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Memory for elements of a complex scene : binding and the influence of attention

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MEMORY FOR ELEMENTS OF A COMPLEX SCENE: BINDING AND THE INFLUENCE
OF ATTENTION

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Abstract

Memory of a complex event includes a multitude of features (e.g., objects, people, and actions) as well as the overall context (e.g., going to a picnic). To recall a complex event you must bind together these features and context into an episodic memory representation. This process of binding creates the subjective experience that certain details belong together. In two experiments, I examined whether particular types of information are bound together (object-to-object, object-to-context) within a memory representation of a scene and how attention may influence this process. Participants viewed a series of scenes and their attention was drawn to some objects (focus of attention), but not others. At test, they attempted to identify previously seen objects that were cued by objects-only, context-only, or a blurred context. Exp. 1 provided evidence of object-to-object binding when the objects used as cues and targets had been in the focus of attention at encoding. Exp. 2 revealed evidence of object-to-context binding, in that context cues enhanced memory for target objects whether or not the objects had been in the focus of attention at encoding. Altogether, these studies demonstrate the importance of attentional deployment in determining which components of an episodic memory will bind together.

Introduction

Sometimes when we remember events from our lives, we feel as if we were re-experiencing the event all over again (Tulving, 1985). For example, suppose you are remembering your college graduation. You might vividly recall the person sitting next to you, the color of your robes, the annoying way your cap kept falling off, the sound of your name being called, and your feelings upon receiving your diploma. Remembering like this feels like you are watching a film; as if the memory is a coherent, dynamic whole. In fact, this experience is so strong and commonplace that it may be one reason that many people believe that memory behaves like a video camera (e.g., Simons & Chabris, 2011). Yet, this feeling is misleading. Instead, memories for events are comprised of many independent components that are processed and represented separately (Buckner, 2003; Koutstaal & Cavendish, 2006; Schacter, Norman, & Koutstaal, 1998; Shiffrin, 2003).

If memory of an event is actually made up of many individual components, where does the feeling of coherence come from? The answer appears to be in the relationships or bindings between individual memory components (e.g., Mather, 2007; Starns & Hicks, 2008). These bindings, created at the time of encoding, appear critical for enabling accurate recollection (Johnson, 1983, 1992). For example, in order to accurately remember that it was your seatmate at graduation who told you he felt sick, you would need to have bound that information to other information about him (e.g., his face, his voice). Conversely, problems with binding may lead people to forget details or make source-monitoring errors (e.g., in the above situation, falsely remembering it was your brother that felt sick; Lampinen, Meier, Arnal, & Leding, 2005; Lampinen, Ryals, & Smith, 2008; Lyle & Johnson, 2006). Understanding the conditions that

affect the reliability of binding is thus of great theoretical and applied interest, and is the focus of the following study.

The current study examines the role of binding in the representation of memories of complex events. To do this, participants studied complex visual scenes that are much like those encountered in real-world events. These scenes had information that was represented at different levels (see Figure 1). As represented in the figure, a scene can include information about its theme or gist, the background or context, as well as relationships between groups of items or individual items themselves.
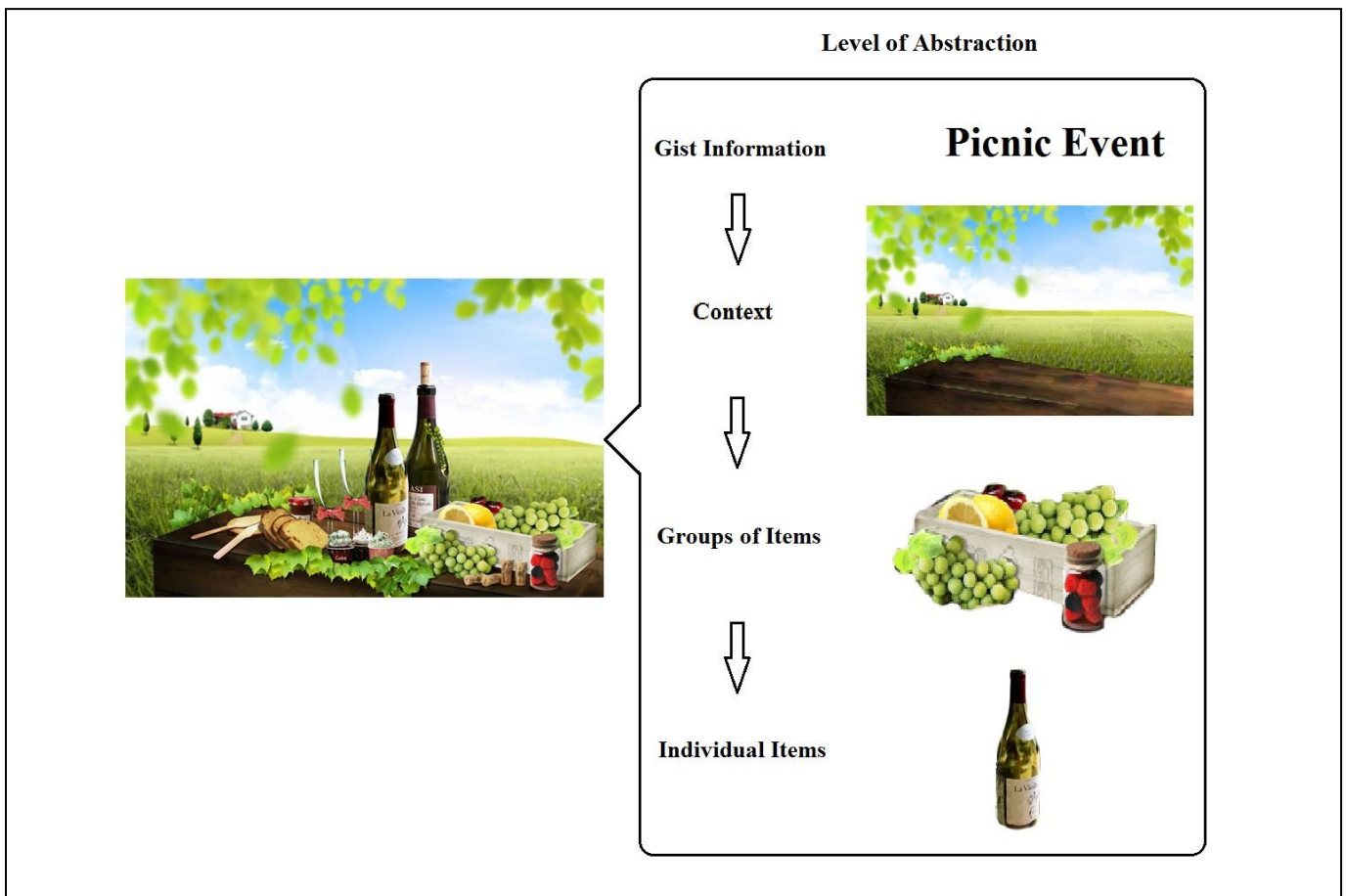

Figure 1. Graphic example of the differing levels of abstraction for information in a complex scene.

There are two main issues explored in this study. The first issue is how different components of complex memories are related to each other. One possible structure of an event memory is that individual components are relatively independent; in other words, they are bound to the overall gist or theme (e.g., a picnic), but are not associated with one another. Alternatively, you could imagine that these components are relatively dependent; that is, they are linked to other memory components from that event (e.g., the grapes and the wine bottle) as well as to the overall gist. To examine this issue, I assessed how cuing one aspect of an event influences the retrieval of another. The second issue concerns the role of attention on binding processes. There are two aspects to this issue. The first concerns the *focus* of attention. In event memory research, it is common to differentiate between central objects (i.e. objects that are the focus of attention) and peripheral objects (i.e. objects away from the focus of attention; Brown, 2003; Levine & Edelstein, 2009). In this study, I examined whether the binding between objects differed as a function of whether objects had been the focus of attention or not. The other aspect concerns the *nature* of attention paid to an object. Prior researchers have argued that individual components of an event need to be actively linked to one another for binding to occur (Johnson, 1983, 1992; Morey, 2011). In other words, binding should not occur between different elements (e.g., objects) unless attention is paid to *their relationship* at the time of encoding. In order to examine this question, the likelihood that participants focus on how objects within a scene are related to each other was manipulated.

Practical Motivations for the Current Study

Although the focus of this research concerns the exploration of basic memory questions, it is also important to note that answering these types of questions may motivate useful applications for real-world situations where memory performance is particularly consequential. For example,

it is important for investigators to elicit accurate and complete reports about events from witnesses. Understanding how episodic memories are structured can potentially provide ways of enhancing or evaluating witness reports. For example, knowing which type of event information might better cue other aspects of the event could be useful in the context of an interview. In addition, a common problem for investigators is that they often have no way of assessing the accuracy for elements of a witness's statement. However, suppose that an investigator can verify the accuracy of a particular detail. Knowing which aspects of an event are likely to be bound to this detail may allow the investigator to use this information to assess the likely accuracy of other unverified details provided by the witness.

Topics Discussed

In the remainder of this introduction, I will first summarize the types of evidence that have been interpreted as evidence for binding in memory. Second, I will discuss relevant research about the type of information that is bound in memory. This section is further divided into research that addresses how specific features (e.g., color, size, location) of an individual object are related to one another, research that examines the relationship between context and item memory, and the relationship between groups of objects and individual items. I will then introduce two relevant theoretical models along with a brief description of the current study's methods. These models, as well as previous experimental findings, will provide the basis for the hypotheses of the current study. Finally, I will describe the design and hypotheses of the current study.

<center>**Literature Review**</center>

Research Findings Interpreted as Binding

In the research literature, three types of empirical findings have been interpreted as providing evidence for memorial binding. First, it has been argued that evidence for binding is obtained when providing one piece of information enables the successful retrieval of another related detail (Hollingworth, 2007; Starns & Hicks, 2005, 2008). An example of this is provided by research from the associative memory literature (e.g., Epstein & Phillips, 1976; Kleinsmith & Kaplan, 1963; Paivio, 1965). In this type of research, participants are asked to study pairs of items (e.g., words) and then are given one item in the pair (i.e. one word) to use as a cue to recall the missing item. Evidence for associative learning (i.e. binding) is demonstrated when participants use this cue to successfully recall the missing component of the item pair. Similarly, a second way binding is demonstrated occurs whenever the retrieval of an item is reduced by either changing or removing other related items at test (i.e., modifying the available cues; Godden & Baddeley, 1975; Hollingworth, 2007). A classic example of this comes from research into context effects. Godden and Baddeley (1975) found that the recall of words learned in one environment (i.e. underwater) was impaired when testing took place in a different environment (i.e. above water). A third, though arguably weaker, form of binding evidence may be obtained when the accurate recollection of an item is positively correlated with the accurate recollection of another studied item (Fisher & Cuervo, 1983; Meiser & Bröder, 2002; Wells & Leippe, 1981). For example, Meiser and Bröder (2002) found that when a word was correctly recognized as "old", accuracy for the word's original font color and its location on the screen was positively correlated. They interpreted this finding as evidence that these features (color and location) were

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bound to one another. In the next section, I will discuss the specific findings of the prior work that use these different types of evidence to argue for the presence or absence of binding.

Binding Research: Features of an Object

A considerable amount of research in visual perception has examined what has come to be known as "the binding problem" (Brockmole & Franconeri, 2009; Treisman, 1999; Treisman & Gelade, 1980). At its core, this problem refers to the question of how people are able to integrate visual information, such as colors, shapes, and features, into coherent holistic representations. That is, how do the features of an object (e.g., color, shape, location etc.) become bound to that object? Most of this prior research has examined binding in relatively simple visual stimuli (i.e., they contain few features; e.g., shapes, colors) over short delays, using measures of change detection and visual search (Eng, Chen & Jiang, 2005; Oakes, Ross-Sheehy, & Luck, 2006; Treisman & Zhang, 2006; Vidal, Gauchou, Tallon-Baudry, & O'Regan, 2005). The focus of this research literature involves binding as it relates to visual perception, visual short-term memory, and visual working memory. In contrast, the current work differs in two ways. First, the emphasis is on associations at a higher level – the binding between objects (object-to-object binding) and between an object and its context (object-to-context binding). Second, the central interest is how this information is represented in long-term memory. Although there are relatively few studies examining binding at this higher level (which are reviewed later), there is research on feature-to-feature binding within objects in long-term memory (Meiser & Bröder, 2002; Meiser, Sattler, & Weißer, 2008; Starns & Hicks, 2005, 2008; Uncapher, Otten, & Rugg, 2006; Vogt & Bröder, 2007). This research is particularly relevant to the current studies because of the conceptual and methodological issues that are raised.

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The central question of research on feature binding in long-term memory concerns whether features of an object are bound to each other or merely bound to the object itself (see Figure 2). Some researchers argue that their findings support a memory structure where the features of an object are bound to one another and to the object (see Figure 2A for an illustration of this *binding hypothesis*; Meiser & Bröder, 2002; Meiser et al., 2008; Uncapher et al., 2006). The key finding of these studies is that recalling one feature of a word at test, such as font size, font color and word location, is significantly correlated with recalling another feature of that word.

For example, Meiser et al. (2008) presented participants with a series of words that were displayed in one of two font sizes and in one of two locations on the screen. During a subsequent memory test, participants were asked to make old/new judgments for these studied items. When an item was judged to be old, participants were also asked to make a remember/know judgment (i.e. a distinct recollection of the word [remember] vs. feeling that the word seems familiar [know]) and provide the original font size and word location for that item. Meiser et al., found that the features of studied items labeled as "remembered" were stochastically dependent on one another; that is, accuracy for one feature was significantly related to accuracy for the other feature. This pattern was not obtained for items that were simply "known" to be studied. Similarly, Uncapher et al. (2006) had participants study a series of concrete nouns that were located in one of four locations on the screen and presented in one of five colors. For each word, participants were asked to make a living/non-living judgment about the item. To ensure that participants were paying attention to the color feature, when a word appeared in black, they were asked to make a judgment concerning that item's size rather than a living/non-living judgment. At test, participants were presented with a list of studied and non-studied words and asked to

make an old/new recognition judgment for each item (black items were not included in the test lists). When an item was judged "old", participants were asked to report that item's original location and color. Like Meiser et al., Uncapher et al. found that accurate memory for these features was stochastically dependent.

Starns and Hicks (2005, 2008) argued that previous research examining this question suffers from a significant methodological flaw. Because participants are always provided with the object information (i.e. the word itself), this information could have been used as a cue for both features. Consequentially, any correlations found between the correct recognition of features may not reflect binding; instead, this finding may have been due to the strength of the memory for the object, including its contextual features (the *variable strength* hypothesis, see Figure 2B). Thus, they contend that the stronger the memory for the object, the greater the probability that the object will cue these contextual features.
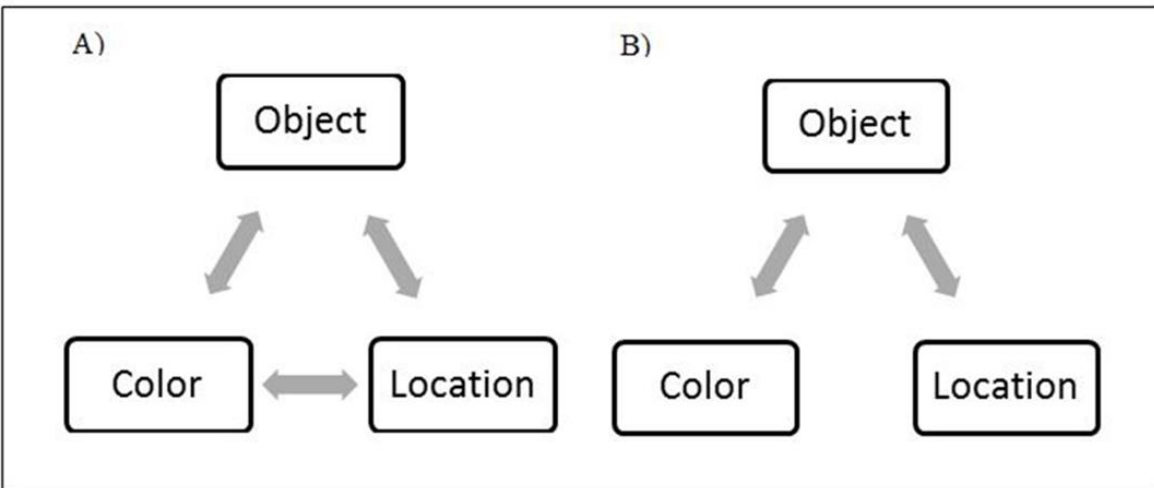
Figure 2. Comparison between (A) binding hypothesis and (B) variable strength hypothesis. Both figures represent theories concerning binding of features to an object. Configuration A represents the binding hypothesis, which argues that features are bound to both the object and one another. Configuration B represents the variable strength hypothesis, which suggests that because features are bound to the object, memory strength for the object determines the likelihood they will both be recalled.

