measuring individual differences of WMC is to administer multiple measures (e.g., symmetry span, operation span, and rotation span). Collectively, these three measures accounted for 87% of the variance in predicting working memory within the first block only. With all three blocks, this predicted variance increases to nearly 100%. In comparison, using only the operation span task, about 50% of the variance predicts working memory performance. This difference in predicting working memory is significant, and therefore future research will utilize more than one measure of WMC to see how WMC correlates with multidimensional source memory.

Furthermore, the present study used a change detection task based on Luck and Vogel (1997) as a measure of visual working memory. In this change detection task, different set sizes of colored squares were displayed twice, with a 500 msec inter-stimulus interval. Participants answered whether a circled square changed color or stayed the same color. Using this task, we did not find change discriminability to correlate with multidimensional source memory, however it did correlate with the OSPAN task. The present task used did not assess participant's ability to bind two different contexts. For example the present task only had the color change occur. But, other change discrimination tasks, such as changing two features in a change detection task would me a better measure of binding. By using this, a better measure of individual differences in binding is possible. van Lamsweerde and Beck (2013) measured participant's ability to bind features using a change detection task where color, shape, or both color and shape (either given instructions for color OR shape), or binding color and shape changed in a change detection task. Furthermore, van Lamsweerde and Beck (2013) presented each stimulus in sequential order. The results showed that the difference in performance between shape only instruction and the binding manipulation was not significant, indicating that binding was not significantly more difficult than only one feature change. Therefore, adapting a change detection paradigm as described above may be a better measure of binding and this could result in a significant correlation between change detection and source memory.

The source memory parameters found using the multinomial model, while in the right direction, were not found to be reliable to the model not fitting to the data. Future research will attempt to manipulate the parameter estimations in order to use multinomial modeling as an additional analysis of source memory and stochastic dependence as was found by Boywitt and Meiser (2012a; 2012b). Interestingly, the joint parameter in the context of remembering for the separate condition was found to be significantly above chance with all participants response frequencies included. Therefore, future research will attempt a replication of the present study to further explore this new finding of stochastic dependence when the source contexts are not presented simultaneously. Specifically, the separate condition in the present study had two intervening trials between each source. This separation can be even smaller by having one intervening trial between each source. Thus, future research will further explore how stochastic dependence may or may not change with only one intervening trial.

Moreover, in the present study, for every test trial participants were asked about the side of the word before the gender of the word and never asked about the gender first. The future replication study will address this by having only one intervening trial, resulting in the location and gender being equally presented first or second. Therefore, asking about the same context first will no longer be an issue. Additionally, the way in which questions are phrased about the source(s) of an item in a multidimensional source memory task can influence item memory. For example, Dobbins and McCarthy (2008) found that by asking whether an item was from only one source (e.g., Source A) results in different source memory accuracy than asking whether an item was from the alternative source (e.g., Source B). The authors found that participants remembered source contexts for items in a heuristic fashion based on the question asked. To take this a step further, one question is what happens to source memory when one source context (side) is stressed as more important to remember during encoding than the second source context (gender). In terms of stochastic dependence, if the stressed source is answered correctly at test, how does this influence memory for the unstressed source? Future research will examine this to assess how strong stochastic dependence is when one source dimension is emphasized over the other.

Lastly, the present study operationalized the separate condition as having two intervening trials between each context. One question is whether stochastic dependence will be found in a separate condition based on the number of intervening trials or due to the length of time. Boywitt and Meiser (2012a) and the present study created a separate condition by manipulating the number of trials between one context (location) and a second (gender). But, the question remains whether stochastic dependence is not found (using behavioral data) due to the number of trials separating the two sources or because of the length of time. Future research should address this important question.

To conclude, the present research provides additional support to Boywitt and Meiser (2012a) that binding of two context features in a source memory paradigm can only occur when two contexts are simultaneously presented and during the feeling of recollection, not knowing. Even with only two trials separating a visual source context and an auditory source context, stochastic dependence was not found with the behavioral data. However, the multinomial model provided some tentative evidence that stochastic dependence can be found in the feeling of remembering in the separate presentation. This provides further evidence that attention allocation, as well as other cognitive processes at encoding are necessary for successful binding of different contexts in a source memory paradigm.

