Investigating Familiarity's Contribution to Source Recognition

by

Matthew V. Mollison

B.A., Brandeis University, 2005

A thesis submitted to the

Faculty of the Graduate School of the

University of Colorado in partial fulfillment

of the requirements for the degree of

Master of Arts

Department of Psychology and Neuroscience

2010

This thesis entitled:
Investigating Familiarity's Contribution to Source Recognition
written by Matthew V. Mollison
has been approved for the Department of Psychology and Neuroscience

Tim Curran

Albert Kim

Akira Miyake

Date

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

IRB protocol #0101.09

Mollison, Matthew V. (M.A., Psychology)

Investigating Familiarity's Contribution to Source Recognition

Thesis directed by Dr. Tim Curran

In a dual-process framework, two processes are involved in successful recognition memory: recollection involves the retrieval of specific information from the study episode, and familiarity supports recognition without remembering additional episodic details. The differences between these processes have been examined using patterns of activity in the electroencephalogram (EEG) correlated with behavior. Event-related potentials (ERPs) dissociate these recognition memory processes, specifically with an early (approximately 300–500 ms) frontal effect relating to familiarity (the FN400) and a later parietal (500–800 ms) effect relating to recognition. It has been debated whether source information for a studied item (i.e., contextual associations from when the item was previously encountered) is only accessible through recollection, or whether familiarity can contribute to successful source recognition. Importantly, prior research has shown that while familiarity can assist in perceptual source monitoring when the source attribute is an intrinsic property of the item (e.g., an object's surface color), only one prior study has demonstrated its contribution to recognizing extrinsic (unrelated) source associations. Perceptual and conceptual source associations were examined in three experiments involving memory judgments for pictures of common objects. In Experiment 1, source information was arbitrary perceptual associations presented visually (screen side and frame color). Results were inconsistent with the idea that only recollection supports the recognition of correct source information: the FN400 ERP component was significantly different between trials that had correct and incorrect source judgments. Source information in Experiment 2 was defined according to the conceptual encoding task completed during the study lists (size and animacy judgments); the FN400 did not differ between correct and incorrect source monitoring. Experiment 3 combined the perceptual and conceptual source aspects of the first two experiments, and behavioral analyses support the results of the first two experiments. Overall, the results suggest

that familiarity's contribution to source monitoring depends on the type of source information being remembered. The familiarity process is more likely to successfully contribute to source recognition when the attributes are perceptually defined than when they are conceptual, and familiarity can successfully monitor extrinsic sources.

Keywords: recognition memory, source memory, familiarity, recollection, EEG, ERP

Acknowledgements

The authors acknowledge support from National Institutes of Health grant MH64812. We are grateful to Chris Bird, Brent Young, and Megan Freeman for assistance with data collection.

Contents

Tables

Table

Figures

Figure

Chapter 1

Introduction

The study of recognition memory involves examining how we remember the people, places, and things that we have previously encountered. This could be as basic as questioning whether you have had a previous experience with one of these things, or you could probe even deeper into memory by asking about specific details from a particular previous event. Importantly, we remember different amounts of information for the variety of past situations that we have experienced. We have all seen someone who you know you have met before, but are unable to recall how you know them and no details about them come to you. Here, you might say that this person feels familiar to you. On the other hand, you may have encountered an acquaintance with whom you socialized recently (or not so recently), and were able to recall all sorts of details about both them and your prior interactions. In this case, you successfully recollected episodic details from these prior happenings. The everyday episodes that we experience consist of intricate details found at various levels of perception and attention, and memory is the key process in binding our experiences into useful knowledge. Understanding the neural mechanisms and the patterns of brain activity that correlate with either remembering or failing to remember prior episodes and their assorted contextual details is a basic and important objective to be explored by cognitive psychology and neuroscience.

1.1 Overview of recognition memory

In the dual-process framework of recognition memory, familiarity and recollection are the two main cognitive processes involved in remembering information (Parks & Yonelinas, 2007; Yonelinas, 2002). Familiarity involves a fast and automatic recognition process that allows for an awareness of a previous experience with the item without retrieval of details from the encoding episode, whereas recollection is a slower process that retrieves item-specific episodic information. There has been much debate in this field concerning whether recognition memory consists of these two separate memory processes, or if it can be accurately described by a single recognition process where each memory varies in its strength (for reviews, see Parks & Yonelinas, 2007; Vilberg & Rugg, 2008; Wixted, 2007). Single-process recognition memory models describe memories as being located along a continuous strength-spectrum (Hicks & Starns, 2006; Ratcliff, Van Zandt, & McKoon, 1995; Squire, Wixted, & Clark, 2007). Recent evidence, including dissociative results from studies using neurophysiological recordings and those involving neuropsychological patients, clearly points to a dual-process recognition memory system (for reviews, see Curran, Tepe, & Piatt, 2006; Eichenbaum, Yonelinas, & Ranganath, 2007; Rugg & Curran, 2007; Skinner & Fernandes, 2007; Vilberg & Rugg, 2008; Yonelinas, 2002). For example, neuroimaging investigations have found that different areas of the brain are involved when either recollection or familiarity is assumed to be taking place (e.g., Yonelinas, Otten, Shaw, & Rugg, 2005). Similarly, some patient populations have exhibited deficits in recollection while familiarity-based judgments remain intact (e.g., Düzel, Vargha-Khadem, Heinze, & Mishkin, 2001; Yonelinas et al., 2004).

Another method of investigating the cognitive processes and neural substrates involved in recognition memory is to examine recordings of the brain's electrical activity (the electroencephalogram, or EEG). When the EEG is segmented into brief windows of activity that are time-locked to an event such as the presentation of a stimulus, these epochs are called event-related potentials (ERPs). In relation to an experiment, ERPs are subdivided into conditions based on specific criteria and are averaged within these conditions to show the common voltage deflections in the EEG signal associated with each condition. Comparisons between conditions can then be made, such as when a stimulus or a detail from the encoding period is correctly versus incorrectly recognized, or when studied (old) and unstudied (new) stimuli are correctly recognized as being such.