To address this possibility, Starns and Hicks (2008; see also 2005) conducted a series of experiments using one feature of an object as a test cue for the other feature of that object. In each experiment, participants studied a series of simple line drawings (e.g., *hairbrush*) where each drawing was presented in a different color and location. Specifically, participants were shown a screen that had been divided into a 6 X 6 grid. In sequence, a series of colored objects appeared in separate grid locations. No two objects were presented in either the same color or the same grid location. In other words, each color as well as each grid location was associated with only one studied object. Consequently, each presentation of a line drawing created one unique feature pair (e.g., turquoise-position 1 in the grid). Afterwards, participants completed an old/new recognition test for these studied items. Critically, this old/new recognition test did not provide the actual item. Rather, participants were given a color and/or a location and asked if *any* item was studied in that color or that location. For example, in their color condition, participants were given trials where a color swath, appeared outside of the grid (i.e. uncued trial), and trials where a color marker was presented within the grid (i.e. location cued trial). For both trial types, participants were asked to indicate if any line drawing had been studied in that color regardless of its location. They argued that if memory for one feature is dependent on another, providing the corresponding location of a studied color will enhance memory for that color as compared to uncued trials (e.g., accurately judging turquoise as old will be increased if the turquoise marker is in its original studied position). Overall, they found that performance on cued trials was no different from performance on uncued trials. Providing correct color or location information did not improve participants' recognition of the other feature of a studied item. They interpreted this finding, as well as findings from other experiments within this study, to suggest that color and location details are bound to the object, but are not bound to one another (Starns & Hicks, 2005,

2008; Vogt & Bröder, 2007). Thus, their results were consistent with the variable strength hypothesis.

Although work by Starns and Hicks (2005, 2008) seems to strongly suggest that features are not bound to each other, other researchers have argued that there is data to support the binding hypothesis. Specifically, Uncapher et al. (2006) used conditionalized source accuracy rates for individual features to assess whether the retrieval of one feature was affected by the successful retrieval of the other feature. They found that accuracy for these feature judgments were not independent. Furthermore, they supplemented this behavioral data with fMRI measures that also provided evidence for feature binding. They found that successful retrieval of both the location and color of an item was linked to a unique activation pattern (activation in the intra-parietal sulcus), which was not found for the retrieval of any other items (items associated with the correct location or the correct color judgment, but not both). Further, this unique area of activation has been previously linked to perceptual binding.

They argue that the binding found in this work was influenced by participants' allocation of attention during the encoding of these items. Unlike Starns and Hicks (2008), the stimuli and procedures in Uncapher et al.'s (2006) learning phase encouraged participants' to actively attend to both the color and location of each item. To encourage attention and increase location saliency, each item was placed within a grid that distinctly separated the four locations. Participants were compelled to pay attention to the color of each item by requiring a separate judgment for items presented in black font. These manipulations may be partially responsible for these conflicting findings of Uncapher et al. and Starns and Hicks.

There are clear similarities between the research question addressed in these studies and the current research question as they are both related to the level of abstraction of to-be-bound

information. As discussed, one aim of the current work was to examine how the individual parts of a complex scene may be related to one another. It could be argued that features of an object may be bound together in memory in ways that are analogous to the process used for binding components of a complex event. For example, complex events have multiple pieces of information (details regarding people, objects, and actions) all bound into the overarching memory representation. Comparatively, objects have features such as color, location, and orientation bound to them. Thus, an understanding of how item-to-item binding might occur should be informed by what is known about inter-feature binding, or how features of an object are related to one another in memory. In the subsequent section, I will introduce another area of research that has examined the relationship between information from differing levels of abstraction - how memory for individual objects is related to overall context and to groups of items.

Binding Research: Effects of Context or Groups of Items on Object Memory

To date, no research has specifically examined binding between individual objects within a complex scene. However, some work has examined the influence of contextual information (Brockmole, Castelhano, & Henderson, 2006; Chun & Jiang, 2003; Hollingworth, 1998; Hollingworth, 2007; Hollingworth & Henderson, 1999; Hollingworth, Williams, & Henderson, 2001), as well as information about groups of objects, on memory for individual objects (Brady & Alvarez, 2011; Brady, Konkle, & Alvarez, 2009; see also Chun & Turk-Browne, 2008; for a review of associative learning in vision). For example, Hollingworth (2007) found that memory for an object was enhanced when displayed with its original contextual information at test (*contextual cueing*). Participants in this experiment studied multiple complex scenes and then completed a discrimination task for items within these studied scenes. In this discrimination task,

test items were displayed either with their original context, another studied context, or with no contextual information. Participants were asked to make a "same" or "different" judgment. Participants were told to indicate "different" if the object was only similar to the original object (i.e. token substitution) or when the test item was oriented differently than the original object (i.e. orientation change). They found that discrimination accuracy was highest for those items displayed in their original context as compared to the no context or changed context trials. Lower accuracy rates for changed context trials suggest that the mere presence of familiar context does not enhance memory for the object. Rather, the bond between the item and its original context is what enables the context to be a better cue for that item (for similar findings see: Brockmole et al., 2006; Chun & Jiang, 2003; Hollingworth et al., 2001).

Evidence of relationships between an object and other objects from the same scene can be found in the visual statistical learning literature. Visual statistical learning examines factors associated with the learning of visual stimuli that co-occur frequently (Baker, Olson, & Behrmann, 2004; Brady & Alvarez, 2011; Brady et al., 2009; Fiser & Aslin, 2001, 2002, 2005; Turk-Browne, Jungé & Scholl, 2005). Most pertinent to the current study are the findings of Brady, and Alvarez (2011), who found evidence that object memory can be influenced by other objects in the same display. In their study, participants were shown 30 displays consisting of multiple colored circles of various sizes. Participants studied each display for 1.5 seconds, which was followed by a 1 second blank screen. After the offset of each blank screen, a black circle appeared in the same spatial location as one of the colored circles. Participants were instructed to move their mouse button to estimate the size of the circle previously studied in that location. They found that this size judgment was biased according to the average size of other circles within the same color set. For example, making a size judgment for a circle that was blue was

influenced by the overall average size of all blue circles. Altogether, their results suggest that chunks of visual information, grouped together by the observer, have a biasing effect on memory for individual items. For this biasing to occur, a relationship between memory for an individual item and memory for a grouped unit of items must exist. Thus, this suggests that memory for objects are not necessarily stored independently in memory. Although Brady and Alvarez's study examined visual short-term memory, they argue that their results are due to the same reconstructive processes that influence long-term memory. Further, they contend that these short-term memory representations are dependent on information from long-term memory (Hemmer & Steyvers, 2009). Thus, this study's findings are applicable to the current research despite the short duration of their memory task.

Though evidence from both the context cueing and visual statistical learning research suggests that some components of a scene may be bound together, there are researchers that argue otherwise. In particular, some studies from the eyewitness memory literature have come to a different conclusion (Brewer, Potter, Fisher, Bond & Luszcz, 1999; Fisher & Cuervo, 1983; Wells & Leippe, 1981). For example, Brewer et al. (1999) found that memory accuracy for a given event detail was not correlated with accuracy for other details from that same event. In this study, participants first watched a video of a mock robbery and then answered a series of questions concerning this event. Their responses were classified into five categories: 1) offender description, 2) offender actions, 3) bystander description, 4) bystander actions, and 5) objects. Overall, they found no correlation between the accuracy of responses in one category and the accuracy of responses in the other categories. They interpreted this lack of correlation as suggesting that the individual components recalled in each category were not related to components in other categories. Based on a number of studies, they argue that this pattern of

results suggests that components of memory are relatively independent (see Fisher, Brewer, & Mitchell, 2009). There are, of course, reasons to question this conclusion, including the nature of their evidence (correlations between item types). Yet, it could be that objects are bound to the overarching theme (or context) of the event, but not to each other.

Despite the many differences between these studies, all of the research reviewed in this section has examined the relationship between components of a complex memory. From this body of research, there is suggestive evidence that there may be binding between objects (object-to-object) and between objects and their context. Providing contextual information at test enhances individual item memory (Brockmole et al., 2006; Chun & Jiang, 2003; Hollingworth, 2007; Hollingworth et al., 2001). Furthermore, research on visual statistical learning (e.g., Brady & Alvarez, 2011; Brady et al., 2009) finds that memory for an object is influenced by memory for other groups of objects. With these results, it can be argued that there are clearly discernible relationships between individual items and between items and their context. Conversely, there are also findings that conflict with this area of research. From the eyewitness literature, studies have found no correlation between memory for one detail of an event (or group of related details) and memory for other details from that same event (Brewer et al., 1999; Fisher & Cuervo, 1983). This finding may suggest that these items are bound only to the event and not to one another. Thus, one can see similar arguments arise when considering the evidence for higher-level binding (i.e., object-to-object and object-to-context) as when doing so for lower-level binding (features-to-features; e.g., Starns & Hicks, 2005, 2008).

In the next section, I introduce two pertinent theoretical models that consider the issue of binding in memory – Marcia Johnson's Multiple-Entry Modular Memory System (i.e. MEM model; 1983, 1992), and Brady, Konkle, and Alvarez's (2011) Hierarchical Feature Bundle

(HFB) model. Both models have important implications concerning my overall research question (i.e., general memory structure of complex events/scenes), and my more specific research goals (i.e. levels of information and binding). Furthermore, these models will also introduce another factor that plays an important part in the current research, namely attention.

Theoretical Models

One of the primary goals of the MEM model is to explain how episodic memories can acquire details that create the phenomenal sensation of re-experiencing a past event (Johnson, 1983, 1992). That is, this model seeks to explain how and when certain features become bound to a memory record. It does this by describing a series of cognitive actions that are theorized to be involved in the creation of these memories. These actions are categorized into four subsystems, two perceptual sub-systems (P1 and P2), and two reflective sub-systems (R1 and R2; see Johnson, 1992). The actions of the perceptual sub-systems allow us to process and integrate perceptual information. For example, some of the actions of this subsystem include *locating* objects in the environment, *tracking* stimuli, and extracting the features necessary to *identify* stimuli. Alternatively, the actions of the reflective sub-systems enable us to maintain, organize, and refresh information. The reflection subsystem allows us to reactivate and maintain information learned in the past so that it can be easily used or associated with new information. Moreover, this subsystem is responsible for the creation of a coherent series of events, including the building of relationships between items, actions, and context. Thus, it is fundamental in building the necessary links between individual memorial details and the overall episodic memory. In short, an essential operation of the reflection subsystem is to bind information together.

As previously mentioned, the reflection subsystem is divided into two units, R1 and R2. The actions ascribed to both the R1 and R2 units can be described as fulfilling two functions: making information available for use (or further processing) and creating associations. For example, the cognitive actions of the R1 unit include, *noting* relationships, *shifting* attention, *refreshing* information and *reactivating* information. The R2 unit provides actions that correspond to, but are more deliberate than, the actions of the R1 unit. They include activities such as *discovering* relationships, *initiating* attention, *rehearsing* information, and *retrieving* information.

The functions of both the perceptual and the reflective sub-systems are coordinated and controlled by our *agendas*. These agendas include both our goals (varying from very general to task specific) and a series of steps that will be used to achieve these goals. Through coordinating the cognitive actions of the perceptual and reflective sub-systems, agendas play a critical role in separating central information from peripheral information. Simply put, central information is anything that may be important to the completion of that agenda. This agenda-relevant information is made more accessible through functions such as *noting, shifting, refreshing,* and *reactivating*. Noting and shifting functions create relationships by shifting attention from one item (or aspect of an item) to another item (or aspect), then noting how they may be related (i.e., similarities, differences etc.). As elements are associated and combined, information is organized into a mental representation making specific information easier to locate. Refreshing and reactivating functions serve to either maintain or increase the availability of item or relationship information. As these functions repeat, the fidelity of the item or the strength of the relationship information is increased. Together, these functions produce a more cohesive memory representation.

Several aspects of this model are particularly important to the current research. First, this model suggests that any information may be bound together. Once relations have been noted or discovered, evidence for binding between these individual elements may be demonstrated. Second, attention plays an essential role in this binding process (see also Uncapher et al., 2006). Third, a person's goal, or agenda plays a critical role in what is attended to, organized and strengthened in the memory representation (see also Morey, 2011).

Like the MEM model, Brady et al.'s (2011) Hierarchical Feature Bundle (HFB) suggests that complex visual scene memory is comprised of visual information stored at various levels of representation (e.g., features, objects, conceptual representations, etc.). More specifically, they suggest that as attention is guided to sub-regions of a complex scene your memory for features, objects, and scene information accumulates. This accumulated information is stored at multiple levels of representation (from basic features to scene information) and organized into a hierarchical structure. It is this structure that will guide any further attention to this scene and will also aid in the interpretation of any newly encoded information. In addition to influencing attention, they also suggest that information, represented at these varying levels, can influence memory for a single item. This would suggest that these levels of abstraction can interact (i.e., "are mutually informative and constraining", Brady et al., 2011, p. 22). For example, your memory of a wedding scene (scene level representation) may influence your memory for what one individual guest was wearing (item level representation), resulting in a bias to recall more formal clothing (scene level representation influencing item representation). Brady et al. finds support for this claim from research examining contextual effects on visual memory and research in visual statistical learning (Brady & Alvarez, 2011; Brady et al., 2009).

In summary, several theories have made the argument that individual components of a complex event can be bound to one another. Furthermore, theoretical arguments have been made for attention playing a vital role in the process of binding (Brady et al., 2011; Cowan, 2005; Johnson, 1983, 1992; Johnson, Hashtroudi, & Lindsay, 1993; Mammarella & Fairfield, 2008; Morey, 2011). In particular, some have suggested that binding only occurs when attention is devoted to the individual items *and* to the creation of the binding (Morey, 2011). For the purposes of this study, attention is simply defined as employing cognitive resources to activate either sensory and/or memorial information. Thus, you are attending to an object in your environment when information regarding that object (e.g., category, color, location) is at a heightened state of activation (Cowan, 2005).

Empirical Findings in Attention and Binding

Beyond the theoretical arguments, there is also empirical support for attention as an important factor in the binding process. For instance, binding appears to be disrupted in conditions where attention is divided (Brown & Brockmole, 2010; Troyer & Craik, 2000; Troyer, Winocur, Craik, & Moscovitch, 1999), in older adults (i.e., age-related attentional deficits; Chalfonte & Johnson, 1996; Craik, Luo, & Sakuta, 2010; Hashtroudi, Johnson, Vnek, & Ferguson, 1994; Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000) or when attention is captured by arousing stimuli (Mather, 2007; Mather et al., 2006; Mather & Sutherland, 2011). Other research suggests that attention plus an intention to bind items together may be what is required to find evidence of binding. For example, Morey (2011) examined how item-location binding was influenced by the nature of attention and set size. She found that an explicit intention to bind items to their locations resulted in increased accuracy for item-location judgments as compared to an incidental binding condition. Moreover, this difference in accuracy

increased as a function of set size (i.e., the number of items and locations to be bound). This suggests that not only is attention essential for binding, but that certain circumstances may also require a deliberate intention to encode these associations.

Studies have also found that the focus of attention can influence binding (Boywitt & Meiser, 2012; Johnson, Nolde, & DeLeonardis, 1996). For example, Johnson et al., demonstrated how the focus of attention could affect peoples' ability to bind content information to source information. Participants in their study were asked to listen to presentations given by two separate speakers. Focus of attention was manipulated between-subjects by asking participants to either 1) focus on how the statements made them feel (i.e. self-focused condition) or 2) focus on how they believe the speaker felt about each of their own statements (i.e. speaker-focused condition). Following the speeches, participants were asked to identify whether the provided statement originated from speaker 1, speaker 2 or neither (i.e. a new statement not previously presented). Accurately ascribing source to a previously studied statement required participants to have correctly bound the identity of the speaker to the content of the information. They found that participants who focused on the speakers feelings had superior source accuracy compared to participants who focused on themselves. More importantly, they found that the two conditions did not differ in overall accuracy for the content of the statements themselves. That is to say, the attention manipulation did not affect participants' ability to recognize that a statement was old (previously uttered by one of the speakers) or new. This suggests that the attention manipulation significantly affected binding, but had no effect on memory for content (old/new recognition). Johnson et al. (1996) contended that this finding underscores the critical role attention plays in the binding process.

In following with the arguments of both theoretical and empirical research, the current study examined how attention influences the creation of memorial bindings between items within a complex visual scene and between individual items and their context. One important manipulation for this study involved the level of attention devoted to a given object within a scene. In summary, the current study explored how deploying attention to selected individual items within a complex scene affected the bindings between items and the bindings between individual items and their context.

Analogy between Starns and Hicks' (2008) Procedure and the General Procedure Used in Current Studies

To ensure that the current work measured binding and not variability in memory strength, the experimental design was modeled on Starns and Hicks' (2008) procedure. In this and subsequent sections, I will describe the similarities and differences between Starns and Hicks' design and the current methodology. Then I will provide a more detailed description of Experiment 1's methodology and procedure. This will be followed by predictions for Experiment 1.

Earlier, I described Starns and Hicks' (2008) work as having goals analogous to the aims of the current study. In their experiments, they sought to examine whether individual features of an object were bound to each other, as well as to the object itself. Likewise, the current study examined whether components of a complex scene (i.e. objects) were bound to one another, or merely to the overarching memory of the scene (see Figure 3 for a pictorial comparison between Starns and Hicks' work and Experiment 1). More specifically, the principle question Starns and Hicks sought to address concerned whether reinstating one feature of an object would cue memory for a second feature of that same object. They argued that if the presented feature cued memory for a second feature, it would suggest that these feature dimensions are bound together

in memory. In a similar fashion, the primary question of the current work asked whether the presentation of selected objects would cue participants' memory for other objects within that scene.