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APPENDIX A. REMEMBER AND KNOW DESCRIPTIONS

"Remember" means that your recognition of the word is accompanied by a conscious, maybe even vivid recollection of its prior occurrence in the learning phase. That is, to "remember" is the ability to become aware again, or to "relive," the earlier experience of the word. For example, if a certain association, idea, or feeling you had during the prior exposure comes to your mind again when you recognize the word, you are "remembering" it.

To "Know" that a word occurred during the learning phase means that you recognize the word but you cannot actually "remember," or recollect, its earlier presentation. That is, your recognition is not accompanied by a conscious revival of the event when the word was presented to you earlier. In other words, you recognize the word from the learning phase, but it does not evoke a personal recollection of your previous experience of the word during the learning phase.

APPENDIX B. SOURCE MEMORY TEST STIMULI TAKEN FROM THE ANEW DATABASE

Access
Account
Alligator
Anchor
Apple
Ball
Balloon
Banana
Barn
Baseball
Basket
Bell
Belt
Bird
Blood
Boot
Bottle
Bread
Broom
Brush
Button
Cake
Camel
Candle
Cannon
Carrot
Chair
Cherry
Chicken
China
Church
Cigar
Circle
Clock
Clown
Corn
Crown
Deer
Desk
Doll
Dress
Eagle
Fable
Health
Heart
Horse
Iron
Kite
Knife
Lamp
Lawyer
Leaf
Lion
Lobster
Lock
Monkey
Moon
Mouse
Mouth
Nail
Nose
Ocean
Pants
Pencil
Piano
Rabbit
Ring
Ruler
Scissor
Screen
Sheep
Shirt
Skunk
Snake
Spider
Spoon
Squirrel
Start
Stool
Table
Teacher
Thimble
Tiger
Toaster
Train
Tree

Fence
Fish
Flower
Foot
Football
Goat
Grape
Hammer
Harp

Truck
Trumpet
Turtle
Vase
Watch
Water
Wheel
Whistle
Window

APPENDIX C. EQUATIONS FOR MULTITREE SOFTWARE

Parameters and Equations for MultiTree Software.