The recognition memory processes described above have come to be associated with particular voltage changes, or components, in the ERP depending on the type of behavior seen in the experiment, for example, whether information was correctly remembered (e.g., Curran, 2000; Curran & Cleary, 2003; Curran & Dien, 2003; Duarte, Ranganath, Winward, Hayward, & Knight, 2004; Jäger, Mecklinger, & Kipp, 2006; Tsivilis, Otten, & Rugg, 2001; Wilding & Rugg, 1996) (for reviews, see Curran, Tepe, & Piatt, 2006; Allan, Wilding, & Rugg, 1998; Mecklinger, 2006; Rugg & Curran, 2007). The component thought to reflect recollection is known as the *parietal old/new effect*, which manifests as a positive-going component in the parietal area of the scalp, peaking between 500–800 ms. It is labeled as an old/new effect because it differentiates between correctly identified old and new stimuli (hits and correct rejections, respectively). Though it sometimes appears bilaterally, it is often left lateralized, and is greater in amplitude when episodic information is correctly recognized or retrieved compared to correctly identifying either new items or old items without recall of episodic details. Interestingly, the parietal old/new effect has been shown to index the amount of episodic information retrieved such that its amplitude varies with the amount of information remembered (Vilberg, Moosavi, & Rugg, 2006; Wilding, 2000; Wilding & Rugg, 1996). The other recognition process, familiarity, is thought to be indexed by a frontally distributed negative-going component that peaks around 400 ms, often called the *frontal old/new effect* or the *FN400* because of these properties. Here, correct rejections produce a component with greater negative amplitude than hits. Unlike the parietal old/new effect, the FN400 typically shows no differences between recognizing varying amounts of episodic information; however, this is not always the case, as is discussed below.

Some researchers have interpreted the FN400 effect as evidence for a conceptual priming memory effect (Yovel & Paller, 2004; Paller, Voss, & Boehm, 2007; Lucas, Voss, & Paller, 2010). Specifically, they posit that that when the stimuli presented during a recognition test are conceptually similar to those that were observed during the study period, this will produce an attenuated FN400 component. However, others have shown that this is not the case by varying the amount of conceptual priming under conditions in which either recollection or familiarity should contribute to the recognition of stimuli (e.g., Stenberg, Hellman, Johansson, & Rosén, 2009; Stenberg, Johansson, Hellman, & Rosén, 2010). FN400 effects are also seen under conditions when there is no conceptual information to encode and instead there is only a perceptual congruency between the study and test presentations (Groh-Bordin, Zimmer, & Ecker, 2006). Thus, these authors demonstrated the dissociation necessary to link the FN400 to a familiarity process and not to conceptual priming. The present experiments, especially Experiment 1, show results that are in line with the latter studies and do not agree with the conceptual priming case.

1.2 Overview of source memory

When forming a memory, in addition to attending to something of interest (e.g., a stimulus in a psychology experiment), we also process the temporal, spatial, semantic, and other associated contextual aspects of the event. These aspects are called source information because they make up the circumstances from which an item seems to originate (Johnson, Hashtroudi, & Lindsay, 1993; Mitchell & Johnson, 2009; Senkfor & Van Petten, 1998). The source information is sometimes incidental to the actual item being studied, where it is encoded with the item as part of its surrounding context, but this does not always have to be the case. Some examples of source information are the particular person who said the phrase that you remembered, spatial information like the location of your keys in your house, or even your emotional state during a certain event. These source attributes are pieces of information that are contextually associated with an event. When attempting to remember an episode people use these contextual details, such as the perceptual features that stood out to them or the emotions that they were feeling at the time they formed a memory, to reconstruct the memory.

It is important to be explicit about the difference between item recognition memory, which was described earlier, and source memory. Item recognition involves making a relatively simple decision about whether a particular thing has been previously encountered, whereas source memory involves recognizing or recalling contextual details from a previous episode involving that item. As an illustration, item recognition would involve being able to remember that you have seen a particular movie before. On the other hand, source memory would allow you to remember which friends you went with, where or when you saw the movie, or how you felt throughout the event. Thus, the important distinction from item memory is that here, contextual associations are encoded. Interestingly, the source information here is not limited to always being source information; instead, this could easily be turned around such that the thing you remember is where you were last Saturday night and some of the source information associated with that evening is which movie you saw.

An alluring question to ask is whether source details can only be recognized using a recollection process, or whether familiarity can contribute to source recognition. Source information is certainly part of the array of episodic details to be retrieved from the encoding period, meaning that recollection should, almost by definition, contribute to correct source retrieval (Allan et al., 1998; Cansino, Maquet, Dolan, & Rugg, 2002; Gruber, Tsivilis, Giabbiconi, & Müller, 2008; Rugg, Schloerscheidt, & Mark, 1998; Unsworth & Brewer, 2009; Wilding, 2000). Among some of this early recognition memory research, the intuitive feeling was that a recollective process is necessary in order to retrieve any episodic details. Regarding familiarity, it has been shown that if the retrieval of contextual details is not needed, familiarity alone can successfully differentiate between old and new items, as in the dual-process model of recognition memory discussed above and in recognition memory ERP studies (Curran, 2000; Curran, DeBuse, Woroch, & Hirshman, 2006; Yonelinas, 2002; Yonelinas et al., 2005). However, recent source memory research has provided evidence for cases in which the familiarity process is able to contribute to the recognition of source information, possibly manifesting as the retrieval of partially reconstructed episodic details. Here, familiarity has been indexed either behaviorally (e.g., Hicks, Marsh, & Ritschel, 2002; Yonelinas, Kroll, Dobbins, & Soltani, 1999), by the involved brain region (e.g., Diana, Yonelinas, & Ranganath, 2008; Staresina & Davachi, 2006), or by the FN400 ERP component (e.g., Ecker, Zimmer, & Groh-Bordin, 2007b; Mecklinger, 2006). The circumstances under which familiarity can contribute to source monitoring are intriguing cases to study and they provoke an interesting avenue of investigation, especially when only some studies have found that familiarity processes are involved in source recognition.