A second similarity between Starns and Hicks (2008) and the current work concerns the need to obtain a clear measure of binding. They have argued that earlier research examining this feature binding question had a flaw; the original object was always presented along with the other feature dimensions. They argued that any correlations between participants' memory for one feature and a second feature might have been mediated by their memory for the object (see Figure 2 for reference). Thus, presenting the original object could have cued participants' memory for either both or neither features (depending on the strength of their memory for that item). To correct for this, Starns and Hicks presented only the features of an object (i.e., color and/or location), rather than the object itself. Likewise, the current study presented individual objects of the scene as cues separated from the original background information.

For the purposes of comparing Starns and Hicks' (2008) procedure to the current study, the following is a brief summary of their methodology. First, participants were asked to study a series of 18 colored objects presented within a grid. Following this encoding phase, participants were given a memory test concerning the features of those objects. During the recognition phase, participants indicated whether an item had been studied, a) in this color (e.g., color condition) or b) in this location (e.g. location condition). For half of their judgments, participants were given only the feature that was related to the test question (i.e., color or location; *uncued trials*). Specifically, participants in the color condition were given a colored swatch and those in the location condition were given a black marker indicating the location in the grid. In other judgments, participants were given both features (i.e., color and location; *cued trials*), but were

told to make their judgments solely from the feature indicated for their condition; in both conditions, participants saw a colored marker within the grid. Thus, a key question in this procedure was whether the presence of the additional feature in the cued trial would lead to better memory performance than when the additional feature was lacking (uncued trials).

In the current study, participant studied a series of complex scenes that included a large number of objects rather than individual objects presented alone (as in Starns & Hicks, 2008). Because the goal, in the first experiment, was to examine binding between objects rather than memory strength for the scene, the testing phase did not provide the original stimuli (i.e. scene) as a cue. Similar to Starns and Hicks (2008), trials in the testing phase were divided into two types, no-object cue trials, and object-cued trials; each provided only selected information from the original scene.
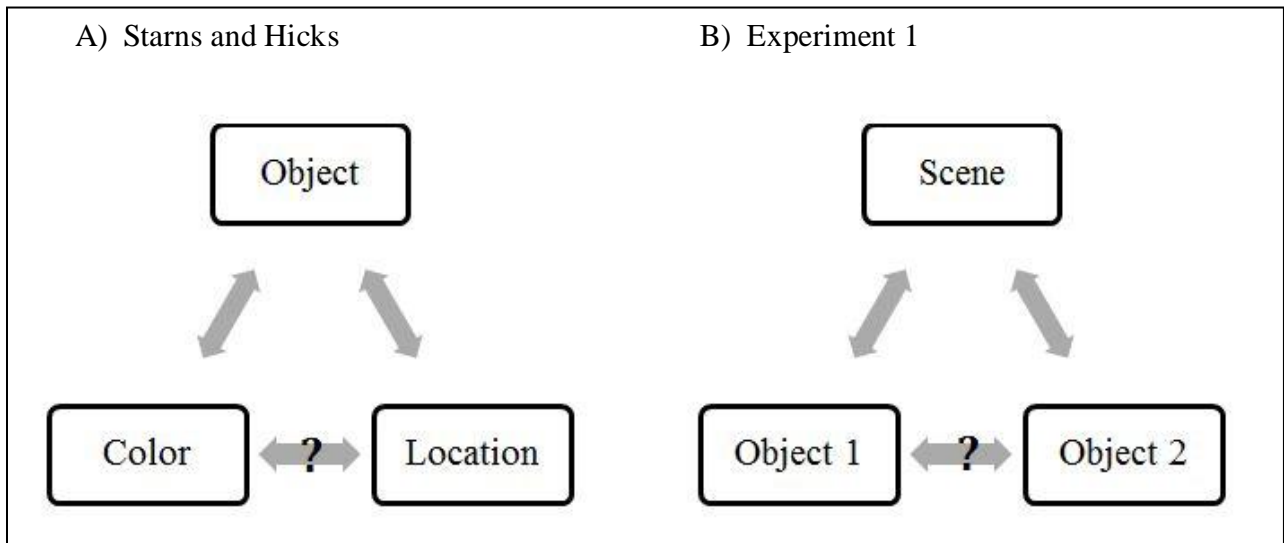

Figure 3. A pictorial comparison between the aims of Starns and Hicks' (2008) experimental goal (A) and Experiment 1's goal (B).

For the no-object cue trials, participants were given a target marker indicating the location of a missing object. Because objects from many scenes had the same approximate spatial location, some scene information was required so that the target marker clearly denoted one specific object. However, as was previously noted, it was critical that participants not be provided with the original scene information to make their judgment. As a result, these target markers were superimposed over a modified and blurred version of the original scene. Modifications to the original scene were as follows. First, all individual objects were removed; all information that remained (e.g., large furniture, fixtures, and the general layout of the room) was considered background information. Second, this remaining background information was blurred so that only color and indistinct shapes were visible (see Figure 4 for an example of an original learning phase scene and the no-object and object-cued trial scenes derived from it; see Appendix A for more detailed images).

Object-cued test trials also included a target marker denoting the location of a specific object. In Experiment 1, these target markers were superimposed on top of a blurred version of the original scene, the same as for no-object cue test trials. The only difference between the two test trial types was the addition of three selected objects that were reinserted into the scene in their original spatial locations. It is important to note that these objects were unaltered from the original scene[1] (i.e. their visual clarity was unchanged; see Figure 4 for an example of an object-cued test trial).

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[1] To examine object-to-context binding, Experiment 2 superimposed both the target marker and the three object cues over the original, non-obscured, contextual information. See Experiment 2's methods section for further details.

By using a procedure analogous to Starns and Hicks (2008), I was also able to use similar measures of binding. In their research, accuracy differences between the two trial types could only be the result of the presence or absence of a second feature. Consequentially, if accuracy for object-cued trials was significantly greater than no-object cue trials, this would suggest that the objects that were present were capable of cuing memory for other objects. This would provide evidence for object-to-to-object binding.

Learning Phase Scene

No-Object Cue Trial

Object-Cued Trial

Figure 4. Comparison between a learning phase trial scene and its corresponding testing phase scenes (object-cued and no-object cue trials). The red square is the location cue provided during the test trial. Objects from the original learning phase scene were used as retrieval cues for object-cued test trials.

Purpose of Current Studies

As I noted in the introduction, the current studies were designed to examine two major questions. The first concerns how different components of a complex event are related in memory. In these experiments, I focused on whether there was evidence of object-to-object binding (Exp. 1 and to some extent, Exp. 2) and object-to-context binding (Exp. 2). As described above, I employed a procedure to evaluate these issues that was conceptually based on the procedure used by Starns and Hicks (2008) to evaluate feature-to-feature binding. The second question concerns the role of attention on binding processes. In both experiments, I examined whether objects that were the focus of attention (central objects) were better cues to memory than were objects that were away from the focus of attention (peripheral objects). In other words, were central objects more likely to be bound to one another than peripheral objects? In Experiment 1, I also assessed whether the nature of attention paid to objects played a role in binding. Prior researchers have argued that individual components of an event need to be actively linked to one another for binding to occur (Morey, 2011). In this experiment, I manipulated the degree to which encoding processes were focused on the relationships between objects in the scenes.

Experiment 1: Goals and Hypotheses

Experiment 1 was designed to evaluate 1) whether object-to-object binding occurs 2) if so, whether binding is moderated by focus of attention at encoding and 3) whether people must deliberately attend to associative information in order to bind objects together. As described above, participants were presented with a series of scenes. During this learning phase, attentional focus was varied such that some objects were the focus of attention (central-objects) while others were less likely to receive attention (peripheral objects). This was accomplished by presenting

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the complex scene in tandem with auditory information that highlighted particular objects within the scene. Peripheral objects were not discussed in the auditory presentation.

Furthermore, I also manipulated how participants attended to these objects. Participants in one condition were provided with auditory information that drew attention to individual objects in the form of a narrative, encouraging them to attend to objects and how these objects were associated with one another. These participants were compared to participants in a second condition, the labels condition, who merely heard the names of a series of objects with no additional associative information.

After being presented with both the scene and auditory information, participants were given a forced-choice recognition test for selected items from each scene. On each trial, participants attempted to identify the original object that appeared at the target location by choosing from a "lineup" of objects taken from other scenes. Each test scene displayed only selected information from the originally encoded learning phase scene. The type of information from the learning phase scene varied according to the following trial types: 1) no-object cue test trials, and 2) object-cued test trials. However, in line with the attention manipulation, the object-cued trials were further segmented with respect to whether the selected objects were central or peripheral objects only. That is to say, each object-cued trial displayed only central objects or peripheral objects.

The first hypothesis I evaluated was whether object-to-object binding occurred. Evidence for this would be demonstrated if identification accuracy was significantly higher for either central or peripheral-object cued trials compared to no-object cue trials. My second hypothesis concerned whether focus of attention moderated binding processes. If attention does moderate binding, this would suggest that I would find a significant difference between central and

peripheral-object cued trials. In other words, if increased attention at encoding increases the likelihood that objects would be bound to each other, then participants' memory for objects should benefit more from central-object cues compared to peripheral-object cues[2].

Finally, the third goal of Experiment 1 was to examine whether attention to associations at encoding is necessary for binding to occur. To address this question, I included a between-subjects manipulation that varied whether participants' attention focused on the objects alone (labels condition) or focused on both the objects and the associative information between the objects (narrative condition). The motivation for this manipulation comes from previous theoretical and empirical arguments that suggest that binding may not result from attention alone (Johnson, 1983, 1992; Morey, 2011). In particular, the previously described MEM model suggests that attention is necessary for the active creation of links between individual items (using functions such as *discovery* and *rehearsal* in the R2 subsystem). It may be interpreted to suggest that some instances of binding may also require *intention*; that is, one must deliberately encode associative information in order to bind two or more pieces of information. I hypothesized that if binding required an intention to encode the associations between individual items (Morey, 2011), then evidence of binding in the narrative condition (which included objects and object relationship information) should be greater than in the labels condition (which focused on objects alone).

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[2] In particular, central object test cues should be stronger cues to other central objects than they are cues to peripheral objects.

Experiment 1: Methods

Participants

A total of 156 LSU students participated in Experiment 1 (78 in each condition; narrative and labels). A power analysis for Exp. 1, computed using G*power (Faul, Erdfelder, Buchner, & Lang, 2009) suggested that the appropriate number of subjects to achieve 80% power was 164. This value was determined based on the following parameters: A) an *ES f* of .10 (small effect size *f*), B) a type I error rate of .05, C) a within-subjects ANOVA with three levels, and D) an estimated .50 correlation between measures. Participants were comprised of students taking psychology courses at Louisiana State University who received course credit for their involvement.

Experimental Design

This experiment utilized a 3 x 2 x 2 mixed model design with Test Cue type (i.e. no-object cue, central-object cued, and peripheral-object cued) and Target type (i.e. central or peripheral target object) as the within-subjects factors and Attention condition (narrative and labels) as the between-subjects manipulation.

Stimuli

Learning phase scenes. A series of 12 complex visual scenes were used for the current study. Scenes were created using the SIMS™ software program. This software is ideal for creating and modifying realistic images of 3D environments. (see Figure 5 for an example). Each scene displayed 17 unique objects were classified as one of the following scene types: bedroom, living room, or personal office. Each scene, both across and within these categories, differed with respect to layout, color scheme, furniture, and objects. Furthermore, each scene of these 12 scenes had a corresponding counterbalanced version to ensure that memory for any individual

item did not depend on its physical location within the scene. To that end, each counterbalanced version contained the same background information and objects (how this was categorized will be discussed below), but differed as to where individual objects were located. That is, select objects in the scene switched locations with other objects from that scene.

The following guidelines were used to categorize scene information into objects and background information (context). First, all items classified as objects were easily manipulated by hand; anything that was too large, heavy, or immobile was considered contextual information (e.g., large furniture, fixtures). Second, only those items that an individual could hold, move, or use were categorized as objects; anything that was a static part of the environment was also considered background information. Third, due to the nature of the task, objects were an individual unique part of a scene; items that were components of a larger whole (e.g., toys in a basket) or segments in a series (e.g., books on a bookshelf) were not considered individual objects for the purposes of this experiment.

Figure 5. Example scene from the learning phase. Counterbalanced versions A and B. In version A, those objects circled in blue trade places with objects circled in red resulting in version B.

Learning phase auditory information. Each of the visual scenes was also paired with auditory information. The auditory information and its corresponding scene were presented simultaneously. This audio information served to emphasize certain objects within the scene. The current study included two types of auditory information that varied between-subjects.

Narrative condition auditory information. For some participants, the auditory information presented with each scene was in the form of a narrative (i.e. narrative condition). Each narrative focused on a hypothetical person and his or her interaction with a series of six objects within the scene. These objects will now be referred to as *central* (items or objects). The same hypothetical person was used for each scene within a scene type (e.g., "Jennifer" was the focus of all bedroom scenes)[3].Take for example the following short description of a scene centered on a woman named Jennifer.

"Jennifer set out to write a killer short story for a writing competition. After quickly straightening her *poster*, she walked over to the *chalkboard* and scribbled down some notes for her paper. She then, opened up the *wooden chest* and grabbed some writing supplies. After sitting at her desk, she moved her *dragon statue* to make more room to write. Finally, she took a pen out of the *penholder*, and began writing. Despite throwing away several drafts of her paper into the *trashcan,* she finally completed her killer story. "

Labels condition auditory information. For other participants, the auditory information was not in the form of a cohesive story; instead, six selected objects were named with no additional information provided. More specifically, participants in this labels condition heard

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[3] This measure was taken to ensure that participants could not use the "type" of scene (e.g., living room) as a cue for a specific hypothetical person's story. For example, a living room scene could not be used as a cue for Jennifer's unique story; Jennifer was associated with all four stories that took place in each of the four living rooms.

only the name of six (central) objects spoken sequentially. Each object label was heard in the same temporal position as its object counterpart in the narrative condition. Using the previous scene example, participants in the labels condition heard the following.

"-- -------------- *poster*, ------------------------- *chalkboard* -- -------------------------------*wooden chest* -- ------------------------*dragon statue* --- ----------*penholder*-- ----*trashcan* ------------------------------------- "

In both conditions, five peripheral items were selected from the remaining objects not referenced in the audio file. Furthermore, items selected as peripheral were 1) irrelevant to the narrative (or not mentioned in the labels condition) 2), not located within two-inches of any central object and 3) not in the direct path between two central objects that were discussed (or named) consecutively.

Like the visual scenes, all auditory files also had a corresponding counterbalanced version. These versions served to counterbalance the attention manipulation for the central and peripheral objects. That is, all objects discussed in version A became peripheral objects in version B, and correspondingly, the peripheral objects in version A were the focus of the auditory information in version B. All counterbalanced auditory files were paired with their associated scene's counterbalanced version. To reiterate, the only difference between the original visual scenes and their counterparts is the physical location of certain objects. In particular, central objects switched locations with peripheral objects (see Figure 5 for example).

Testing phase scenes. During the testing phase, altered versions of the 12 studied scenes were presented. Each test scene contained: 1) a blurred version of the learning phase scene, 2) a red square indicating the location of the target object, and 3) an array of six objects located at the bottom of the screen. Due to the aims of the current study, and the nature of binding research, it was critical that participants were not provided with the original scene while they were making their identification judgments (e.g., Starns and Hicks, 2008). However, due to the nature of the task (i.e., multiple objects sharing a single location over the course of the 12 scenes), it was necessary to provide enough "scene" information to isolate a single object as the missing target object.

Each test scene contained information from the original scene that was both edited and blurred; however, some of these test scenes displayed more information than other test scenes (i.e. select objects). Accordingly, test scenes were separated into one of two categories – no-object cue test scenes and object-cued test scenes.

No-object cue test scenes. For the no-object cue test scenes, the distorted version of the original learning phase scene was created using the following transformations. First, all objects were removed from the original scene (refer to object classification guidelines described above). Second, the remaining contextual information was distorted using a Gaussian blur filter, which uses a normal distribution to transform the original pixels. The effect is a blurring of the original image, similar to looking through a translucent film. The filter for each scene was set to a pixel radius of 25. This parameter was set to ensure that any detail information was eliminated and only indistinct colored shapes remained from the original contextual information.

Object-cued test scenes. Like the no-object cue test scenes, object-cued test scenes used the same transformations in creating their distorted versions of the original studied scenes.

However, following these transformations, three objects from the original scene were re-inserted in their original spatial locations. These three objects were selected from that scene's set of central or peripheral objects. Accordingly, each object-cued test scenes will now be referred to as either central-object cued or peripheral-object cued.

Across all participants in the experiment, all scenes served as both no-object cue and object-cued scenes (central and peripheral) equally often.

Targets and lineup arrays. For each test scene, half of the target objects were central and half were peripheral; the order in which targets were identified was random. Each target was associated with a different object lineup array. Five objects in the array were lures selected from objects studied in other scenes (and thus were familiar); the remaining object was always the target. Of the five object lures, there was a central and a peripheral object (each taken from different scenes) and the remaining three objects were filler (i.e., additional objects from other scenes not designated as central or peripheral). When an object appeared as a lure, it did not serve as either an object cue or a target for any test scene within this particular testing phase. Similarly, when an object served as an object cue, it did not appear as either a lure or a target within this testing phase.