1	LMLMR	Dlm*Rlm*dlmR
1	LMLMR	Dlm*Rlm*(1-dlmR)*eDim1R*eDim2R
1	LMLMR	Dlm*Rlm*(1-dlmR)*eDim1R*(1-eDim2R)*aDim2R
1	LMLFR	Dlm*Rlm*(1-dlmR)*eDim1R*(1-eDim2R)*(1-aDim2R)
1	LMLMR	Dlm*Rlm*(1-dlmR)*(1-eDim1R)*eDim2R*aDim1R
1	LMRMR	Dlm*Rlm*(1-dlmR)*(1-eDim1R)*eDim2R*(1-aDim1R)
1	LMLMR	Dlm*Rlm*(1-dlmR)*(1-eDim1R)*(1- eDim2R)*aDim1R*aDim2GR
1	LMLFR	Dlm*Rlm*(1-dlmR)*(1-eDim1R)*(1- eDim2R)*aDim1R*(1-aDim2GR)
1	LMRMR	Dlm*Rlm*(1-dlmR)*(1-eDim1R)*(1-eDim2R)*(1- aDim1R)*aDim2GR
1	LMRFR	Dlm*Rlm*(1-dlmR)*(1-eDim1R)*(1-eDim2R)*(1- aDim1R)*(1-aDim2GR)
1	LMLMK	Dlm*(1-Rlm)*dlmK
1	LMLMK	Dlm*(1-Rlm)*(1-dlmK)*eDim1K*eDim2K
1	LMLMK	Dlm*(1-Rlm)*(1-dlmK)*eDim1K*(1-eDim2K)*aDim2K
1	LMLFK	Dlm*(1-Rlm)*(1-dlmK)*eDim1K*(1-eDim2K)*(1- aDim2K)
1	LMLMK	Dlm*(1-Rlm)*(1-dlmK)*(1-eDim1K)*(eDim2K)*aDim1K
1	LMRMK	Dlm*(1-Rlm)*(1-dlmK)*(1-eDim1K)*(eDim2K)*(1- aDim1K)
1	LMLMK	Dlm*(1-Rlm)*(1-dlmK)*(1-eDim1K)*(1- eDim2K)*aDim1K*aDim2GK
1	LMLFK	Dlm*(1-Rlm)*(1-dlmK)*(1-eDim1K)*(1- eDim2K)*aDim1K*(1-aDim2GK)
1	LMRMK	Dlm*(1-Rlm)*(1-dlmK)*(1-eDim1K)*(1-eDim2K)*(1- aDim1K)*aDim2GK
1	LMRFK	Dlm*(1-Rlm)*(1-dlmK)*(1-eDim1K)*(1-eDim2K)*(1- aDim1K)*(1-aDim2GK)
1	LMLMR	(1-Dlm)*b*R*gDim1R*gDim2R
1	LMLFR	(1-Dlm)*b*R*gDim1R*(1-gDim2R)
1	LMRMR	(1-Dlm)*b*R*(1-gDim1R)*gDim2GR
1	LMRFR	(1-Dlm)*b*R*(1-gDim1R)*(1-gDim2GR)
1	LMLMK	(1-Dlm)*b*(1-R)*gDim1K*gDim2K
1	LMLFK	(1-Dlm)*b*(1-R)*gDim1K*(1-gDim2K)
1	LMRMK	(1-Dlm)*b*(1-R)*(1-gDim1K)*gDim2GK
1	LMRFK	(1-Dlm)*b*(1-R)*(1-gDim1K)*(1-gDim2GK)
1	LMN	(1-Dlm)*(1-b)
2	LFLFR	Dlf*Rlf*dlfR
2	LFLFR	Dlf*Rlf*(1-dlfR)*eDim1R*eDim2R
2	LFLMR	Dlf*Rlf*(1-dlfR)*eDim1R*(1-eDim2R)*aDim2R
2	LFLFR	Dlf*Rlf*(1-dlfR)*eDim1R*(1-eDim2R)*(1-aDim2R)
2	LFLFR	Dlf*Rlf*(1-dlfR)*(1-eDim1R)*eDim2R*aDim1R
2	LFRFR	Dlf*Rlf*(1-dlfR)*(1-eDim1R)*eDim2R*(1-aDim1R)
2	LFLMR	Dlf*Rlf*(1-dlfR)*(1-eDim1R)*(1- eDim2R)*aDim1R*aDim2GR
2	LFLFR	Dlf*Rlf*(1-dlfR)*(1-eDim1R)*(1-eDim2R)*aDim1R*(1-
2	LFRMR	Dlf*Rlf*(1-dlfR)*(1-eDim1R)*(1-eDim2R)*(1- aDim1R)*aDim2GR
2	LFRFR	Dlf*Rlf*(1-dlfR)*(1-eDim1R)*(1-eDim2R)*(1- aDim1R)*(1-aDim2GR)
2	LFLFK	Dlf*(1-Rlf)*dlfK
2	LFLFK	Dlf*(1-Rlf)*(1-dlfK)*eDim1K*eDim2K
2	LFLMK	Dlf*(1-Rlf)*(1-dlfK)*eDim1K*(1-eDim2K)*aDim2K
2	LFLFK	Dlf*(1-Rlf)*(1-dlfK)*eDim1K*(1-eDim2K)*(1-aDim2K)
2	LFLFK	Dlf*(1-Rlf)*(1-dlfK)*(1-eDim1K)*(eDim2K)*aDim1K
2	LFRFK	Dlf*(1-Rlf)*(1-dlfK)*(1-eDim1K)*(eDim2K)*(1-aDim1K)
2	LFLMK	Dlf*(1-Rlf)*(1-dlfK)*(1-eDim1K)*(1- eDim2K)*aDim1K*aDim2GK