As mentioned above, it has been hypothesized and demonstrated that familiarity can, under certain circumstances, contribute to source recognition (for reviews, see Diana, Yonelinas, & Ranganath, 2007; Mecklinger, 2006; Zimmer & Ecker, 2010). More specifically, this seems to occur when the source attributes are perceptual—that is, perceived purely with the senses (e.g., a visual or auditory feature)—and are encoded as intrinsic properties of the item such that they become bound or unitized with the item into a distinct representation (e.g., Diana et al., 2008; Ecker et al., 2007b; Rhodes & Donaldson, 2007; Staresina & Davachi, 2006; Yonelinas, 1999). When the item is subsequently presented as a recognition cue at test, one must retrieve or recognize the source information that was encoded as an intrinsic part of the item.

To more clearly describe what is meant by unitization with an example, say you saw a noun surrounded by a colored box, such as the word elephant inside a pink frame, and you were instructed to imagine the noun as being the color of the frame; the memory you form here would be of a pink elephant. Your memory processes would have encoded the perceptually based color as part of the trace such that the color is an intrinsic property of the elephant (i.e., when you think of this elephant, it is pink—they are bound into a single representation). In order to contrast the unitized memory with another case involving source memory, the perceptual context can instead be encoded as an extrinsic source property, meaning that an object and its perceptually based contextual information are not unitized (or are less unitized than in the intrinsic case). Less unitization would occur in the case of seeing the same noun and colored frame (elephant inside a pink frame) and being instructed to imagine the elephant interacting with an object of that color, such as eating cotton candy. Here, the studied information was the same, but the encoding task required you to form an episode distinct from the unitized example. In the research cited above, familiarity has been shown to only contribute to recognizing source information when the source and item were unitized. Interestingly, only some types of perceptual or sensory source attributes have shown this unitization/binding property; this is important because the way the information is perceived and encoded affects the manner in which they are later retrieved.

It should be noted that even under conditions in which unitization occurs during encoding, source memory is still involved when retrieving the source information at test. In the example above, the studied material, and therefore the source information, was the same in both the intrinsic and the extrinsic encoding conditions—the only thing that differed were the instructions regarding how to encode the item and its context. The recognition question at test involves remembering the color of the frame, where the color of the frame is the source information.

In addition to source memory paradigms, associative recognition paradigms also use contextual associations. These involve encoding distinct pairs of items and have also been shown to exhibit familiarity effects when, for example, pairing images of objects with unique and salient landmarks (Tsivilis et al., 2001) and in remembering unique pairs of fractal images (Speer & Curran, 2007). Thus, these familiarity effects are not necessarily limited to perceptual attributes, so long as a unitized representation is encoded. Associative memory paradigms using pairs of words studied as having either a compound (i.e., unitized) relationship or a co-occurring (i.e., non-unitized) relationship have also shown dissociative effects such that the familiarity process only contributes to recognizing unitized conceptual relationships (e.g., Ford, Verfaellie, & Giovanello, 2010; Haskins, Yonelinas, Quamme, & Ranganath, 2008; Quamme, Yonelinas, & Norman, 2007; Rhodes & Donaldson, 2007). To explain what would happen here in the compound relationship case, participants might be instructed to form a association between the words *carrot* and *car*, and they may think of a car in the shape of a carrot thereby forming a unitized conceptual representation. At test, one of the words might function as a cue to remember the other and the unitized representation could likely be easily recognized. Despite the differences in how item–item pairs are encoded compared to the item–source paradigms discussed above, associations such as these can nonetheless be considered a type of source memory because there is a relational association established between items (and sources), and the features of the items (and sources) can become unitized (Mitchell & Johnson, 2009; Zimmer & Ecker, 2010).

1.3 Evidence for familiarity's involvement in source memory

The following sections review cases of familiarity contributing to source monitoring in numerous areas, including evidence from behavioral experiments, models of memory, patient studies, and recordings of brain activity.

1.3.1 Behavioral evidence

A number behavioral experiments that have investigated source recognition have used the Remember–Know (RK) procedure to assess the contribution of recollection and familiarity in recognition memory tasks. Here, "remember" and "know" responses are thought to be subjective indices of recollection and familiarity, respectively (Duarte et al., 2004; Düzel, Yonelinas, Mangun, Heinze, & Tulving, 1997; Klimesch et al., 2001; Smith, 1993). Another way to estimate the involvement of the recognition memory processes is to assess the linearity of the Receiver-Operating Characteristic (ROC) curves calculated from how accurate and confident participants are regarding their answer; this is typically paired with fits of dual-process recognition memory models to the data, which can provide estimates of recollection and familiarity. The paradigms that have found familiarity to be involved in source recognition have typically used perceptual source information such as imagining an object to be a specific color (Diana et al., 2008), presentation modality (e.g., words that were heard in a male or female voice) (Yonelinas, 1999), pictures of faces (Yonelinas et al., 1999), and spatial information like presentation location and list membership (Yonelinas, 1999). Of note, Hicks et al. (2002) used two experiments to investigate familiarity's contribution to source monitoring, one with perceptual source information (words that were seen or heard) and one with reality monitoring source information (words that were seen or generated internally by the participant). In both cases they found source accuracy for "know" responses to be equal to accuracy for "remember" responses, which suggests that a sense of familiarity is sufficient enough to contribute to successful source monitoring.