Each test scene was classified as either a no-object cue or object-cued test scene. Each participant received four no-object cue test scenes and eight object-cued test scenes (four central and four peripheral), presented in a single randomized order. Participants made four identification judgments for each scene. This means that each participant made eight central and eight peripheral object identifications associated with each of the three trial types, for a total of 48 test items (see Figure 6 for a schematic of this identification breakdown). Across the experiment, each learning phase scene served as each type of test scene equally often.

Procedure

Participants were run in groups of up to four. The experimental procedure was divided into a learning phase and a testing phase. Before beginning the learning phase, participants were told that they would see a series of scenes and that each scene would contain numerous objects. It was their job to try to remember each scene because they would be tested on that information in a later part of the experiment. They were also told that each scene was to be accompanied by a short story describing an event that occurred in the picture (narrative condition), or that they would hear the names of various objects within the scene. In both conditions, participants were instructed to pay close attention to the auditory information that accompanied each scene because they would be asked about a visual detail associated with one of the objects mentioned in the audio file following each scene. Participants were then told to put on headphones and begin when they were ready.
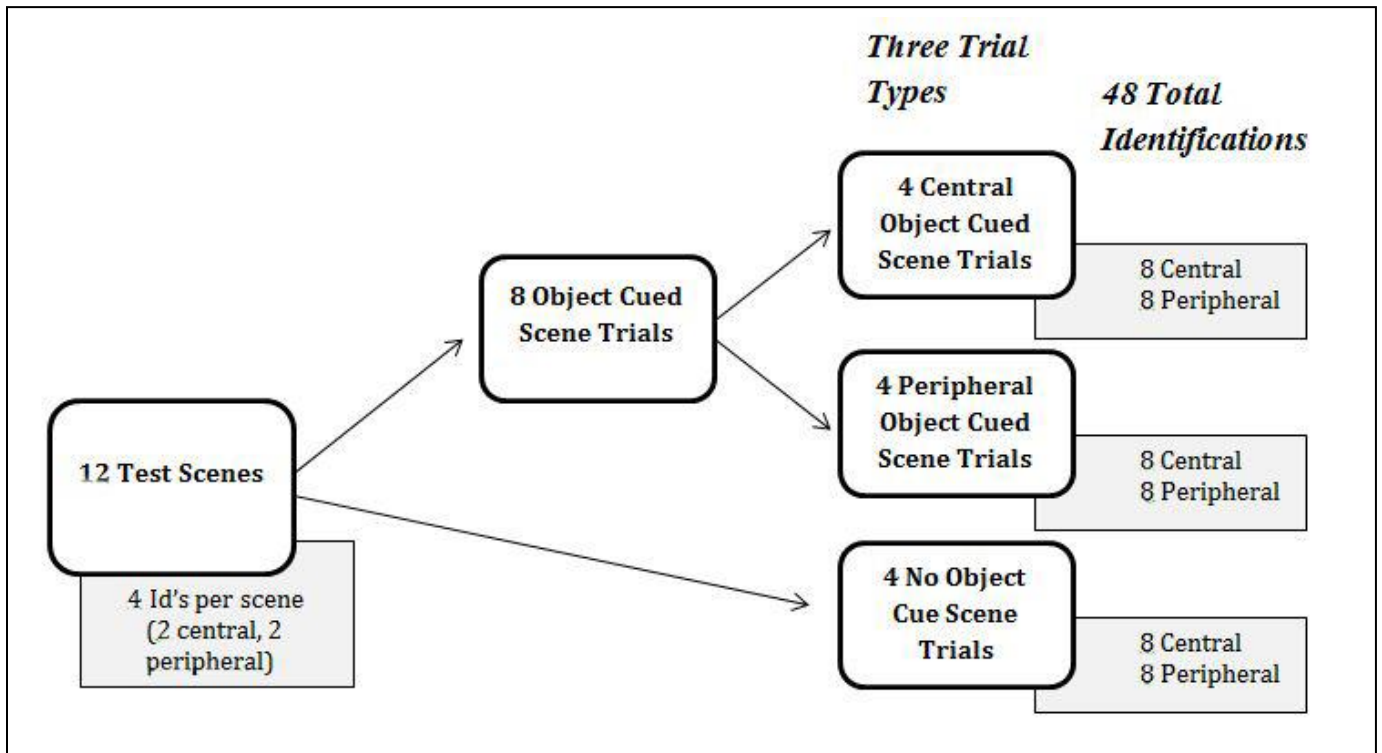

Figure 6. Diagram providing information concerning the categorization of identifications in the testing phase. Central and peripheral objects were those that were and were not, respectfully, the focus of attention in the auditory information provided during the learning phase.

Learning phase. Prior to each scene, a "get ready" signal appeared for 1 second. Afterward, a scene and corresponding auditory file began simultaneously. The duration of each scene and its associated auditory information was 25 seconds. Following their offset, participants answered a short multiple-choice question, concerning an object that was mentioned in the audio file. For example, in the narrative condition, participants answered the question, "When Jennifer wrote her paper, what colors were the pencils she had to choose from? 1) Red and Green 2) Blue and Black 3) Black and Green 4) Red and Blue. Similarly, those participants in the labels condition were asked the following question, "What colors were the pencils in the pencil holder? 1) Red and Green 2) Blue and Black 3) Black and Green 4) Red and Blue" (objects referenced in these questions did not appear in the testing phase). Accuracy for these responses was used to assess whether individual participants were completing the task as instructed. Following their response, participants would see the "get ready" signal, which was again followed by the next scene presentation. Scenes were presented in a set random order. After studying all 12 scenes and answering their associated multiple-choice questions, text appeared on the screen asking participants to wait for experimenter instructions. Once all participants had completed the learning phase, they were provided with instructions for the testing phase of the experiment. These testing phase instructions were both on the screen and read aloud; reading the testing phase instructions took approximately four minutes.

Testing phase. During this part of the experiment, participants were presented with a series of test scenes derived from the 12 learning phase scenes. Before beginning the testing phase, participants were given instructions concerning the test's objectives and organization. Specifically, they were told that they were about to see a series of altered versions of the scenes that they had studied during the learning phase. Furthermore, they were told that each of these

previously studied scenes would have missing objects and the background information would be blurred. They were told that their goal would be to try to remember selected objects from each scene.

In each test scene, a red square marked the location of a missing object. It was their task to identify what object was originally studied in that location when they saw that scene in the learning phase. They made their identifications by selecting the correct missing object from an object lineup that was located at the bottom of the screen. For each scene, they were asked to identify four missing objects, one at a time. Following each identification, they were also asked to rate their confidence in each judgment.

Additionally, they were also told that some scenes contained more information than others did. They were then provided with a description of these scene types. It was explained that some test scenes contained only a blurry version of the original scene's background, while other test scenes contained both this blurry background information and a few objects from the original scene in their original locations. They were instructed to do their best to use the available information to make an accurate identification (for either type of scene). After receiving these instructions, participants began the first set of identifications in the first test scene trial.

Participants completed the following sequence of events for each of the 12 test scenes (see Figure 7). First, a screen appeared asking participants to "get ready for the next scene". After 1 second, the test scene appeared with one red square marking the location of a missing target object. Participants were instructed to select the target object from the objects in the lineup. In particular, they were asked to press the number associated with their chosen object (1-6). Following the identification, a second screen appeared asking participants to estimate their confidence in this judgment on a scale from 1 (*guessing*) to 7 (*very sure*). After making their

confidence rating, the previous scene reappeared, but now the red square was in a second location and the previous objects in the lineup were replaced with another set of objects. They were then asked to identify this new target object. This process continued for two more identifications. Following the fourth identification and confidence rating, the screen asking participants to "get ready for the next scene" appeared again. Once participants completed this process for all 12 scenes, they were asked a series of demographic questions and then received a debriefing statement.
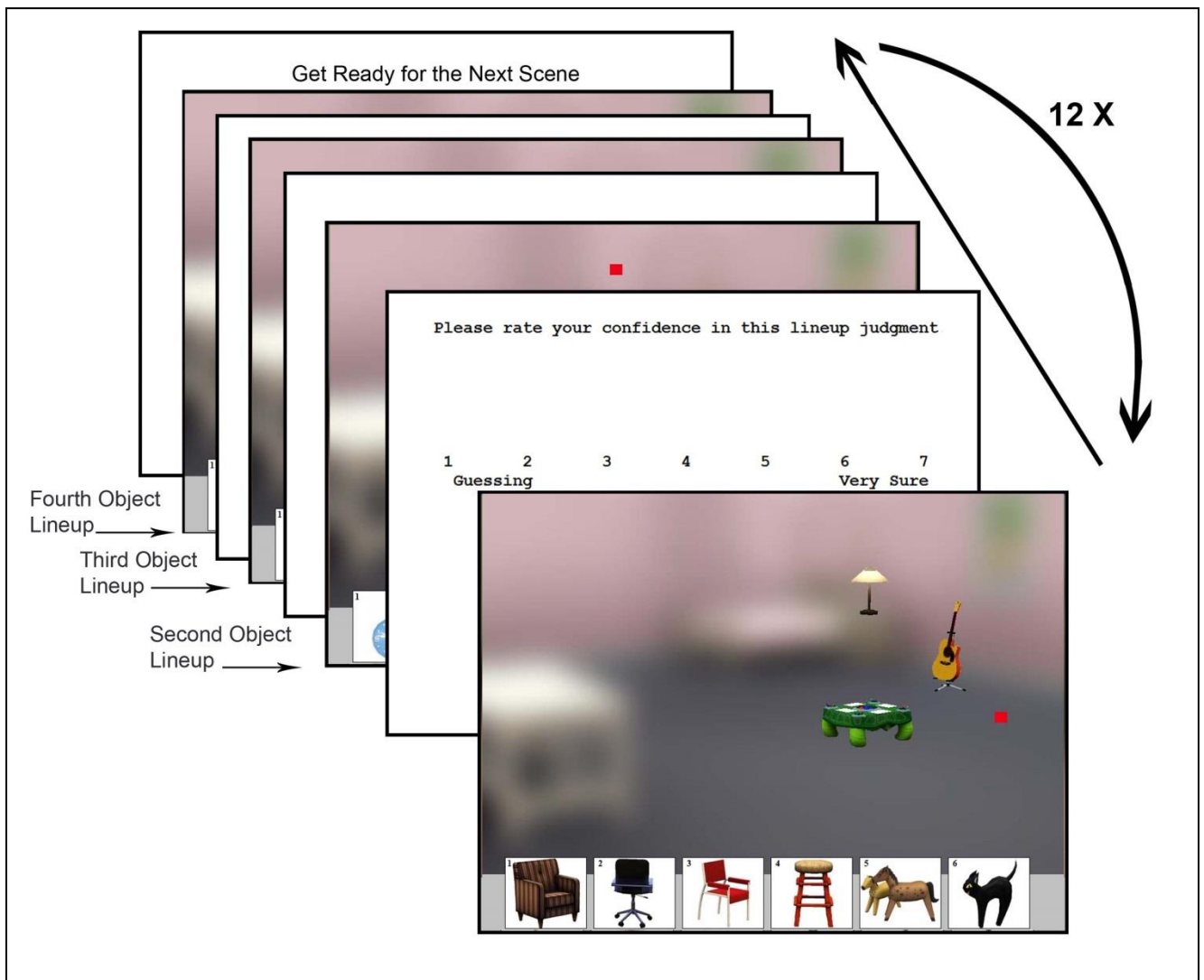

Figure 7. A graphic representation of the testing phase.

Experiment 1: Results

For both experiments reported here, partial eta squared was used as the estimate of effect size and $\alpha < .05$ was used as the criterion for statistical significance. Descriptive statistics concerning the accuracy of performance for participants in both attention conditions are displayed in Table 1. Because each lineup contained six objects, the probability of choosing the correct target by chance is 16.6%.

The major question motivating Experiment 1 was whether object-to-object binding occurs. This involved two separate questions. Does binding depend on the focus of attention during encoding? Is binding enhanced by drawing attention to the role played by items in an event? To address these questions, a 2 (Target type) X 3 (Test Cue type) X 2 (Attention condition) mixed model ANOVA, with Target type and Test Cue type manipulated as within-subjects variables, was conducted with accuracy rate as the dependent variable. The primary analyses concentrate on how the type of cue (i.e., no-object cue vs. object-cued test scenes) will influence the probability of identifying the correct target object. As previously described, all target objects were either the focus of attention at encoding (i.e. central) or they were not (i.e. peripheral). Because it was predicted that focus of attention will have a significant impact on object-to-object binding, I will also focus on the interaction between test cue type (no-object, central vs. peripheral-object cued) and target type (central vs. peripheral) on accuracy.

Table 1
Mean Identification Accuracy Performance

	Attention Conditions			
	Narrative		Labels	
	Central Targets	Peripheral Targets	Central Targets	Peripheral Targets
Test Cue Type				
Central	0.63 (.02)	0.22 (.02)	0.70 (.02)	0.18 (.02)
Peripheral	0.58 (.02)	0.21 (.02)	0.62 (.02)	0.19 (.02)
No-object	0.56 (.02)	0.24 (.02)	0.64 (.02)	0.19 (.02)

Note: Standard errors appear in parentheses.

For the question of whether deliberate attention to the role played by an object at encoding is required to bind objects together, I will focus on whether the type of information given during encoding influences object-to-object binding. As noted earlier, a between-subjects manipulation of attention varied the type of information provided during the encoding phase. Those in the narrative condition attended to both specified objects and the role those objects played in the event, while participants in the labels condition were merely told to focus on specific objects and received no additional associative information. Below I discuss the results from the omnibus analysis broken down by the effects and interactions that are relevant to a particular hypothesis.

Object-to-Object Binding

Is binding mediated by attention? The omnibus analysis yielded both a significant main effect of target type, with higher accuracy rates for central targets ($M = .62$) as compared to peripheral targets ($M = .20$), $F(1,154) = 1092.33$, $p < .01$, $MSE = .04$, $\eta_p^2 = .88$, and a significant main effect of test cue type, $F(2,308) = 3.57$, $p = .029$, $MSE = .02$, $\eta_p^2 = .02$. Pairwise comparisons indicate that test cues using central objects elicited significantly higher performance ($M = .43$) compared to either test cues containing peripheral objects ($M = .40$) or test cues that did not contain any objects ($M = .41$).

However, these main effects were qualified by a significant interaction between cue type and target type, $F(2,308) = 5.72$, $p = .004$, $MSE = .03$, $\eta_p^2 = .04$, with the highest accuracy rates associated with central targets cued by central objects. See Figure 8 for a graphical representation. To explore this interaction paired sample t-tests were conducted. Most pertinent to the hypotheses regarding focus of attention are the comparisons between central targets cued with central objects (vs. no objects) and peripheral targets cued with central objects (vs. no

objects). For central targets, accuracy was significantly higher when central objects were used as cues ($M = .67$) as compared to when no objects were present in the test cue ($M = .60$; $t(155) = 3.48$, $p = .001$, $MSE = .02$). Additionally, peripheral-object cues ($M = .60$) were no more effective in cuing central targets than no-object cues ($t < 1$). In other words, we do see object-to-object binding, but only when objects that are the focus of attention at encoding were cued by other objects similarly in focus of attention during encoding. In contrast, peripheral target performance did not appear to be enhanced by the presence of any object, central ($M = .20$) or peripheral ($M = .21$) when compared to the no-object cue trials ($M = .21$; $t < 1$). Thus, objects that were not the focus of attention at encoding showed no evidence of object-to-object binding.
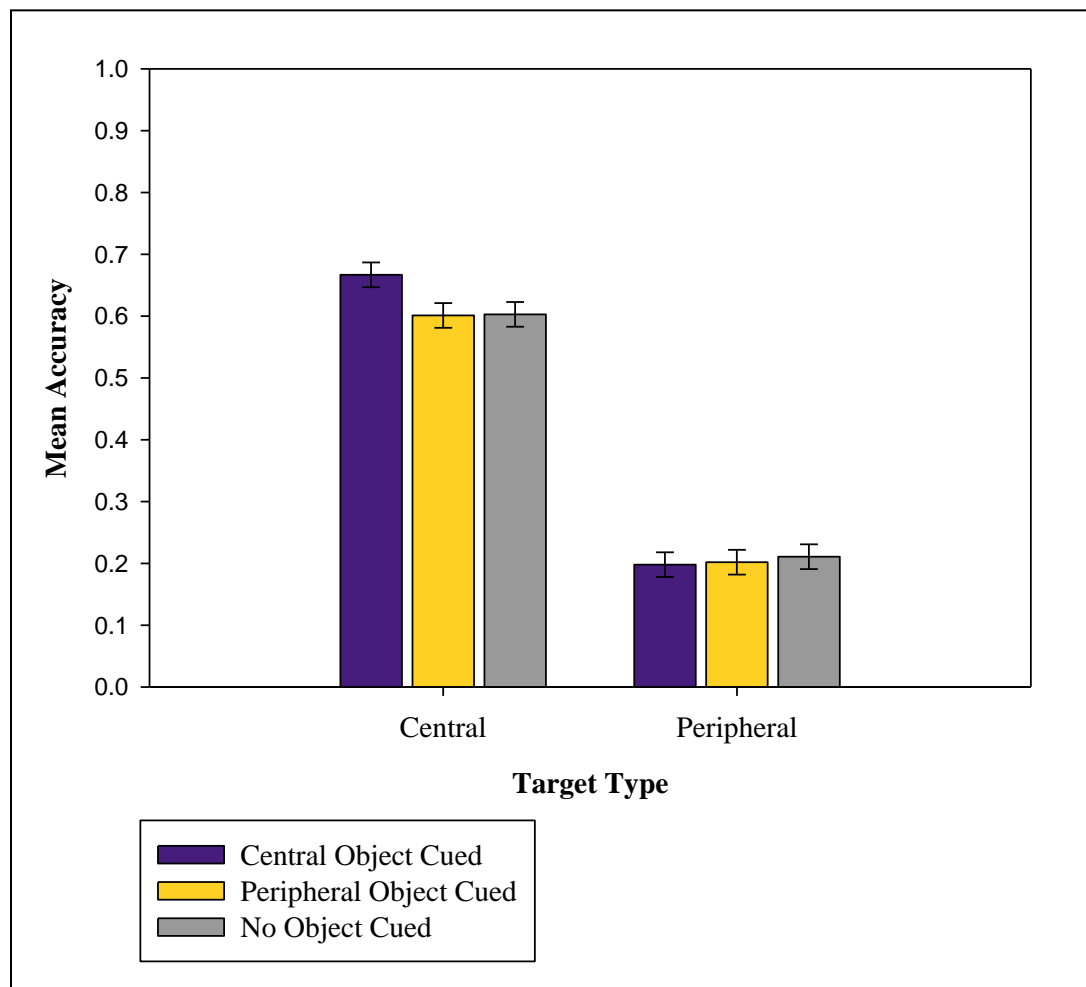

Figure 8. Graphic representation of the interaction between target type and test cue type on identification accuracy, collapsed across attention condition.