2	LFLFK	Dlf*(1-Rlf)*(1-dlfK)*(1-eDim1K)*(1- eDim2K)*aDim1K*(1- eDim2K)*aDim1K*(1-aDim2GK)
2	LFRMK	Dlf*(1-Rlf)*(1-dlfK)*(1-eDim1K)*(1-eDim2K)*(1- aDim1K)*aDim2GK
2	LFRFK	Dlf*(1-Rlf)*(1-dlfK)*(1-eDim1K)*(1-eDim2K)*(1- aDim1K)*(1-aDim2GK)
2	LFLMR	(1-Dlf)*b*R*gDim1R*gDim2R
2	LFLFR	(1-Dlf)*b*R*gDim1R*(1-gDim2R)
2	LFRMR	(1-Dlf)*b*R*(1-gDim1R)*gDim2GR
2	LFRFR	(1-Dlf)*b*R*(1-gDim1R)*(1-gDim2GR)
2	LFLMK	(1-Dlf)*b*(1-R)*gDim1K*gDim2K
2	LFLFK	(1-Dlf)*b*(1-R)*gDim1K*(1-gDim2K)
2	LFRMK	(1-Dlf)*b*(1-R)*(1-gDim1K)*gDim2GK
2	LFRFK	(1-Dlf)*b*(1-R)*(1-gDim1K)*(1-gDim2GK)
2	LFN	(1-Dlf)*(1-b)
3	RMRMR	Drm*Rrm*drmR
3	RMRMR	Drm*Rrm*(1-drmR)*eDim1R*eDim2R
3	RMRMR	Drm*Rrm*(1-drmR)*eDim1R*(1-eDim2R)*aDim2R
3	RMRFR	Drm*Rrm*(1-drmR)*eDim1R*(1-eDim2R)*(1-aDim2R)
3	RMLMR	Drm*Rrm*(1-drmR)*(1-eDim1R)*eDim2R*aDim1R
3	RMRMR	Drm*Rrm*(1-drmR)*(1-eDim1R)*eDim2R*(1-aDim1R)
3	RMLMR	Drm*Rrm*(1-drmR)*(1-eDim1R)*(1- eDim2R)*aDim1R*aDim2GR
3	RMLFR	Drm*Rrm*(1-drmR)*(1-eDim1R)*(1- eDim2R)*aDim1R*(1-aDim2GR)
3	RMRMR	Drm*Rrm*(1-drmR)*(1-eDim1R)*(1-eDim2R)*(1- aDim1R)*aDim2GR
3	RMRFR	Drm*Rrm*(1-drmR)*(1-eDim1R)*(1-eDim2R)*(1- aDim1R)*(1-aDim2GR)
3	RMRMK	Drm*(1-Rrm)*drmK
3	RMRMK	Drm*(1-Rrm)*(1-drmK)*eDim1K*eDim2K
3	RMRMK	Drm*(1-Rrm)*(1-drmK)*eDim1K*(1-eDim2K)*aDim2K
3	RMRFK	Drm*(1-Rrm)*(1-drmK)*eDim1K*(1-eDim2K)*(1- aDim2K)
3	RMLMK	Drm*(1-Rrm)*(1-drmK)*(1-eDim1K)*(eDim2K)*aDim1K
3	RMRMK	Drm*(1-Rrm)*(1-drmK)*(1-eDim1K)*(eDim2K)*(1- aDim1K)
3	RMLMK	Drm*(1-Rrm)*(1-drmK)*(1-eDim1K)*(1- eDim2K)*aDim1K*aDim2GK
3	RMLFK	Drm*(1-Rrm)*(1-drmK)*(1-eDim1K)*(1- eDim2K)*aDim1K*(1-aDim2GK)
3	RMRMK	Drm*(1-Rrm)*(1-drmK)*(1-eDim1K)*(1-eDim2K)*(1- aDim1K)*aDim2GK
3	RMRFK	Drm*(1-Rrm)*(1-drmK)*(1-eDim1K)*(1-eDim2K)*(1- aDim1K)*(1-aDim2GK)
3	RMLMR	(1-Drm)*b*R*gDim1R*gDim2R
3	RMLFR	(1-Drm)*b*R*gDim1R*(1-gDim2R)
3	RMRMR	(1-Drm)*b*R*(1-gDim1R)*gDim2GR
3	RMRFR	(1-Drm)*b*R*(1-gDim1R)*(1-gDim2GR)
3	RMLMK	(1-Drm)*b*(1-R)*gDim1K*gDim2K
3	RMLFK	(1-Drm)*b*(1-R)*gDim1K*(1-gDim2K)
3	RMRMK	(1-Drm)*b*(1-R)*(1-gDim1K)*gDim2GK
3	RMRFK	(1-Drm)*b*(1-R)*(1-gDim1K)*(1-gDim2GK)
3	RMN	(1-Drm)*(1-b)
4	RFRFR	Drf*Rrf*drfR
4	RFRFR	Drf*Rrf*(1-drfR)*eDim1R*eDim2R
4	RFRMR	Drf*Rrf*(1-drfR)*eDim1R*(1-eDim2R)*aDim2R
4	RFRFR	Drf*Rrf*(1-drfR)*eDim1R*(1-eDim2R)*(1-aDim2R)
4	RFLFR	Drf*Rrf*(1-drfR)*(1-eDim1R)*eDim2R*aDim1R
4	RFRFR	Drf*Rrf*(1-drfR)*(1-eDim1R)*eDim2R*(1-aDim1R)
4	RFLMR	Drf*Rrf*(1-drfR)*(1-eDim1R)*(1- eDim2R)*aDim1R*aDim2GR
4	RFLFR	Drf*Rrf*(1-drfR)*(1-eDim1R)*(1-eDim2R)*aDim1R*(1- aDim2GR)
4	RFRMR	Drf*Rrf*(1-drfR)*(1-eDim1R)*(1-eDim2R)*(1- aDim1R)*aDim2GR