1.3.2 Modeling evidence

There are *a priori* reasons to expect that familiarity can, at least in some cases, contribute to source recognition. One of these relies on the strength of the familiarity signal and can be interpreted using evidence from the recognition memory modeling literature. Even single-process familiarity-based recognition memory models that do not use a recollective process, such as global matching models, can achieve source recognition judgments when correct sources seem more familiar than incorrect sources (Clark & Gronlund, 1996; Hicks & Starns, 2006; Ratcliff et al., 1995; Squire et al., 2007). This shows that a recognition judgment theoretically based on the familiarity signal alone (i.e., memory strength) allows for correct source identification. To demonstrate how a familiarity process can help to later recognize the source of a previously encoded item, an item is first studied in one of two source contexts, and the content and context are encoded together into an episodic memory trace. The subsequent test task is to remember the source information; when the item is presented as a cue, memory is probed twice, once with each item–source combination, and a scalar strength value is produced representing the strength of the familiarity signal for each source. The resulting recognition response (i.e., the source choice) is specified by the item–source combination that corresponds to the largest familiarity signal. Thus, a single-process memory model can exhibit familiarity-based source recognition resulting from this matching process.

Norman and O'Reilly (2003) present a biologically plausible model of recognition memory based on the complementary-learning-systems (CLS) framework that includes hippocampal, neocortical, and medial temporal lobe cortex (MTLC) connections. They suggest that, in line with the patient and neuroimaging studies presented below, the hippocampus primarily contributes to recollection and that the surrounding MTLC, including the perirhinal cortex, contribute to familiarity. Additionally, O'Reilly, Busby, and Soto (2003) present a model in which the hippocampus binds episodic information using higher-order associations, which represents a recollective process that can unitize disparate elements of an experience, while the familiarity process involves lower-order binding mediated by the MTLC that creates a representation using few features from an encoding episode, such as perceptual features like the spatial relationship between two items. The authors do not specifically discuss source monitoring, but it seems likely that the recognition memory processes involved would operate in accordance with the results of neuroimaging studies regarding the contribution from recollection and familiarity to associative memory and source recognition. Extending these results, Elfman, Parks, and Yonelinas (2008) assessed whether the CLS model was able to successfully recognize source information in three source recognition tasks that were also run with behavioral participants. In addition to confirming that the CLS framework is a viable model of both item and source recognition, they showed that source was able to be recognized based on only a global matching signal, which they posit is a familiarity-based signal that would be used in a recognition process like the one described in the previous paragraph.

1.3.3 Neuropsychological patient evidence

The medial temporal and frontal lobes of the brain are regions that are deeply involved in encoding and retrieving memories. Research involving brain lesions patients who have damage to the frontal cortices, including the prefrontal cortex (PFC), and to the medial temporal lobe (MTL) closely follows the modeling results presented above and the neuroimaging results presented below in Section 1.3.4. MTL patients demonstrate heavy disruption in episodic memory processing (Scoville & Milner, 1957) (for a review, see Wixted & Squire, 2010). Aggleton et al. (2005) examined a hippocampal patient with a recollection deficit, but the patient demonstrated spared familiarity processing. Interestingly, part of the patient's MTL cortex called the perirhinal cortex was intact, which is an area that recent neuroimaging studies have come to focus on when investigating familiarity (see Düzel et al., 2001, for a similar finding). The frontal lobes and PFC are also thought to be involved in both familiarity-based recognition and source monitoring because patients with lesions in these regions have demonstrated deficits in these contexts (e.g., Janowsky, Shimamura, & Squire, 1989). There is also evidence specifically linking frontal lobe lesions to deficits in both familiarity-based recognition (with bilateral PFC lesions) and source memory (with left PFC lesions) (Duarte, Ranganath, & Knight, 2005). Some researchers have interpreted the latter effect as a recollection impairment, where recollection was operationalized on source retrieval (reviewed in Yonelinas, 2002).

Interestingly, and in accordance with the source memory research already reviewed, patients with damage to the hippocampus have been shown to have intact source memory when a stimulus and its source are unitized compared to cases in which unitization does not occur. Giovanello, Keane, and Verfaellie (2006) and Quamme et al. (2007) examined such patients in associative memory paradigms and found above chance source recognition for unitized items but not for non-unitized items. Thus, this is another example of the familiarity process contributing to source monitoring.

1.3.4 fMRI evidence

The MTLs and their surrounding cortices (the parahippocampal cortex, which located in the posterior parahippocampal gyrus, and the perirhinal cortex, which is located in the anterior parahippocampal gyrus) are of particular interest to memory researchers because these areas are integral to memory encoding and retrieval. Neuroimaging research using functional magnetic resonance imaging (fMRI) has shown that there are distinct regions of the MTL that dissociatively contribute to recollection and familiarity (Aggleton & Brown, 1999; Diana, Yonelinas, & Ranganath, 2010; Montaldi, Spencer, Roberts, & Mayes, 2006; Ranganath et al., 2003; Staresina & Davachi, 2008). Specifically, the hippocampus and parahippocampal gyrus are involved in recollective processing, such as associating an item with its episodic context, while the perirhinal cortex does familiarity-based recognition. Additionally, as was briefly mentioned earlier, the left PFC has been shown to be particularly active for source retrieval attempts, which is likely involved in the monitoring of remembered information (e.g., Cabeza, Locantore, & Anderson, 2003; Gallo, McDonough, & Scimeca, 2010; Kahn, Davachi, & Wagner, 2004; Rugg, Fletcher, Chua, & Dolan, 1999; Wais, Squire, & Wixted, 2010).

Showing that familiarity can contribute to correct source monitoring in fMRI research requires a dissociation between correct and incorrect source recognition related to the familiarity signal; here, that is activity in the perirhinal cortex. This has been shown to occur for unitized, and not for non-unitized, item and contextual source pairs (e.g., Diana et al., 2008, 2010; Ford et al., 2010; Haskins et al., 2008; Staresina & Davachi, 2006, 2008).