In short, object-to-object binding was observed, but only for those objects that were in the focus of attention during encoding. These findings support my earlier predictions; those objects in the focus of attention produce not only higher fidelity memories (Johnson, 1992; see also Levine & Edelstein, 2009), but also are more strongly bound to other central objects. Importantly, this evidence of binding was obtained using a procedure developed to be analogous to the one used by Starns and Hicks' (2008), which rules out the possibility that the obtained differences were due to variability in the strength of item memory.

There are a couple of potential reasons why evidence was obtained for binding in this experiment, but not in previous research (Starns & Hicks, 2005; 2008). First, complex event memories are associated with a much broader hierarchy of information (i.e., gist, context, ensemble, item etc.) as compared to individual objects. Because of this, it is possible that binding will occur more frequently at the scene level than at the object level. Second, there are procedural differences between these studies. One critical difference involved Starns and Hicks' use of an incidental encoding procedure; in contrast, the current work used deliberate encoding. In order to observe feature binding in memory, it may be necessary to attend to the specific features at encoding.

Is binding mediated by the nature of attention? There is evidence that the manipulation of *how* participants attended to these objects did have an effect on performance, but not specifically on binding processes. There was a significant interaction between target type and attention condition, $F(1,154) = 15.29$, $p < .01$, $MSE = .04$, $\eta_p^2 = .09$. As expected, performance for central targets (narrative = .59 and labels = .66) was significantly higher than peripheral targets (narrative = .22 and labels = .19). For participants in the labels condition, accuracy was higher for central targets but lower for peripheral targets when compared with the narrative

condition. This finding suggests that the labels manipulation increased memory for the central objects relative to the narrative manipulation. That is, those participants who were not provided any information concerning any named object's role in that scene's event, had better memory for those objects than those participants who were told about why these particular objects were important to the event.

Importantly, there was no significant interaction between attention condition and cue type or between attention condition, target type and cue type (F 's< 1). Therefore, we must conclude that object-to-object binding was not appreciably affected by the inclusion of associative information at encoding. This finding suggests that participants do not need to deliberately attend to associative information in order for objects that had been in the focus of attention, to bind to one another.

Additional Measures

      Confidence measures. I will now turn to some of the supplementary measures, namely confidence ratings. As described earlier, participants were asked to rate their confidence in the accuracy of each identification judgment on a scale from 1 (*guessing*) to 7 (*very sure*).

      Although there were no specific hypotheses for confidence judgments, they nevertheless provide important information about the perceived strength of memory evidence for targets. The following confidence results have been grouped according to the type of target identified (central or peripheral) and the type of test cue (central, peripheral, and no-object)[4]. In addition, I focus on confidence ratings that reflect only accurate identification judgments. For descriptive statistics for confidence ratings see Table 2.

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[4] Because there was no significant interaction between attention condition and test cue type and no significant three-way interaction (i.e., differences in object-to-object binding between attention conditions) the following analyses collapsed across those conditions.

Because confidence ratings are only calculated for "hits", not every participant enters into the analyses. For instance, it frequently happened that a participant did not make a hit for a peripheral item for every cue type. Running a 2 X 3 within-subjects ANOVA for Cue type and Target type would reduce the number of participants in the data set from 156 to 80. For this reason, I conducted a within-subjects ANOVA for central targets and peripheral targets separately. In each, Cue type functioned as the within-subjects variable. Using this method, no participants were excluded in the analysis for central targets; on the other hand, the analysis for peripheral targets reduced the number of participants to 80. It should be noted that all means discussed within the text reflect this reduced number of participants; in contrast, Table 2 provides descriptive statistics for all participants.

A significant effect of test cue type was obtained for central targets, $F(2,310) = 22.68$, $p < .01$, $MSE = 0.79$, $\eta_p^2 = .13$. Pairwise comparisons reveal that central targets cued with central objects have significantly higher confidence ratings ($M = 5.32$) compared to either targets cued with peripheral objects ($M = 4.83$) or no-objects ($M = 4.70$). Unlike the central targets, there is no significant effect of test cue type for peripheral targets, $F(2,158) = 2.73$, $p = .069$, $MSE = 1.67$. In short, these findings indicate that participants have more confidence in identifications when the test cue included objects that were in the participants' focus of attention during encoding. From a signal detection theory perspective, this finding implies that the presence of central objects enabled participants to retrieve evidence of stronger memory for the correct target. That is, when objects, attended during the encoding of a complex visual scene, are present in the test cue, a more detailed representation of another attended object can be retrieved from the memory of this scene.

Response time measures. Figure 9 displays an average of participants' median response times for identification judgments; response times are separated by accuracy of the identification, target type, and test cue type (no-object cue, central and peripheral-object cued).

In an examination of response time data (for both accurate and inaccurate judgments), a 2 (Target type) X 3 (Test Cue type) within-subjects ANOVA revealed two main effects. First, participants were significantly faster for judgments where the target was central ($M = 7591.45$ ms) as compared to when the target was peripheral ($M = 9642.06$ ms; $F(1,155) = 213.34$, $p =.000$, $MSE = 4612126.88$, $\eta_p^2 = .58$). Second, participants were significantly faster when no objects were presented in the test cue ($M = 8255.96$ ms) as compared to test cues containing either peripheral objects ($M = 8785.52$) or central objects ($M = 8808.80$; $F(2,310) = 11.99$, $p < .01$, $MSE = 2544767.54$, $\eta_p^2 = .07$). Said another way, when objects were present in the test cue, participants took significantly longer to make their identifications as compared to when these objects were absent. There was no significant interaction between these two factors ($F<1$).

Although these findings were not important to my research aims, they do suggest that the manipulation of test cue was effective. Participants were instructed to use all the information available in the test cue to make their identifications; as we see, participants took significantly more time with test cues that contained additional information that they needed to process (objects) than when that information was absent.

Table 2
Mean Confidence Ratings

	Test Cue Type		
	Central-object cued	Peripheral-object cued	No-object cue
Target Type			
Central Target	5.32 (0.11)	4.83 (0.11)	4.70 (0.11)
Peripheral Target	3.66 (0.16)	3.04 (0.14)	3.19 (0.13)

Note: Standard errors appear in parentheses. Mean confidence ratings reflects the confidence ratings for accurate judgments for all participants.
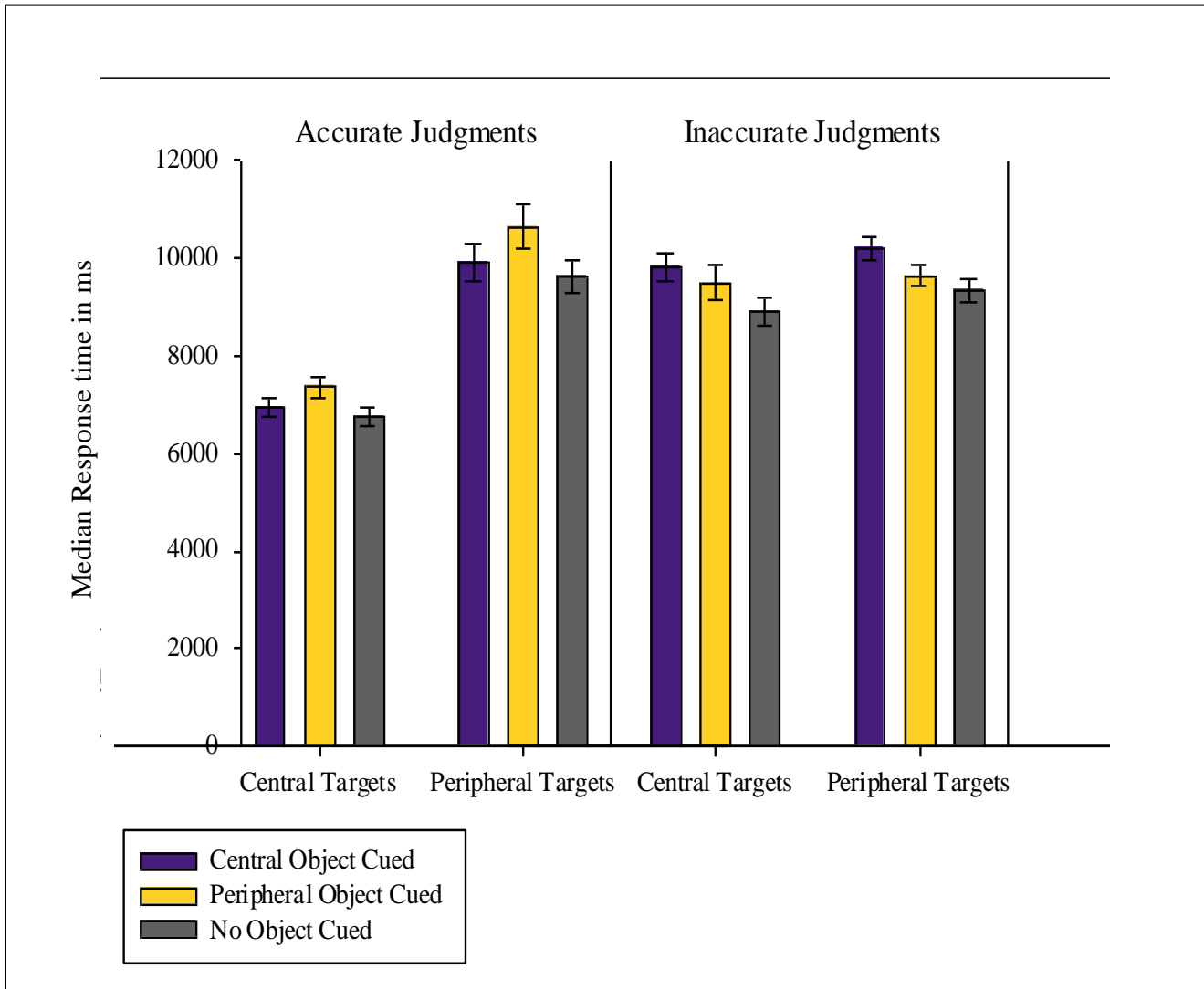
Figure 9. Average median response time for identifications separated by accuracy of identification, test cue type, and target type.

Experiment 2

In the introduction, I discussed the idea that complex events are represented in memory at multiple levels. One major goal of Experiment 2 was to explore the role of contextual information in binding. In particular, the focus was on *object-to-context* binding, which was accomplished by providing clear contextual (background) information in some test cue conditions. Since evidence of object-to-object binding *was* observed in Experiment 1, the focus of Experiment 2 was on determining the relative cuing value of context. That is, I explored whether adding contextual information to object-cued trials provides a better cue compared to either context alone (Experiment 2) or objects alone (Experiment 1).

Methodological Changes in Experiment 2

To address these questions, Experiment 2 included the following methodological changes. First, all trials, with the exception of the no-object cued trials, included undistorted contextual (i.e. background) information. Using the same procedure as for the no-object cue trials, all individual objects were removed from the original scene. Any information that remained was considered *contextual* information (e.g., large furniture like couches/beds, and permanent fixtures like windows/doors). Unlike the no-object cue scenes, this information was not blurred; instead, it was presented unaltered from the learning phase. Second, Exp. 2's cued trials were subdivided into three categories. In addition to a modification of Experiment 1's central-object cued trials and peripheral-object cued trials, participants were also presented with *context-only cued* trials. As the label implies, these trials did not contain any object information; rather participants were only provided with the undistorted background information with the target-marker (see Figure 10 for examples).

Because we found no binding differences when comparing the between-subjects manipulation of attention (narrative vs. labels) in Exp. 1, the narrative condition was eliminated in the current study. Thus, all participants in Exp. 2 heard only the object labels, rather than a narrative concerning the objects within the scene.

Predictions for Experiment 2

In this study, the goal was to examine the role of context on memory binding, and in particular, the binding between objects, and their context. With respect to object-to-context binding, I hypothesized that context-only cue trials would enhance performance accuracy relative to no-object cue test trials based on the findings of previous research on context cuing (Brockmole et al., 2006; Chun & Jiang, 2003; Hollingworth et al., 2001).

A) Learning Phase Scene

B) No-Object cue Test Trial Scene

C) Context-Only Cued Test Trial Scene

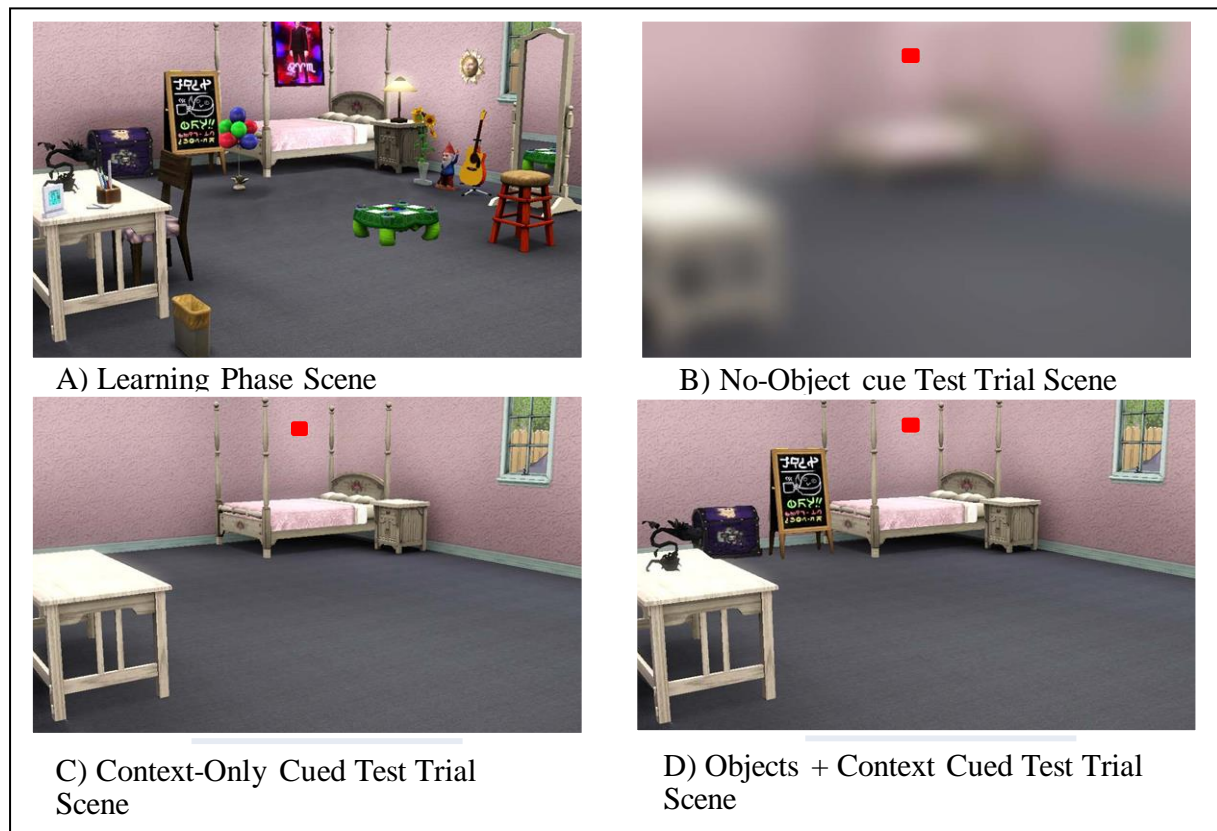D) Objects + Context Cued Test Trial Scene

Figure 10. Comparison between the original encoding scene (A) and the three types of test scenes: no-object cue trial scenes (B), context-only cued trial scenes (C), and objects + context cued trial scenes (central or peripheral; D).