4	RFRFR	Drf*Rrf*(1-drfR)*(1-eDim1R)*(1-eDim2R)*(1- aDim1R)*(1-aDim2GR)
4	RFRFK	Drf*(1-Rrf)*drfK
4	RFRFK	Drf*(1-Rrf)*(1-drfK)*eDim1K*eDim2K
4	RFRMK	Drf*(1-Rrf)*(1-drfK)*eDim1K*(1-eDim2K)*aDim2K
4	RFRFK	Drf*(1-Rrf)*(1-drfK)*eDim1K*(1-eDim2K)*(1-aDim2K)
4	RFLFK	Drf*(1-Rrf)*(1-drfK)*(1-eDim1K)*(eDim2K)*aDim1K
4	RFRFK	Drf*(1-Rrf)*(1-drfK)*(1-eDim1K)*(eDim2K)*(1- aDim1K)
4	RFLMK	Drf*(1-Rrf)*(1-drfK)*(1-eDim1K)*(1- eDim2K)*aDim1K*aDim2GK
4	RFLFK	Drf*(1-Rrf)*(1-drfK)*(1-eDim1K)*(1- eDim2K)*aDim1K*(1-aDim2GK)
4	RFRMK	Drf*(1-Rrf)*(1-drfK)*(1-eDim1K)*(1-eDim2K)*(1- aDim1K)*aDim2GK
4	RFRFK	Drf*(1-Rrf)*(1-drfK)*(1-eDim1K)*(1-eDim2K)*(1- aDim1K)*(1-aDim2GK)
4	RFLMR	(1-Drf)*b*R*gDim1R*gDim2R
4	RFLFR	(1-Drf)*b*R*gDim1R*(1-gDim2R)
4	RFRMR	(1-Drf)*b*R*(1-gDim1R)*gDim2GR
4	RFRFR	(1-Drf)*b*R*(1-gDim1R)*(1-gDim2GR)
4	RFLMK	(1-Drf)*b*(1-R)*gDim1K*gDim2K
4	RFLFK	(1-Drf)*b*(1-R)*gDim1K*(1-gDim2K)
4	RFRMK	(1-Drf)*b*(1-R)*(1-gDim1K)*gDim2GK
4	RFRFK	(1-Drf)*b*(1-R)*(1-gDim1K)*(1-gDim2GK)
4	RFN	(1-Drf)*(1-b)
5	NN	Dn
5	NNLMR	(1-Dn)*b*R*gDim1R*gDim2R
5	NNLFR	(1-Dn)*b*R*gDim1R*(1-gDim2R)
5	NNRMR	(1-Dn)*b*R*(1-gDim1R)*gDim2GR
5	NNRFR	(1-Dn)*b*R*(1-gDim1R)*(1-gDim2GR)
5	NNLMK	(1-Dn)*b*(1-R)*gDim1K*gDim2K
5	NNLFK	(1-Dn)*b*(1-R)*gDim1K*(1-gDim2K)
5	NNRMK	(1-Dn)*b*(1-R)*(1-gDim1K)*gDim2GK
5	NNRFK	(1-Dn)*b*(1-R)*(1-gDim1K)*(1-gDim2GK)
5	NN	(1-Dn)*(1-b)