In light of the neuroimaging and neuropsychological patient studies presented above concerning the familiarity process, it is critical to note that the temporal resolution of analyses of fMRI data is quite low, likely on the order of multiple seconds, and for patient data is likely unanalyzed. Though these results should not be discounted regarding the involvement of recognition memory processes, the focus of this paper is on familiarity's initial contribution to source recognition and not on its possible involvement in processes that occur later. Another method of investigating the neural correlates of behavior that was introduced earlier is to examine EEG activity recorded during a task thought to elicit the cognitive processes of interest. EEG is recorded with high temporal resolution, on the order of milliseconds, making ERP analyses an invaluable method for investigating and separating the processes involved in recognition memory. Thus, we turn to discussing these relatively early familiarity effects and later recollection effects that are involved in source memory recognition.

1.3.5 ERP evidence

As was briefly reviewed earlier, the parietal old/new effect differentiates between identifying old compared to new stimuli and its voltage is correlated with the amount of associated episodic information retrieved from memory, such as contextual source information (Peters & Daum, 2009; Senkfor & Van Petten, 1998; Vilberg et al., 2006; Wilding, 1999; Wilding, Doyle, & Rugg, 1995; Wilding & Rugg, 1996). This effect also distinguishes between "remember" and "know" judgments made in the RK procedure, which are the responses used for when a participant thinks that either recollection or a feeling of familiarity occurred, respectively (Düzel et al., 1997; Vilberg et al., 2006; Rugg et al., 1998). The FN400 ERP component, on the other hand, is thought to reflect familiarity processing, and it typically differentiates between correctly identifying old and new items (i.e., hits and correct rejections) (e.g., Curran, 2000; Ecker et al., 2007b; Mecklinger, 2006). However, as has been demonstrated in some of the research presented above, there seem to be some cases in which familiarity can contribute to source recognition.

It is the early aspect of the familiarity process that is important to assess when investigating its potential contribution to source monitoring because we want to exclude any subsequent downstream consequences of its involvement as might occur in fMRI or patient studies. In order to demonstrate that familiarity can contribute to source recognition in the ERP domain, it is necessary to show a physiological difference in the FN400 between items with correct source recognition and those with incorrect source recognition. For example, an experiment by Ecker et al. (2007b) used color as a source attribute in two different encoding conditions. First, when color was encoded as an intrinsic aspect of a studied item (i.e., an image of an object was presented with one of six surface colors) the FN400 showed this required differentiation when participants correctly recognized the color at test compared to when they were incorrect. However, when color was encoded as an extrinsic property (i.e., a colored frame encased the object), the FN400 difference was not seen at test. This first encoding method is a case of the item and its perceptual surface feature becoming unitized, which in these experiments seems to be necessary for familiarity to be a useful process in source recognition. The same group demonstrated another example of intrinsic versus extrinsic perceptual property encoding using object surface color and the background shape on which it was presented (Ecker, Zimmer, & Groh-Bordin, 2007a). They found the same pattern of FN400 results differing between cases in which source information was defined as part of the item (color) compared to when it was a separate contextual attribute (background). In an important contrast to these studies, Peters and Daum (2009) manipulated the perceptual content of source information that was paired with word stimuli (pictures of scenes, faces, and sounds), and while the FN400 (300–400 ms) did not differentiate between the type of source content remembered at test, it did show an effect for correct compared to incorrect source recognition. In this last example there is no reason that the source information would bind with the studied items, but rather it seems that familiarity contributed to source monitoring for extrinsically based perceptual attributes.

Familiarity can also contribute to identifying the modality in which a stimulus was originally presented (e.g., auditory vs. visual encoding—whether participants listened to a word out loud or read it on a screen), as in the study by Wilding and Rugg (1997). Here, an FN400 old/new effect was seen when source information (i.e., the presentation modality) was correctly identified compared to when source judgments were incorrect. Similar contributions of familiarity to source recognition has been found when comparing the congruency of the originally encoded perceptual source information to the source attributes presented at test, such as in the studies by Groh-Bordin, Zimmer, and Mecklinger (2005, using object orientation) and Groh-Bordin et al. (2006, using colored line drawings of objects). These authors found an FN400 effect when the perceptual study–test attributes stayed the same compared to when the study–test attributes were changed. This research supports the idea that familiarity can detect changes in perceptual source attributes, and thus builds on the evidence that this process can successfully assist in the recognition of source information.

On the other hand, familiarity does not seem to contribute to the recognition of source information when the source attributes encoded at study are conceptual, such as thinking about semantic aspects or associations related to the to-be-encoded item (e.g., Hayama, Johnson, & Rugg, 2008; Stenberg et al., 2010). A conceptual property is an abstract characteristic of the item that is not a sensory feature of the item that one perceives, but instead describes a semantic quality of the item. If the encoding period involves answering a question about an aspect of each presented stimulus, such as either judging whether or not it is alive or judging if it is larger than a shoebox, and the subsequent source test period involves remembering the type of judgment made at study, this would not involve remembering a perceptual context or some aspect of a unitized representation because the context was conceptual and no binding was required to occur between the item and source information. Instead, recognizing source information would require the retrieval of the semantically based study context.

There are also some experiments in which source information was perceptual and relatively simple but there was no FN400 effect for correct compared to incorrect source recognition (e.g., a colored frame around an object, as in Ecker et al., 2007b). In these cases, it has been hypothesized that the item and source attributes do not become unitized, as discussed by Diana et al. (2008), who assessed familiarity with ROC analyses (for other examples, see Mecklinger, Johansson, Parra, & Hanslmayr, 2007; Woroch & Gonsalves, 2010). It is possible that the source just does not have attributes that bind well with the studied item. Another possibility for the result observed by Ecker et al. (2007b) is due to their use of six source colors. While they found that familiarity only contributed to source monitoring when source information was intrinsic to the item, this is different from what seemed to occur in the studies mentioned above that used few perceptual sources; that is, those by Groh-Bordin et al. (2006) and Peters and Daum (2009). Relevant to this is an observation by Johnson et al. (1993): "the more similar the memory characteristics from two or more sources, the more difficult it will be to specify the source correctly" (p. 6). Perhaps the similarity across a wide range of source attributes may have contributed to the results seen in experiments like Ecker et al. (2007b).