Experiment 2: Methods

Participants

One hundred LSU students participated in Experiment 2. A power analysis for Exp. 2, computed using G*power (Faul et al., 2009) suggested that the appropriate number of subjects to achieve 80% power was 84. This value was determined based on the following parameters: A) an *ES f* of .15 (calculated from Exp. 1's test cue measure's $\eta_p^2 = .02$), B) a type I error rate of .05, C) a within-subjects ANOVA with four levels, and D) an estimated .29 correlation between measures. Participants were comprised of students taking psychology courses at Louisiana State University; each received course credit for their involvement.

Stimuli

Learning phase scenes. The same series of 12 complex visual scenes used in Experiment 1 were also used in this current study.

Learning phase auditory files. Like Experiment 1, each of the visual scenes was paired with an auditory file; visual scene and auditory file were presented simultaneously. This auditory information served to emphasize certain objects within the scene. Unlike Experiment 1, the current study only included auditory files similar to those used in Exp. 1's labels condition. The only difference between Exp. 1's auditory information and the current study's auditory information concerned the rate at which each object name was spoken. In Exp. 1, each object was named in the same temporal position as those objects that were discussed in the narrative condition. In the current study, the object names were spoken at an even rate (the onset of each spoken object occurred every four seconds). This change was made to allow participants an equal amount of time to attend to each object.

Testing phase scenes. As in the previous experiment, the testing phase presented altered versions of the original learning phase scenes. Overall, the testing phase was unchanged from Exp.1. Each scene still contained an altered version of the learning phase scene, four target markers, and an array of six objects. The primary difference between Exp.1 and the current study involved what information from the original scene was displayed. As before, some of the test scenes displayed more information than others; however, instead of three trial categories, test scenes were separated into four categories: 1) no-object cue test scenes, 2) context-only cued test scenes and 3/4) objects + context cued test scenes (displayed either central or peripheral objects). Across the experiment, each scene served as a no-object cued, context-only cued, and objects + context cued (central or peripheral) scene equally often.

No-object cue test scenes. No-object cue test scenes were unchanged from Exp. 1. They displayed a blurred version of the original learning phase scene without any object information.

Context-only cued test scenes. In contrast, context-only cued test scenes presented the original background information without any distortion. For these test scenes, its corresponding original study scene was stripped of all object information, similar to the no-object cue test scenes. Unlike the no-object cue test scenes, the remaining information was not altered in any way.

Objects + context cued test scenes. As the label suggests, objects + context test scenes were identical to the context-only cued test scenes with the exception that they also included three objects from the original learning phase scene. Like Exp. 1, objects displayed as cues were selected from that scene's central or peripheral object pool. Consequentially, these test scenes were further divided into central objects + context cued scenes and peripheral objects + context

cued scenes. Each of the three objects were shown in their original spatial locations and remained unchanged from the learning phase.

Procedure

The procedure for Experiment 2 was identical to that of Experiment 1. The study was still split into two phases, the learning phase, and the testing phase. During the first phase, participants were asked to study a series of scenes and to pay particular attention to those objects mentioned in the audio information. Like Exp. 1, after each scene, participants were tested on their memory for one of these central objects. After all 12 scenes and their corresponding auditory information had been presented; participants were provided with testing phase instructions and started the testing phase of the experiment.

During this phase, participants again made identifications for each of the 12 testing phase scenes. Participants identified four target objects, two central and two peripheral, from each scene; participants completed a confidence rating after each judgment. Once all 48 identifications had been made, participants were asked a series of demographic questions and received a debriefing statement.

Experiment 2: Results

As Exp. 1 provided evidence for object-to-object binding, Exp. 2 concentrated on binding between objects and context. To accomplish this goal, those test cues used in Exp. 1 were modified to include contextual information in the current study. In addition, a new test cue type, one that only included undistorted background information, was added (i.e. context-only cued). Thus, Exp. 2 included four test cue types: no-object cue (unchanged from Exp. 1), central objects + context cued, peripheral objects + context cued, and context-only cued.

As in Exp. 1, partial eta squared was used as the estimate of effect size and $\alpha < .05$ was used as the criterion for significance. Figure 11 displays the average accuracy rates for judgments associated with each of the four test cue types separated by the two target types. As in Exp. 1, the probability of choosing the correct target by chance was 16.6%. The specific focus of the current experiment was to explore the relative cuing value of context. Like Exp. 1, this involved two separate questions. Does attention influence the probability that an object will bind to its context? Will the relative cueing value of a test cue (i.e. the strength of the binding between the test cue and the to-be-remembered object) be enhanced if objects (central or peripheral) are included with their original context? In other words, I examined whether providing undistorted background information improved accurate identifications and whether this interacted with attention during encoding. To explore these points, a 2 (Target type) X 4 (Test Cue type) within-subjects ANOVA was conducted with accuracy as the dependent variable.

Like Exp. 1, the principal analyses focus on how the test cue type (no-object, context-only, objects + context [central or peripheral]) affected the probability of identifying the correct missing target object. Again, each target object was selected from those objects that either were in the focus of attention during the encoding phase, or were peripheral to those attended objects.

Object-to-Context Binding

The 2 (Target type) X 4 (Test Cue type) within-subjects ANOVA yielded both a significant main effect of target type, again with higher accuracy rates for central targets ($M =$ .65) compared to peripheral targets ($M =$ .24), $F(1,99) = 713.11$, $p < .01$, $MSE = .05$, $\eta_p^2 = .88$, and a significant main effect of test cue type, $F(3,297) = 11.46$, $p < .01$, $MSE = .03$, $\eta_p^2 = .10$. Pairwise comparisons reveal that test cues containing context, central objects + context ($M =$ .46), peripheral objects + context ($M =$ .47) and context-only ($M =$ .47), led to significantly higher performance than no-object cue test trials ($M =$ .38); yet, the test cues containing context were not significantly different from one another.

Again replicating Exp. 1, these results were qualified by a significant interaction, $F(23,297) = 4.57$, $p = .004$, $MSE = .03$, $\eta_p^2 = .04$. To explore this interaction, the effect of test cue type was evaluated separately for the two target types (see Figure 11 for a graphical representation). For both central and peripheral targets, a significant effect of test cue type was found, $F(3,297) = 9.53$, $p < .01$, $MSE = .04$, $\eta_p^2 = .09$ (central targets); $F(3,297) = 6.17$, $p < .01$, $MSE = .03$, $\eta_p^2 = .06$ (peripheral targets). For central targets, pairwise comparisons reveal that the no-object cue test trial was associated with significantly lower accuracy rates ($M =$ .56) as compared to the other test cue types (central obj. + context = .69, peripheral obj. + context = .65 and context-only = .68). This finding indicates that context alone is sufficient for cueing an object that was in the focus of attention during encoding; further, the addition of any object to the test cue did not provide any further aid in retrieving information about the missing target.

Unlike the central targets, pairwise comparisons for peripheral targets show a slightly altered pattern. First, it was found that the no-object cue test trial was associated with significantly lower performance ($M =$ .19) compared to either the context-only cued ($M =$ .25)

and the peripheral obj. + context cued test trials ($M = .29$), however, the no-object cue test trial

was not significantly different from the central obj. + context cued trial ($M = .22$). Taken as a

whole, there is some evidence suggesting that the presence of objects may influence the cuing

value of context in certain circumstances. It appears that when the context itself is a poor cue

(because the target object was not attended to during encoding; i.e. peripheral target) the addition

of other non-attended objects can enhance the cuing value of that context (as compared to when

attended objects were added to the context cue; i.e. central obj. + context cued).

With regards to my original research question, it appears that when the missing target

object was studied during encoding, no differences in identification accuracy were found when

additional objects were present in the test cue (whether or not they were central or peripheral to

attention during encoding). This would suggest that the cuing value for context and the cuing

value for objects are not additive.

However, this pattern is slightly altered when the missing target object was not in the

focus of attention during encoding. It appears that when the cuing value (i.e. identification

accuracy) for context is drastically reduced (from .68 [central targets] to .25 [peripheral targets]),

the addition of objects to the test cue does slightly enhance identification accuracy. Specifically,

it was found that providing both context and peripheral objects improved performance for

peripheral targets, but only when compared to their central object counterparts.

Additional Measures

    Confidence measures. For descriptive statistics concerning confidence ratings for

judgments associated with each of the four test cue types and two target types see Table 3. Like

Exp. 1, the following analyses reflect only confidence ratings associated with accurate

identifications. Two within-subjects ANOVA's were conducted, separately for target type

(central and peripheral) using Cue type as the within-subjects variable for both. With these analyses, only four participants were excluded in the analysis for central targets, however, analysis for peripheral targets reduced the number of participants from 100 to 42. Like Exp. 1, all means discussed within the text reflect this reduced number of participants; in contrast, Table 3 provides descriptive statistics for all participants.
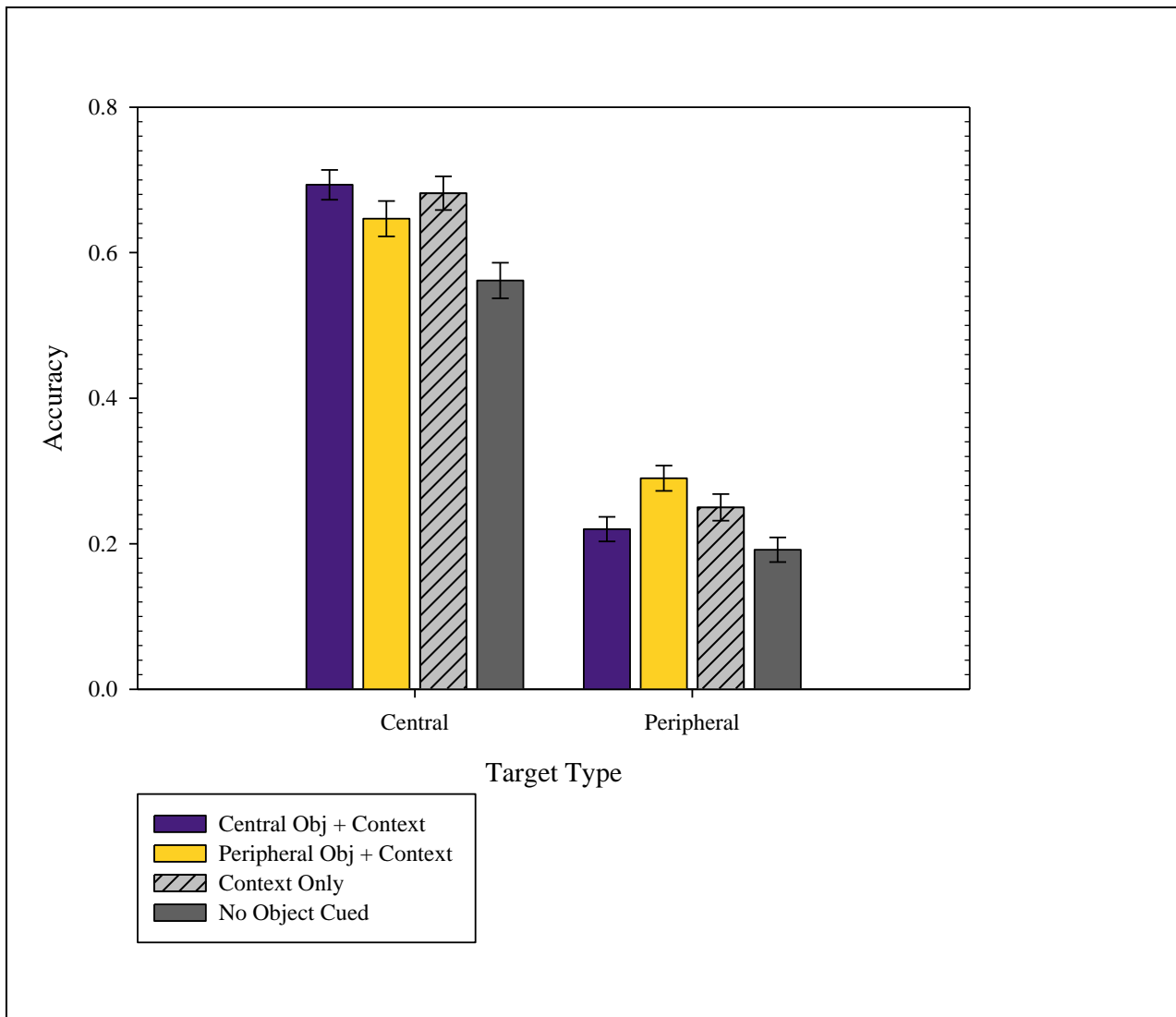

Figure 11. Graphic representation of identification accuracy between the two target types and four test cue types.

Like Exp. 1, a significant main effect of test cue type for central targets was found[5], $F(2.66, 252.78) = 27.41$, $p < .01$, $MSE = 1.25$, $\eta_p^2 = .22$. Pairwise comparisons reveal that central targets cued with central objs. + context have significantly higher confidence ratings ($M = 5.68$) compared to any other test cue type (peripheral objs. + context = 5.34, context-only = 5.23 or no-object cue = 4.36). Furthermore, both peripheral objs. + context and context-only cues have significantly higher confidence ratings compared to no-object cue trials, but they are not significantly different from each other. A significant main effect of test cue type was also obtained for peripheral targets[5], $F(2.46, 100.84) = 3.78$, $p = .019$, $MSE = 3.44$, $\eta_p^2 = .08$. Pairwise comparisons show that although targets cued by central objs. + context have significantly higher confidence ratings ($M = 3.77$) compared to peripheral targets cued with peripheral objs. + context ($M = 2.80$), central objs. + context cues are not significantly different from those targets cued with context-only ($M = 3.88$) or no-object cue trials ($M = 3.21$). Peripheral objs. + context cues are also associated with significantly lower confidence ratings compared to context only cues, but do not differ from confidence ratings where no-object were presented in the cue.

In short, these findings indicate that participants have the most confidence in those identifications where the test cue included objects that were in the participants' focus of attention during encoding. Thus, it appears that the presence of central objects did enhance confidence in those decisions even when only accurate judgments where examined. In addition, confidence is enhanced when test cues contain context only or context + objects that were not attended to during encoding, when compared to test cues containing only a distorted version of the original context.

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[5] Because this analysis violated Mauchly's test of Sphericity a Greenhouse-Geisser correction was used.

From a signal detection theory perspective, this finding suggests that the presence of either contextual information and/or objects from the original encoded scene enabled participants to retrieve a stronger memory for the correct target. This was most true when the test cue provided contextual information and objects that were originally in the focus of attention.

Response time measures. Figure 12 displays participants' average median response time for identification judgments separated by: target type and test cue type. By and large, the same pattern of findings was obtained when comparing the average median response time for participants' in Exp. 1 to the current study's response time data. A 2 (Target type) X 4 (Test Cue type) within-subjects ANOVA shows a main effect of Target type; judgments for central targets were significantly faster ($M = 6645.92$ ms) than judgments for peripheral targets ($M = 8662.92$ ms; $F(1, 99) = 167.36$, $p < .01$, $MSE = 4861733.71$, $\eta_p^2 = .63$).

Second, a main effect of test cue type was obtained, $F(2.63, 260.22) = 10.81$, $p < .01$, $MSE = 8486825.91$, $\eta_p^2 = .10$. Pairwise comparisons reveal that participants were fastest when cued with no-objects ($M = 7117.15$ ms); furthermore, targets cued with context-only ($M = 7563.54$ ms) were significantly faster than if cued by either central ($M = 7944.83$ ms) or peripheral ($M = 7992.17$ ms) objs. + context, which were not significantly different from one another.

However, these main effects were qualified by a significant interaction, $F(3,297) = 4.47$, $p = .004$, $MSE = 2234734.37$, $\eta_p^2 = .04$. To explore this interaction, a within-subjects ANOVA was conducted for each Target type, with Cue type as the within-subject variable for both analyses. For peripheral targets, there was a significant main effect of target type, $F(3,297) = 12.41$, $p < .01$, $MSE = 2964366.32$, $\eta_p^2 = .11$, with both the no-object cued ($M = 7951.43$ ms) and context-only cued ($M = 8366.30$ ms) targets significantly faster than either central objs. + context

(M = 9193.26 ms) and peripheral objs. + context (M = 9140.68 ms), but not significantly

different from one another. Although there was no significant main effect of cue type for central

targets[5] $F(2.60, 257.22) = 2.68$, $p = .056$, the pattern of results is very similar to that of the

peripheral targets.

In the same way as Exp. 1, when any information was added to the test cue (context,

objects, or both), generally participants took significantly longer to make their identifications.

These findings tell us that the experimental manipulation was, again, effective; participants

instructed to use all pertinent information to make their identifications appeared to take more

time to process test cues that contained more information.