APPENDIX D. CORRELATIONS FOR SIMULTANEOUS CONDITION

	1	2	3	4	5	6	7	8	9	10
1 Partial Score	1									
2 Change Discrimination	.02	1								
3 ACSIM Side Remember	.06	.04	1							
4 ACSIM Side Know	.02	-.06	.44*	1						
5 ACSIM Gender Remember	.06	-.01	.65*	.39*	1					
6 ACSIM Gender Know	-.02	-.25	.34*	.41*	.45*	1				
7 Side Remember Difference	.01	.17	.14	-.03	.08	.06	1			
8 Side Know Difference Score	.02	.03	.06	-.01	-.05	-.00	.03	1		
9 Gender Remember Difference Score	.01	.16	.21	.02	.11	.09	.93*	.16	1	
10 Gender Know Difference Score	.03	.04	.07	.02	-.06	.01	.05	.94*	.18	1

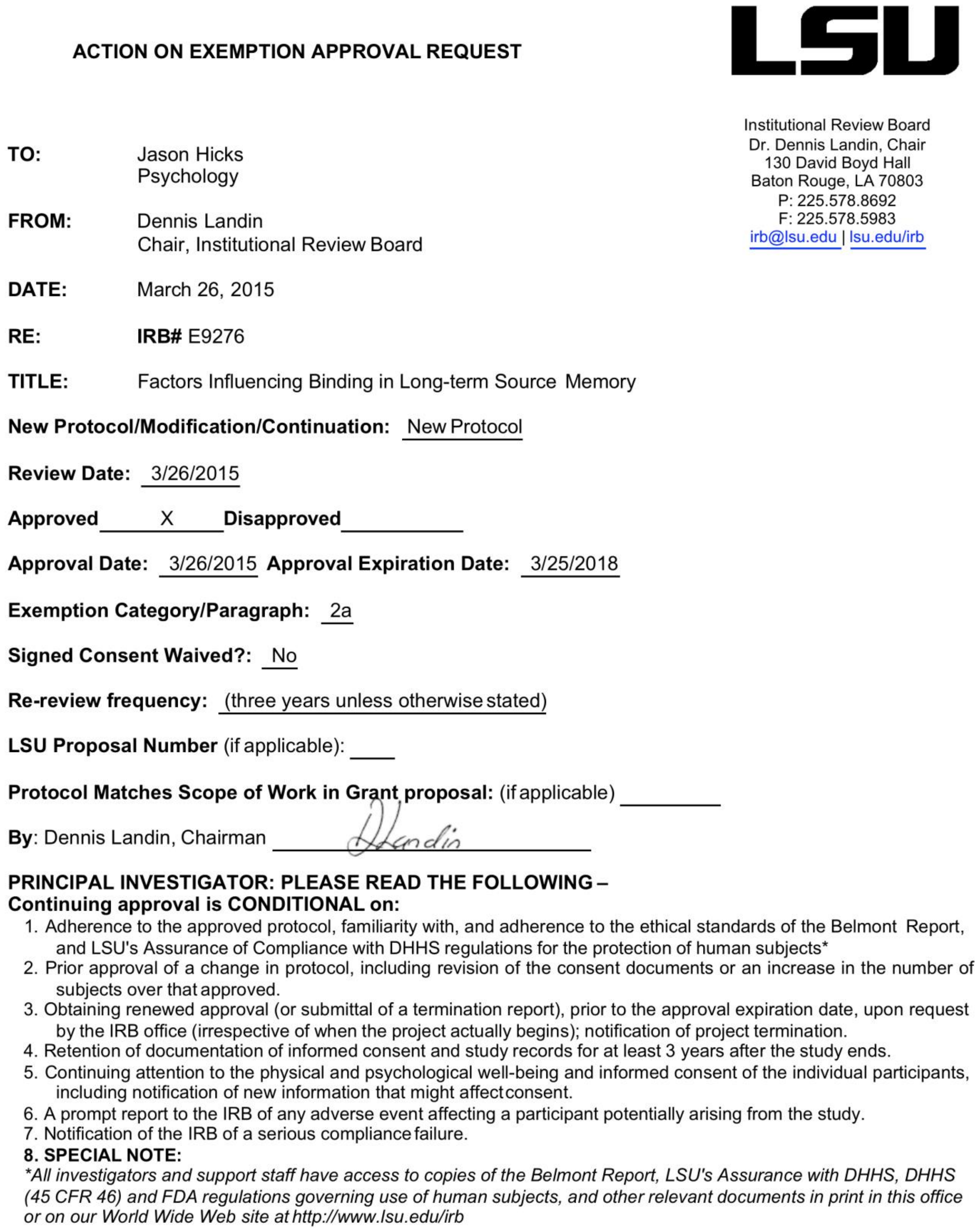
* for correlations significant with $p < .05$.