While some source memory studies that focused on ERP effects other than the FN400, their graphs show what seem to be the differences in familiarity in which we are interested. For example, Cruse and Wilding (2009) examined later right-frontal ERP old/new effects in a perceptual source paradigm (words presented in one of two colors and the task was to remember the color; analyses investigated three time windows, beginning at 500 ms post-stimulus). Interestingly, examining their Figure 1 showing grand average ERPs at various electrodes (p. 2782), the ERP voltages for hits with correct source recognition and hits with incorrect source recognition seem to diverge at both left and right frontal electrodes in approximately the 300–500 ms time window of the FN400. Similarly, Mecklinger et al. (2007) used presentation location (top and bottom of the screen, and the task was to remember the location) as one form of source information, and though they did not analyze the FN400, this component in Figure 1 depicting grand average ERPs for location sources (p .113) seems to show the trend that source correct and source incorrect judgments differ.

The commonality across all of the studies in which familiarity is thought to contribute to source monitoring is that the FN400 old/new effect, which again is thought to be an electrophysiological index of familiarity, differed for correct compared to incorrect source recognition when source information was either a perceptually based attribute that bound to the item or was encoded as an intrinsic property of the studied item. It seems that encoding item and source under one of these conditions is critical for familiarity to contribute to successful source monitoring.

1.4 Motivation for work presented here

The events that we experience (and subsequently encode and remember) are typically composed of something of interest to which we are attending, be it an object or a task, plus some subset of the huge number of contextual details that are spatially and/or temporally associated with the event. Even the thing to which we are attending can have particular features that we want to remember. We experience the world through the (unconscious) integration of features making up our internal and external environments, and remembering these experiences later requires their reintegration. The cognitive and neural processes that are involved in remembering these contextual associations are interesting phenomena to investigate, including the cases in which specific memory processes can contribute to their recognition.

The successful recognition of encoded source details is often used to operationally define the occurrence of a recollection process (e.g., Gruber et al., 2008; Jacoby, 1991; Rugg et al., 1998; Wilding, 2000). However, the evidence reviewed above suggests that source recognition is not a process pure measure of recollection. While past analyses have shown mixed results for familiarity's role in source monitoring tasks, it is certainly involved in the recognition of source information in some situations. Perhaps, then, the well-established ERP correlates of recollection and familiarity can be used to further examine the contribution from each recognition memory process to source monitoring. To analyze these situations using ERPs it would be important to manipulate the type of contextual attributes presented during the encoding period and subsequently see effects in the ERP effects associated with both familiarity and recollection.

I have empirically examined these alternatives using source memory judgments for pictures of common object such that the experiments manipulated the type of source information encoded during the study periods. Though there is much evidence for familiarity contributing to the successful recognition of source information when the features of an item and its context bind together into a singular engram, such as in the work by Ecker and colleagues, among others, the basic hypothesis within which this work is presented is that it is easier for familiarity to contribute to source information at test when the source attributes are concrete and are extrinsic to the studied item (e.g., perceptual, as in Experiment 1) than when source information is more abstract (i.e., conceptual, as in remembering the type of study judgment in Experiment 2). Even under conditions where the item and source will not necessarily unitize into a cohesive representation, it might be easier for familiarity to assist in the recognition of source information at test if it was more perceptual in nature, as is suggested by the results of Peters and Daum (2009). Another study that had results suggesting a similar effect was that of Wilding and Rugg (1997), but the time course of their analysis was such that it began after the typical time window in which familiarity effects are seen. Thus, our hypothesis regarding a modulation of familiarity's contribution to source recognition under different sources is novel and we hope that our results lead to a better understanding of the familiarity process.

As discussed above, it may be necessary to provide a lighter source information load for familiarity to be effective in recognizing unbound perceptual attributes. No familiarity effects were seen using the extrinsically based six-source choice of Ecker et al. (2007b), but studies with few sources have demonstrated this effect under extrinsic conditions (e.g., Groh-Bordin et al., 2005; Peters & Daum, 2009). Additionally, perceptual information may be more readily available than non-perceptual information because it is easier to construct a concrete retrieval cue at test like color or spatial location than a more abstract retrieval cue like a previously associated encoding task. Thus, Experiment 1 used two extrinsic sources that were unlikely to involve unitization in order to test the hypothesis that familiarity-based source recognition is possible under these conditions.

The motivation for Experiment 2 was to test a similar question as in Experiment 1, but the source information was conceptually (or semantically) based. We chose to contrast conceptual with the perceptual source information used in Experiment 1 because these are modalities that have been used in prior source memory studies. In using conceptual source information, making judgments about an item could require accessing intrinsic item information, but it may instead involve accessing higher-level information that would not be considered intrinsic and would require a recollective process to retrieve from memory. To make the source load relatively light and more comparable to Experiment 1, Experiment 2 used two semantic sources. Finally, Experiment 3 was conducted to combine the encoding of both perceptual and semantic source information into a single paradigm.

To briefly introduce what I have found, Experiment 1 involved studying items using a perceptual source and revealed results inconsistent with the idea that only recollection supports the recognition of correct source information: the FN400, an index of familiarity, was significantly different between old items that had correct and incorrect source judgments. The source information for each item was an arbitrary contextual association presented visually (presentation screen side and object frame color), which is unlikely to become bound with the items. Here, the parietal old/new effect showed its typical differentiation between the recognition of additional episodic information and correct rejections. In Experiment 2, source information was defined by the type of question that participants had to answer about each item during the study period (size or animacy judgments). Here, the FN400 did not differ between old items with correct and incorrect source, as might be expected for conceptual source information. Again, the parietal old/new effect showed the typical differentiation. Experiment 3 was conducted so that perceptual and conceptual source context were encoded during the same study task, and a source recognition test queried one or the other type of source information. ERP results regarding the contribution of familiarity were relatively inconclusive because of low statistical power in ERP analyses, but accuracy results (using a modified Remember–Know paradigm) support the findings of Experiments 1 and 2 suggesting that that familiarity can contribute to source recognition when the context was perceptually based and not when it was conceptually based. Together, the results of these experiments suggest that familiarity's contribution to source monitoring depends on the type of source information available, with familiarity being more likely to contribute when the source attributes are perceptually defined.