Table 3
Mean Confidence Ratings

	Test Cue Type			
	Central Objs. + Context	Peripheral Objs. + Context	Context-Only	No-Object
Target Type				
Central Target	5.69 (0.10)	5.31 (0.12)	5.24 (0.14)	4.38 (0.17)
Peripheral Target	3.69 (0.19)	3.08 (0.18)	3.66 (0.20)	3.00 (0.22)

Note: Standard errors appear in parentheses. Mean confidence ratings reflects the confidence ratings for accurate judgments for all participants.
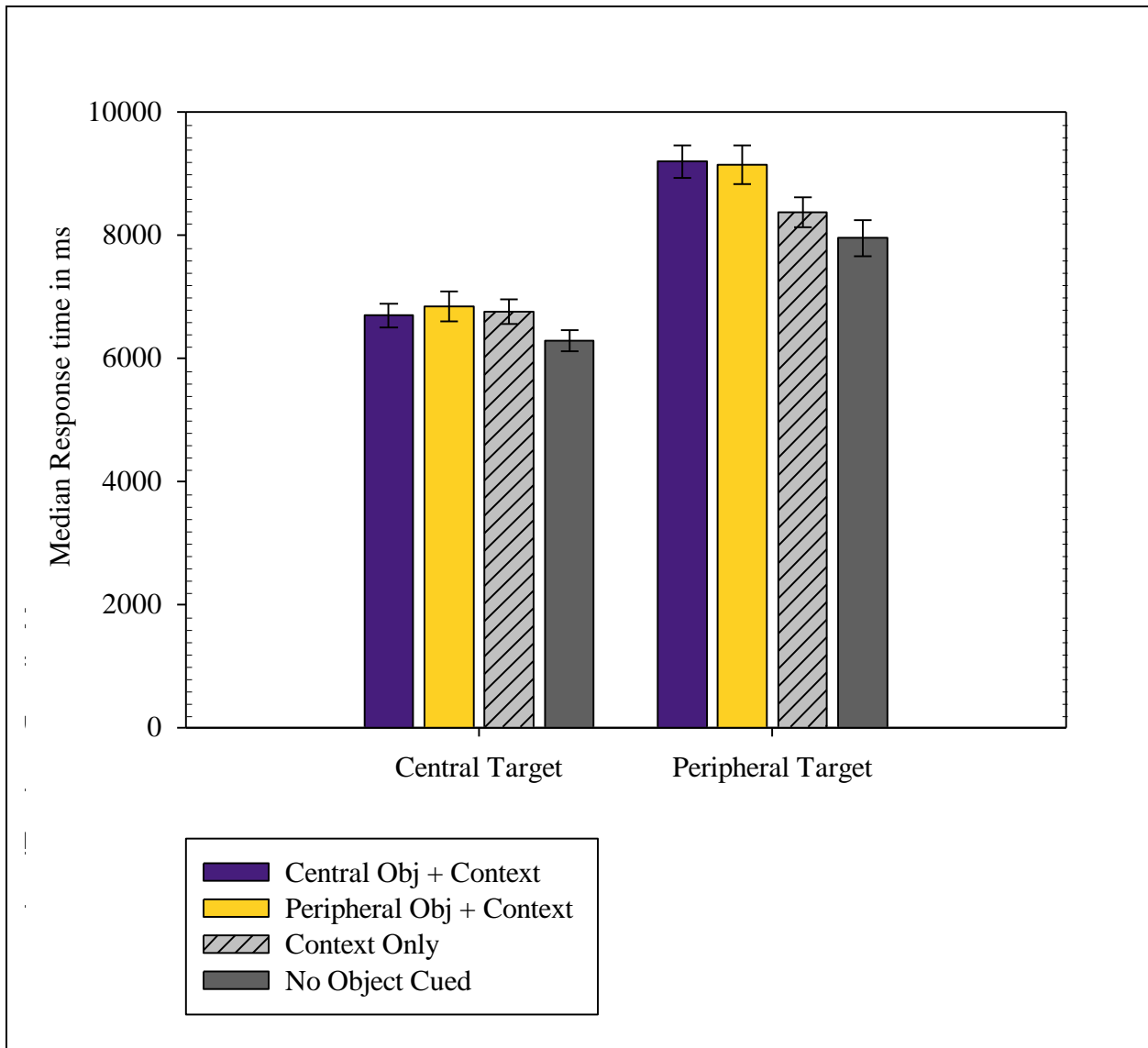
Figure 12. Participants' average median response time for identification judgments separated by target type and test cue type.

General Discussion

The preceding studies examined the structure of memory for a complex event, specifically how individual components of these memories are bound together. There were four main findings. First, cueing one aspect of an event (object or context) can increase the likelihood that another aspect of that event (i.e. object) will be retrieved. In other words, both Exps.1 and 2 found evidence for object-to-object binding and object-to-context binding. Second, when objects are the only cue used to retrieve other missing objects (Exp. 1), the boost to retrieval is only evident when the cued information and the to-be-retrieved information were both in the focus of attention during encoding. That is, attention plays a critical role in whether individual objects become bound to other objects or to background information. In general, targets that were the focus of attention displayed the highest accuracy rates in both Exp. 1 and 2. Moreover, when cued with central objects (Exp. 1) the accuracy for central targets was significantly increased relative to those targets cued by other information (i.e., peripheral objects, or no-objects).Third, and contrary to my initial hypothesis, there was no evidence suggesting that binding depends on attention to the relationships between those to-be-bound elements of a complex event during encoding. More specifically in Exp. 1, there were no significant binding differences between participants who were provided information linking objects in the focus of attention versus merely attending to these central objects during the encoding phase. Fourth, Exp. 2 provides limited evidence suggesting that the cueing value of context may be increased when object information is added to the test cue. That is there are limited circumstances where both context and object information provides a better cue than merely the context alone. This finding was only obtained when peripheral targets were cued with both context and other peripheral objects. In other words, this result was only found when memory for the target was weak (not in the focus

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of attention during encoding) and the test cue contained objects that were also weakly encoded. For all remaining target and test cue combinations, there was no increase in accurate identifications when test cues included both objects and context.

As a whole, these findings appear consistent with a number of previously mentioned studies examining feature-to-feature binding in memory (Meiser & Bröder, 2002; Meiser et al., 2008; Uncapher et al., 2006). In particular, Meiser et al.'s study provides findings that are most equivalent to the current studies' results. Like other feature binding experiments, Meiser et al. found evidence of binding between font size and location. More importantly however, they found this binding exclusively for items judged to be "remembered" (indicating distinct recollection) as compared to those items that were judged to be "known" (indicating a feeling of familiarity). Although the methods differ considerably, Meiser et al.'s "remembered" items are arguably similar to the current study's central objects. Participants were instructed to only select "remember" when the word evoked a "conscious and maybe vivid recollection of a word's prior occurrence" (p. 36). In order for participants to have this conscious recollection, they must have devoted a minimal amount of attention to these items. Likewise, items that were judged to be "known", could be considered similar to our peripheral items, in that they may not have been directly attended to, but some aspect of the item (e.g., feature) may be retrieved from long-term memory.

Furthermore, the findings of the current study also replicate several studies that have examined the relationship between memory for an individual item and its context (Brockmole et al., 2006; Chun & Jiang, 2003; Hollingworth, 1998; Hollingworth, 2007; Hollingworth & Henderson, 1999; Hollingworth et al., 2001) or other groups of objects (Brady & Alvarez, 2011; Brady et al., 2009; see also Chun & Turk-Browne, 2008 for a review of associative learning in

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vision). As previously described, Hollingworth's (2007) study of contextual cueing found that individual item memory was enhanced when presented with its original context. Although the definition of what they term "context" (all information excluding the to-be-tested object) is slightly different from the current study's definition (scene information minus all individual objects), the results of the current work are in line with their findings. To summarize, Hollingworth (2007) assessed participants' memory for individual objects within a series of complex scenes. He tested memory by asking participants to complete a discrimination task for these objects (which may or may not have changed from the original scene). These objects were shown amid their original context, another studied context, or on a blank screen. They found that the original context (as compared to another studied context or no context) increased participants' accuracy in detecting whether the object had been altered. Although there are clear differences between their methods and the procedure used in the current work, my results suggest that providing correct contextual information enhances memory for individual objects as compared to providing degraded context (arguably similar to no context).

While my findings are consistent with the results of several related studies, there are some notable exceptions. One exception comes from Starns and Hicks' (2005, 2008) work. While I took steps to ensure that the methodology used in this study did not suffer from the same flaw as other feature binding research, I found evidence of binding while they did not. However, it is important to note that although Starns and Hicks provided the template for my research design, the aims of my research were considerably different from the goals of their studies.

As described in the introduction, Starns and Hicks (2005, 2008), argued that early evidence of feature binding in memory may have been easily explained by their variable strength hypothesis. That is, the correlations between the different features of an item may be illusory and

merely due to the strength of the memory for the item itself. One may remember both features of an item because they have a very strong memory for that item, conversely, weaker memory for an item may result in weaker memory for features associated with that item. Thus, when the actual item is presented, it may cue both features or neither feature depending on the strength of the memory trace. To account for this flaw, participants in their work were never presented with the original item, but were only given one feature of an item (color or location) as a cue to remember the other feature. In this way, participants could only use that one feature as a cue for the second feature. Similarly, my methodology ensured that the original item (i.e. scene) was never presented as a cue. Although I did not use one feature to cue another (as the current work was not meant to examine feature binding), I instead used the closest analogous cue, a set of objects (excluding the original scene information) as a cue for another object. Since the original scene was not presented to participants as a cue, they would not have been able to use their "scene" memory as a retrieval cue for the missing object. Furthermore, if participants were able to use this degraded scene information to retrieve the actual scene I should have found similar performance between the no-object cue scenes and the object-cued scenes. Instead, I found a significant increase in identification accuracy between these two target types.

Although my findings may appear inconsistent with the findings of Starns and Hicks' (2005, 2008), there are two major reasons that may account for this difference. First, Starns and Hicks (2005) note that their feature dimensions (font size and location) did not share an obvious relationship to one another. This independence may have made it difficult for participants to organize this information into a higher order representation. They suggest that using other source dimensions (i.e. features) that are more easily integrated may produce different findings. Due to the nature of the stimuli used in the current study, it could be argued that the objects in each

scene were easily and naturally integrated into a higher order representation (Hollingworth, 2009). Each scene was designed to resemble a real world setting. This meant that all objects designed to be hung on a wall, placed on a table, or situated on the floor were positioned in those locations. Furthermore, each scene type (living room, bedroom, and office) included both objects and contextual information (i.e., large furniture [beds, couches, desks]) consistent with that room type. This would allow participants to encode each scene into a kind of mental model. (Radvansky & Copeland, 2000).

Traditionally the term mental model has been used to describe the mental representations created after having read a list of objects and their various locations (Radvansky & Copeland, 2000). However, the primary characteristics (objects and locations organized into the structure of a memory representation) are very applicable to the current work. One key point to the concept of mental models is that the spatial relationships between objects affect retrieval (Radvansky & Copeland, 2004). The easier it is to integrate the various elements of a scene into a higher order construct (mental model), the easier it is to retrieve specific information from various elements in the structure. For this reason, I argue that the elements of the stimuli used in both Exp. 1 and 2 had clear and natural relationships with one another, which facilitated their integration into a structured memory representation.

The second reason that the current findings may diverge from those of Starns and Hicks (2008) is related to my attention manipulation. Starns and Hicks acknowledge that their findings may not generalize to those studies that encourage participants to intentionally learn the to-be-bound attributes. They explain that one reason their results differ from previous work may be that their methodology did not include an intentional learning component. Their findings are more pertinent to the independence of peripheral components; how they are only integrated into

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the overarching memory, but not bound to one another. This interpretation of their findings would be supported by the current work. In Exp. 1 and 2, the attention manipulation directed participants to intentionally learn certain "components" of the complex scene, while ignoring (to a more or lesser degree) the remaining information in the scene. Object-to-object binding was found solely between those objects that were directly attended to during the encoding phase.

Outside of feature binding research, a small number of studies also seem inconsistent with the current findings. For example, in the eyewitness literature, Fisher and Cuervo (1983) found no relationship between accurately recalling two distinct traits associated with a group of individuals (gender and language). In this study, Fisher and Cuervo asked participants to listen to a mock court proceeding with the goal of deciding which group was entitled to disputed land. An unannounced source test revealed that accurately identifying one trait had no relationship to accurately selecting the second trait. They interpreted this finding to suggest that episodic event memories contain multiple features that are independent of one another. They argued that if these traits were bound together, then recalling one trait should affect recall of the second trait.

In a related study, Brewer et al. (1999) found no correlation between the accuracy of memory concerning one aspect of a crime (e.g., description of the offender, offender's actions, description of the bystander etc.) with other aspects of that same crime. These findings, along with other similar research (see Fisher et al., 2009), led Fisher and colleagues to argue that the individual components of an event are relatively independent.

As in the previous discussion of Starns and Hicks' (2005, 2008) work, the reason behind why these findings and the results of the current studies diverge may be due to variability in attention at the time of encoding. In Fisher and Cuervo's (1983) research, they manipulated how relevant a given trait (gender and language) was to completing the task. The participants' task

goal was to evaluate a series of arguments from two groups and rule in favor of the group with the best argument. What was fundamental to this task was the association between the statement (argument) and the group identity. For a given participant, only one feature (gender or language) helped to differentiate these groups. Consequently, there was no benefit to attending to the non-discriminating trait, as it was irrelevant to the task goal. As a result, binding between traits may have been reduced because attention was focused on the salient trait (and not on the other trait) or task demands discouraged the creation of these bindings.

In Brewer et al. (1999), participants' attention during a complex event was allowed to vary freely. This freedom allows for unique patterns of attention. Their primary measure of interest concerned the correlations between memory for details sorted into different categories. Averaging across both details (putting them into a category) and participants may have obscured the detection of a relationship. For example, some participants may have found information concerning the offender's actions very attention grabbing, while others focused on the bystander's appearance. Due to this variability, some items may have been bound together while others may show no relationship.

Not only do the current studies' findings support this possible interpretation, the work of Wells and Leippe (1981) lends credence to this argument. In a similar procedure, Wells and Leippe had participants witness a staged theft, complete a lineup identification, and answer an 11-item questionnaire. This questionnaire assessed each participant's memory for the peripheral details of the room where the staged theft took place (e.g., how many light bulbs were on, how many chairs were in the room?). Overall accuracy for the questionnaire was negatively correlated with identification accuracy ($r = -.41$). Importantly however, the correlations between identification accuracy and accuracy for particular questions within this questionnaire varied

significantly (two items showed slight positive correlations, and only one item showed a significant negative correlation when isolated). This suggests that with more items (and categories of items) the correlations between accuracy for a variety of information may be diluted.

As discussed in the introduction, both Johnson's MEM framework (1983, 1992) and Brady et al.'s (2011) Hierarchical Feature Bundle (HFB) theory appear to make relevant predictions for the current study. By and large, both provide arguments for the structure of long-term memory (general or specifically visual memory) that are consistent with my overall findings. As previously explained , MEM describes specific subsystems that are responsible for the creation of event memories The reflection subsystem is particularly relevant as it is responsible for creating links between objects, actions and context that, in turn, allow event memory to appear both cohesive and coherent. The reflection subsystem is argued to be controlled by a person's agenda (i.e., their goals) which create processing differences resulting in central and peripheral information. Relationships between these central items are created through other functions, such as *shifting* (directing attention from one thing to another) and *noting* (identifying how these items may be related). In short, these functions increase the interconnectedness between central items as well as their fidelity in memory. As a consequence, the memory representation becomes more cohesive.

Similarly, the Hierarchical Feature Bundle (HFB) suggests that complex visual memory, scene memory, is represented in a higher order structure. As mentioned previously, the information in these differing levels of the structure vary from the specific features of an object to the gist of the scene itself. Most importantly, elements within and between these levels of abstraction interact with one another (are both informative and constricting; for further research

examining the relationships between these elements see research in visual statistical learning; Brady & Alvarez, 2011; Brady et al., 2009; Baker et al., 2004; Fiser & Aslin, 2001, 2002, 2005; Turk-Browne et al., 2005). HFB also highlights the role attention plays in not only encoding these elements, but also in how they may interact. They suggest that attention shifts amongst featural information, contextual information, and general scene structure. As this information accrues, it also interacts, affecting where attention will be deployed and also influencing memory for the information itself. That is, information that has been encoded influences shifts of attention, which then affects what additional information is encoded and integrated into the overall scene representation.

Most of the predictions taken from both the MEM framework and HFB are not only supported by the current study, but the current procedure itself can be easily translated into the operation of MEM's reflection subsystem. For example, participants were given directions (i.e. an agenda) to attend to specific objects. As each object was mentioned, participants were told to *shift* their attention to that named object. This agenda controlled how attention was shifted and where it was allocated. As a consequence, objects that were central (specific objects that participants were told to attend to) were separated from those that were peripheral (all remaining objects)[6]. At this point participants *noted* the relationships between each item and bound them together.

It is important to mention that although this noting clearly took place[7], it appeared to be unaffected by the between-subjects manipulation of the nature of attention. That is, providing additional information relating objects to each other did not increase binding. The intention of

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[6] Evidence supporting this statement comes from the accuracy differences between targets that were central and those that were peripheral.

[7] This argument is supported by the significant accuracy differences between central targets cued with central objects and central targets cued with either peripheral objects or no objects.

this manipulation was to either provide or withhold information that may be used to actively create the bindings between related objects. Participants in the narrative condition were told to not only attend to the objects, but also the additional details that denoted relationships between these objects. Participants in the labels condition were merely given the instruction to pay attention to the objects that were named; no further information concerning how these objects were related was provided. It has been argued that binding, in certain circumstances, may require both attention to the to-be-bound items and a deliberate intention to encode how they are related (Morey, 2011). According to Morey, the need for this explicit intention to encode relationships may increase based on the difficulty of the recognition task (i.e., how many letters and spatial locations needed to be bound in an individual trial; set size). Due to the complexity of the current study's task, I predicted that binding would require an explicit intention to encode the relationships between items. In other words, I expected to find significantly more binding in the narrative condition than the labels condition. While there was no notable difference between binding in these conditions, it was clear that all participants both shifted their attention and noted relationships between central items, regardless of condition. Although participants in the labels condition were not given additional auditory information that related the objects, the visual information alone could provide many details that may have linked central objects together (e.g., their location within the scene, color similarities, any similarities in function etc.). Thus, these participants may have actively related the objects to each other even in the absence of narrative information.