APPENDIX E. CORRELATIONS FOR SEPARATE CONDITION

	1	2	3	4	5	6	7	8	9	10
1 Partial Score	1									
2 Change Discrimination	.04	1								
3 ACSIM Side Remember	.09	.28*	1							
4 ACSIM Side Know	-.09	-.13	.29*	1						
5 ACSIM Gender Remember	-.09	.20	.46*	.17	1					
6 ACSIM Gender Know	.01	.07	.12	.09	.10	1				
7 Side Remember Difference	.05	.23	-.13	.06	-.30*	-.08	1			
8 Side Know Difference Score	-.04	.17	.03	-.34*	.24*	.02	-.15	1		
9 Gender Remember Difference Score	.07	.23	-.08	.10	-.17	-.21	.90*	-.17	1	
10 Gender Know Difference Score	-.06	.11	-.01	-.41*	.24	.04	-.17	.98*	-.20	1

* for correlations significant with *p* < .05.

APPENDIX F. IRB EXEMPTION FORM



ACTION ON EXEMPTION APPROVAL REQUEST

LSU

Institutional Review Board
Dr. Dennis Landin, Chair
130 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
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irb@lsu.edu | lsu.edu/irb

TO: Jason Hicks
Psychology

FROM: Dennis Landin
Chair, Institutional Review Board

DATE: March 26, 2015

RE: **IRB#** E9276

TITLE: Factors Influencing Binding in Long-term Source Memory

New Protocol/Modification/Continuation: New Protocol

Review Date: 3/26/2015

Approved X **Disapproved** __________

Approval Date: 3/26/2015 **Approval Expiration Date:** 3/25/2018

Exemption Category/Paragraph: 2a

Signed Consent Waived?: No

Re-review frequency: (three years unless otherwise stated)

LSU Proposal Number (if applicable): ____

Protocol Matches Scope of Work in Grant proposal: (if applicable) _________

By: Dennis Landin, Chairman DLandin

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –
Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. **SPECIAL NOTE:**

**All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at http://www.lsu.edu/irb*

VITA

Samantha Nicole Spitler is a third year student in the cognitive and brain sciences program at Louisiana State University (LSU), where she anticipates earning a Doctor of Philosophy in Psychology under the mentorship of Dr. Jason Hicks. Ms. Spitler received her bachelors of Science degree from St. John Fisher College in 2011, graduating cum laude. During her senior year at St. John Fisher College, she completed her honors thesis under the supervision of Dr. Ryan Thibodeau examining the relationship between false memories and fantasy proneness using the Deese-Roediger McDermott (DRM) paradigm. Ms. Spitler received her masters of Science degree from Georgia Regents University in 2013. During her time at LSU, Ms. Spitler has explored her interests in the underlying cognitive mechanisms of event-based prospective memory using mouse tracking, as well as how commission errors occur in a prospective memory paradigm. Moreover, she has developed a particular interest in cross-modal binding in multidimensional source memory and the encoding and retrieval dynamics necessary for successful binding or stochastic dependence to occur.