Chapter 2

Experiment 1

Experiment 1 involved studying items using a perceptual source. During the encoding period, items were presented on either the left or the right side of the computer screen while participants fixated on the cross in the center; the location of the object is the perceptually defined source information that participants were told to remember (see Figure 2.1). A colored frame surrounding each object was always consistent with presentation side so as to make the location more salient. At test, participants saw randomly intermixed old and new items; for each, they were required to make an old/new judgment and then a source judgment, where source was the presentation location of the item during the study period. We predicted that familiarity, as indexed by the FN400 ERP component, will differentiate between correct and incorrect source recognition when source information is perceptually based; additionally, at least source correct trials will differentiate from correct rejections.

2.1 Method

2.1.1 Participants

Thirty-nine University of Colorado undergraduates participated in the experiment for either course credit or payment of $15 per hour (ages 18–28, $M = 19.2$; 22 male, 17 female). All participants were right-handed native-English speakers and had normal or corrected-to-normal vision. Informed consent was obtained from each participant, and the study conformed to the Human Research Committee guidelines.

2.1.2 Materials

The stimulus pool consisted of 882 color images of physical objects on square white backgrounds collected from `http://www.clipart.com`. Each image was resized to 240 $\times$ 240 pixels and the experiment was presented on a 17-inch flat-panel display with a resolution of 1024 $\times$ 768 (60 Hz frame rate) placed 1 m in front of the participants. All portions of the display not occupied by stimuli or text were filled with black pixels.

2.1.3 Design

The experiment consisted of seven study–test list pairs, created at the time of the experiment for each participant. The session, including application of the electrode net and running in the task, lasted approximately 2.5 hours. From the stimulus pool, 56 objects were randomly chosen to make each study list, for a total of 392 studied objects. The three objects at the beginning and end of each study list were not included in the corresponding test list to lessen the possibility of primacy and recency effects. Each test list was constructed by randomly intermixing the 50 old objects from the study list with 50 new objects. 24 of the remaining 140 objects were used to make a shortened study–test list pair for training purposes.

Study status (left, right, new) was manipulated within subjects, with each participant receiving a different random assignment of objects to conditions. Responses were collected using six keys on the bottom row of a standard keyboard. EEG was recorded throughout the entire experiment.

2.1.4 Procedure

An electrode cap was applied to each participant's head, and the participants then completed a practice trial to familiarize them with the study and test procedures.

During each study list, participants fixated the cross in the center of the screen and observed the objects that appeared to the left and right with their peripheral vision. They were instructed to remember the side of the screen on which each object appeared. Presentation side was randomly chosen with the constraint that half of the objects were presented on each side. Additionally,

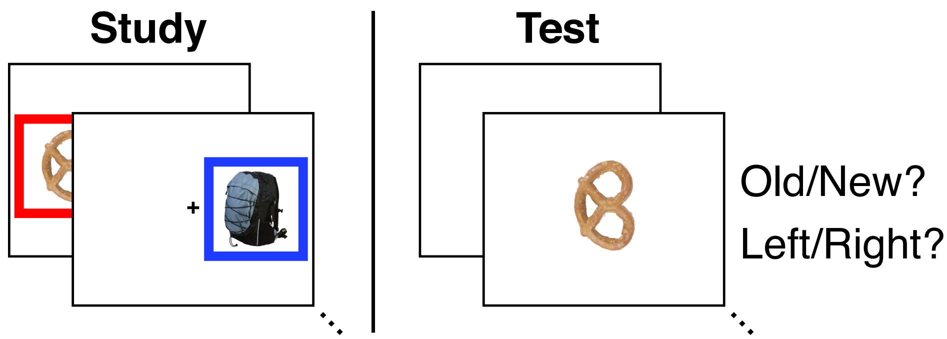

Figure 2.1: An illustration of the study and test tasks used in Experiment 1.

each object was surrounded by a 48-pixel colored frame; objects presented on the left had a red frame, and objects presented on the right had a blue frame. All participants were informed that the color of the frame was redundant with the presentation side, and were instructed to form an association with each studied item and its source features. This was done to make the presentation side more salient. Each object remained on the screen for 1000 ms, followed by a 1000 $\pm$ 200 ms inter-stimulus interval. To prevent after-image effects that could be induced by an object or its frame, a 288 $\times$ 288-pixel image containing visual Gaussian noise was visible in each of the object presentation locations whenever an object was not present; the noise image was precisely occluded by the presentation of an object and its frame. The area containing the possible study image locations subtended a visual angle of 11.4° wide $\times$ 5.6° high.

Each test list was presented immediately after its corresponding study list. A centered fixation cross was visible at all times except when a test probe image was presented, and participants were instructed to keep their eyes focused on the center of the screen. Each centered test probe was presented (without a colored frame) for 1000 ms. Following a 1000 $\pm$ 200 ms pause with fixation only, the words New and Old appeared to the left and right of the cross, respectively, and participants rated their memory for studying the item on the just-presented list using a six-point scale ("sure new" to "sure old"). After making the recognition judgment, the words Left and Right appeared to either side of the cross, and participants then rated their memory for the study location of the item on a six-point scale ("sure left" to "sure right"). Source judgments were collected for every

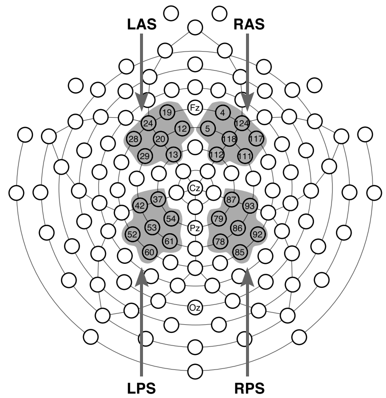

Figure 2.2: The 128-channel HydroCel Geodesic Sensor Net$^{\mathrm{TM}}$ used to measure the EEG and the regions of interest (ROI) on which the analyses were based. Each ROI is labeled with a 3 letter name that describes its position on the skull: R = right, L = left, S = superior, A = anterior, P = posterior.

item regardless of recognition rating, and participants were advised of this during training. A 1000 ± 200 ms pause was included between the source response and the appearance of the next test probe. The visual angle of each test probe image was 4.3° wide × 4.3° high.