Summary

The foregoing studies were designed to examine how the components of a complex event are bound into a unified structure and what role attention may play in this binding process. The

results revealed that the individual components of a complex scene (i.e. objects) are not only bound to the overall scene information (i.e., context, Exp. 2) but also to other objects (Exp. 1). This suggests that these components of complex memories may be, under some circumstances, relatively dependent rather than independent. Furthermore, these results suggest that focused attention may be necessary to bind together certain components of a complex event (i.e. object-to-object), but may be less necessary to bind together other components (object-to-context).

This finding has important implications, particularly for false memory research. The results of the current work suggest that certain components of a complex event may require more attention to be bound into the memory structure than other components. This could imply that these components may be more vulnerable to binding problems and thus errors in memory.

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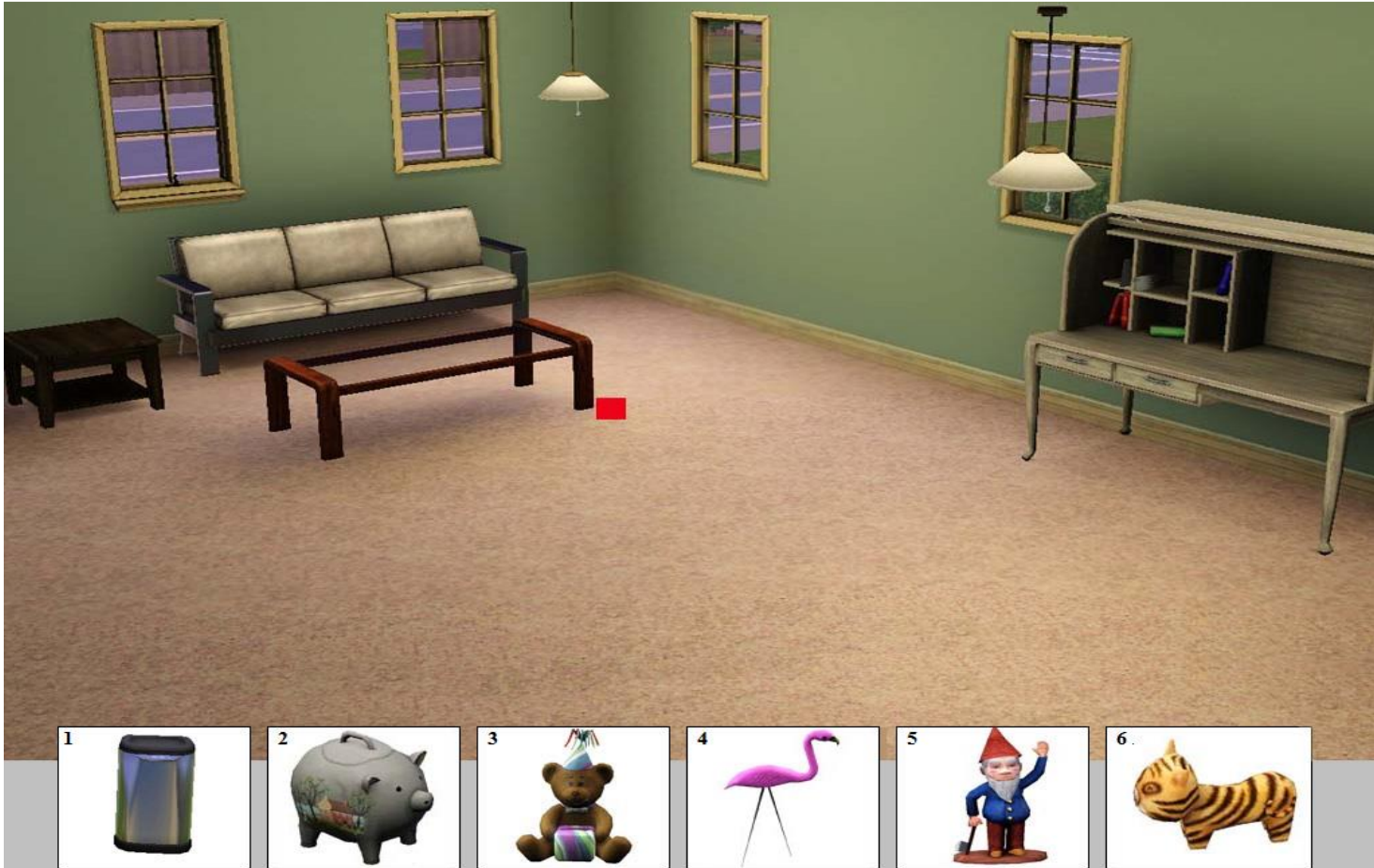
Examples of Testing Scene Types: No-object cue (Exp. 1 & 2), Object-cued (Exp. 1), Context-only cued (Exp. 2), Objects+ Context cued (Exp. 2)
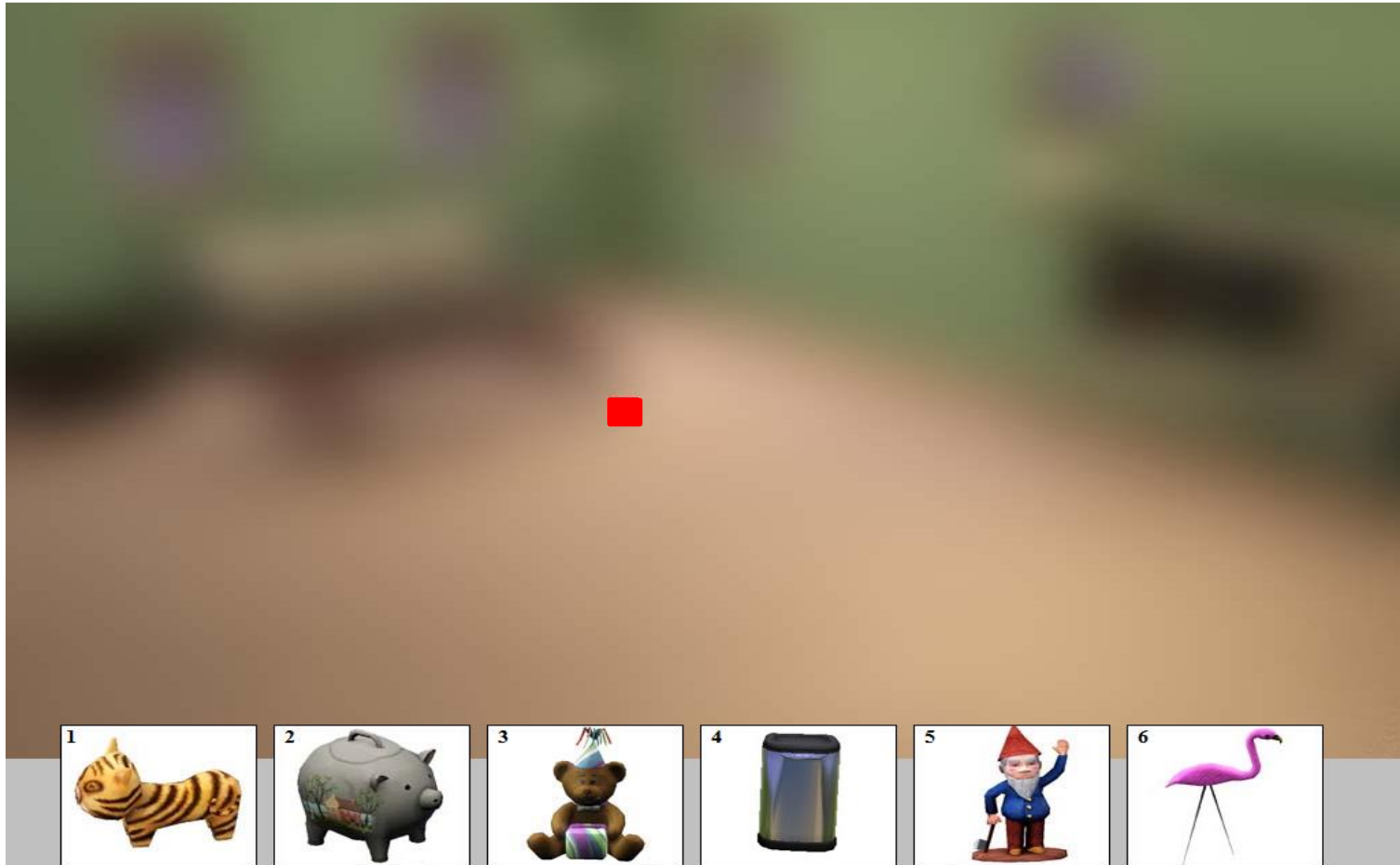
No-object cued Scene Trial
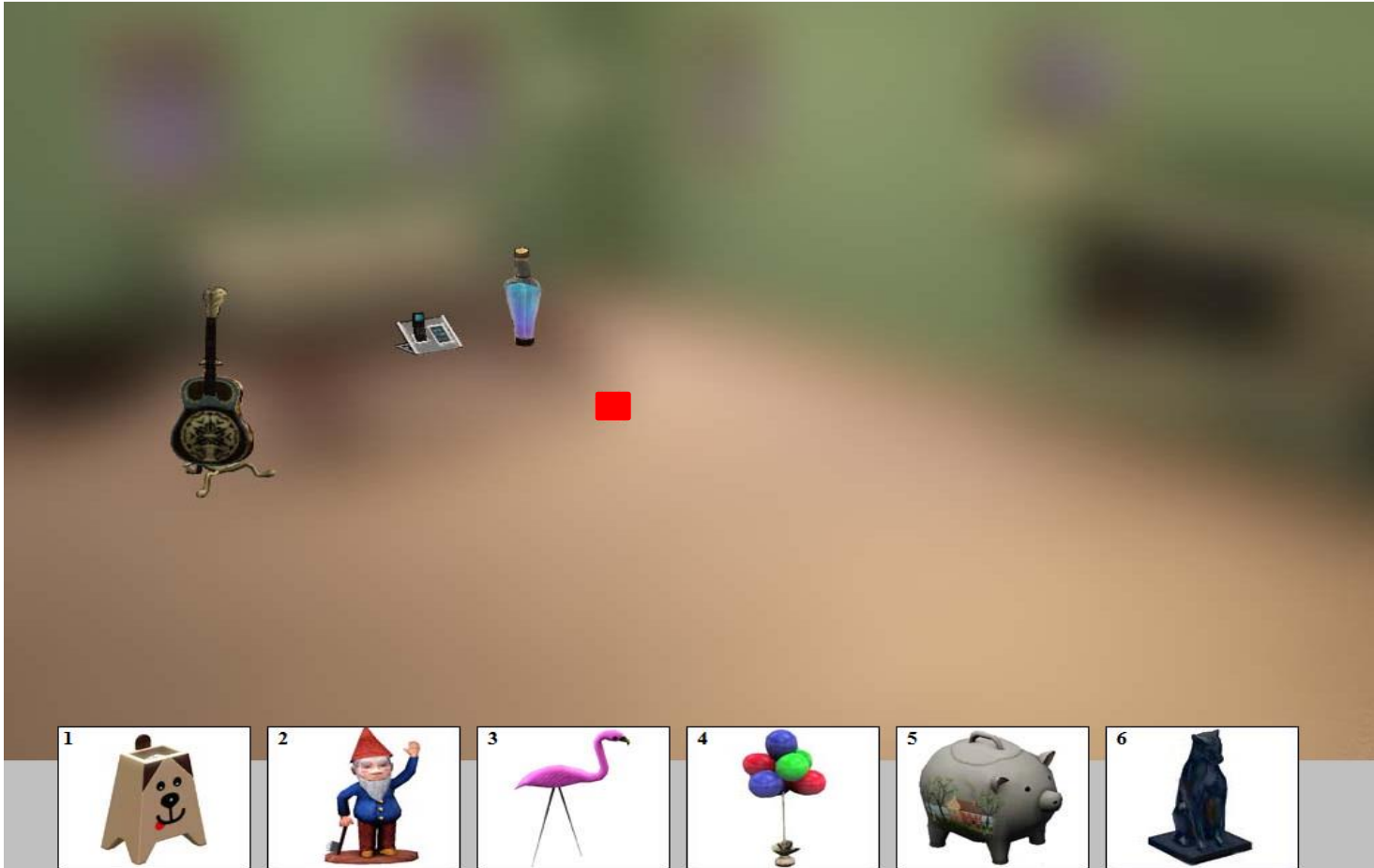
Object-cued Scene Trial (Exp. 1)

Context-Only Cued Scene Trial (Exp. 2)

Objects + Context Cued Scene Trial (Exp. 2)

IRB Approval

Application for Exemption from Institutional Oversight

LSU

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/ projects using living humans as subjects, or samples, or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.

Institutional Review Board
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irb@lsu.edu
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— Applicant,Please fill out the application in its entirety and include the completed application as well as parts A-F, listed below, when submitting to the IRB. Once the application is completed, please submit two copies of the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at http://research.lsu.edu/CompliancePoliciesProcedures/InstitutionalReviewBoard%28IRB%29/item24737.html

— A Complete Application Includes All of the Following:
(A) Two copies of this completed form and two copies of parts B thru F.
(B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1&2)
(C) Copies of all instruments to be used.
   *If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.
(D) The consent form that you will use in the study (see part 3 for more information.)
(E) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (http://phrp.nihtraining.com/users/login.php)
(F) IRB Security of Data Agreement: (http://research.lsu.edu/files/item26774.pdf)

1) Principal Investigator: Stephanie Martin   **Rank:** Graduate Student

Dept: Psychology Department   **Ph:** 225-200-9241   **E-mail:** Smart36@tigers.lsu.edu

2) Co Investigator(s): please include department, rank, phone and e-mail for each
*If student, please identify and name supervising professor in this space
Dr. Sean Lane, Department of Psychology, Associate Professor, (225) 578-4098, slane@lsu.edu

IRB# E7008 LSU Proposal #_____
☑ Complete Application
☑ Human Subjects Training

3) Project Title: Memory for Scenes

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Exemption Expires: 9/12/2015

4) Proposal? (yes or no) No   **If Yes, LSU Proposal Number** _____

Also, if YES, either   ◯ This application **completely** matches the scope of work in the grant
           OR   ◯ More IRB Applications will be filed later

5) Subject pool (e.g. Psychology students) Psychology Students
   *Circle any **"vulnerable populations" to be used**: (children <18; the mentally impaired, pregnant women, the ages, other). Projects with incarcerated persons cannot be exempted.

6) PI Signature [signature]   **Date** 9-4-12   (no per signatures)

** I certify my responses are accurate and complete. If the project scope or design is later changes, I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

Screening Committee Action: Exempted __X__ Not Exempted ____ Category/Paragraph __1__

Signed Consent Waived?: Yes / No

Reviewer ALEX COHEN Ph.D   **Signature** [signature]   **Date** 9-13-12

Consent Form

LOUISIANA STATE UNIVERSITY – BATON ROUGE CAMPUS

Study Title: Memory for Scenes

The purpose of this experiment is to explore how people learn and remember events. In this experiment you will be asked to view a series of scenes and answer some questions about them. This is entirely voluntary and you will not be penalized in any way for not volunteering. Your involvement will last approximately thirty minutes and you will receive extra credit or partial course credit in your psychology course for your participation.

Any discomforts or risks that may result from participation are minimal. On the other hand, participating in this experiment will allow you to learn more about the ways that researchers investigate people's cognitive abilities. The data gathered on you will be kept confidential because all the information you provide will be coded numerically. The coded data will only be examined by duly authorized representative of the research team and you are assured that the information will not be used for any other purpose other than the scientific goals of the experiment. If you choose to participate, you are free to stop at any time without penalty of any sort. Information on LSU policy and procedures for research participation can be obtained by contacting Dr. Robert Mathews, Chairman, Institutional Review Board, 578-8692.

Any questions you may have regarding procedures or any other aspect of the study can be answered by contacting Dr. Sean Lane in the Department of Psychology at 578-4098.

I have been briefed by the project director (or designate) in detail about this project and understand what my participation involves. I agree to participate with the understanding that I may withdraw at any time. I agree with the terms above and have read and understood this consent form.

_____   _____

Participant Signature   Today's Date

_____

Print Your Name

_____   _____

Experimenter Signature   Today's Date

Vita

Stephanie Martin was born in Metairie, Louisiana, on January 1984, to parents Donna Romanko and Jerry Buford. She graduated from Boone County Public High School in Florence, Kentucky. She transferred to Louisiana State University from Northern Kentucky University where she began working with Dr. Sean Lane and Cristine Roussel as an undergraduate lab assistant. In 2006, she received a Bachelor's of Science degree in Psychology and was awarded the university medal for a 4.0 cumulative GPA. Stephanie received a Master's degree in psychology in 2009 and has continued on to pursue a Ph.D. from Louisiana State University with Dr. Sean Lane.