The confidence scale `Sure | Probably | Guess | Guess | Probably | Sure` was visible at the bottom of the screen throughout the entire test phase. Each rating corresponded to one of the six keys used to respond going from left to right across the keyboard, and participants were instructed as such. The same keys were used for both the recognition and source judgments: `Z`, `X`, and `C` for New and Left ratings, and `Comma`, `Period`, and `Forward Slash` for Old and Right ratings, with the strongest (Sure) ratings on the outermost keys. Participants placed their fingers on the keyboard with their index fingers positioned on the Guess (`C` and `Comma`) keys, followed by their middle and ring fingers on the stronger ratings, and were instructed to memorize the key mappings before beginning.

2.1.5 Electrophysiological recordings

A 128-channel HydroCel Geodesic Sensor Net$^{\mathrm{TM}}$ (GSN 200, v. 2.1, Tucker, 1993) was used to measure the EEG at the scalp with a sampling rate of 250 Hz using a bandpass hardware filter from 0.1 Hz to 100 Hz. The net was connected to an AC-coupled, high-input impedance amplifier

(200 MΩ, Net Amps™, Electrical Geodesics Inc., Eugene, OR). The electrodes were adjusted until impedance measurements were less than 50 kΩ.

A central vertex reference (Cz) was used during recording, and all analyses were based on referencing to the average of all electrodes (Dien, 1998). Channels deemed too noisy by visual inspection were excluded from the average in the referencing process and from all subsequent analyses. Furthermore, events with eye-movement or eye-blink artifacts (electro-oculogram exceeding $\pm$ 100 μV) or those containing more than 20% bad channels (average amplitude over 100 μV or transient amplitude over 50 μV) were excluded from the electrophysiological analyses.

2.1.6 Electrophysiological data processing

Net Station (Electrical Geodesics, Inc.) was used to epoch the data into 3000 ms segments, one second before the onset of each test stimulus and two seconds after. Only a portion of each epoch was used for analyses, as described below. The ERP PCA Toolkit (Dien, 2010) was used as an interface for ICA artifact correction for trials that contained an automatically located eye-blink artifact. Subsequently, Net Station's artifact detection and bad channel replacement algorithms were used to either reject trials or interpolate sections of trials with other artifacts. Finally, analyses were done in MATLAB (version R2009b; The MathWorks, Inc.) using the FieldTrip toolbox (currently maintained by the Donders Institute for Brain, Cognition, and Behaviour, The Netherlands).

For analysis of ERP effects, the data were low-pass filtered at 40 Hz and the 200 ms period prior to stimulus onset was used to baseline correct each epoch. We grouped the electrodes into 4 *a priori* regions of interest (ROIs) based on those used in other studies (e.g., Curran, 2004; Curran, DeBuse, et al., 2006; Curran, DeBuse, & Leynes, 2007; Curran & Friedman, 2004; Curran & Hancock, 2007). The shaded regions in Figure 2.2 illustrate these ROIs, and only data from electrodes that fell into these ROIs were analyzed. The FN400 effect was analyzed over two anterior superior regions located near the standard F3 and F4 sites (channels 24 and 124 in Figure 2.2). The parietal old/new effect was analyzed over two posterior superior regions near the standard P3 and P4 sites (channels 52 and 92 in Figure 2.2). Grand average ERP waveforms were created by averaging ERPs from the channels within each region and across participants; ERPs for the three conditions of interest are shown in Figure 2.3. The FN400 was analyzed from 300–500 ms, whereas the parietal effect was analyzed from 500–800 ms.

2.2 Results

Across all experiments and analyses presented in this paper, when an analysis of variance (ANOVA) was conducted, all main effects are reported regardless of significance. Interactions (e.g., hemisphere $\times$ condition) are reported only when significant. When an ANOVA contains a factor with more than two levels, the reported values are adjusted for violations of assumptions of sphericity using the Greenhouse-Geisser procedure (Greenhouse & Geisser, 1959) even if the factors did not violate Mauchly's test of sphericity. Most paragraphs reporting statistical tests are preceded by a brief summary sentence in italics that describes the main result of that test.

Additionally, all ERP voltages were measured from the onset of the test stimuli. Note that all figures in this paper depicting electrophysiological results are plotted with a consistent absolute μV range: ERP plots (e.g., Figure 2.3) have a range of 7 μV on the y-axis and two solid vertical lines denote the time window of interest for the FN400 and the parietal old/new effect. Grand average voltage plots (e.g., Figure 2.4) have a range of 4 μV on the y-axis and the error bars are standard errors of the mean. Topographic contrast plots (e.g., Figure 2.5) depict values from -1 μV to $+1$ μV with the colors ranging from blue to red, respectively.

As described above in the review of relevant literature, there are a few key conditions of interest for dissociating between familiarity and recollection: hits (correctly identified old items), splitting hits into those with correct and incorrect recognition of source information, and correct rejections (correctly identified new items). The latter three conditions are of particular interest when attempting to dissociate familiarity processes from those of recollection, and thus are the focus of the subsequently described analyses. ERPs from other potentially interesting conditions including misses and false alarms were not included in the analyses because of insufficient trial counts, as can frequently be the case in ERP studies of recognition memory.

	Accuracy Condition			
	Hits	Hits-SC	Hits-SI	CRs
Behavioral	270.58 (39.82)	213.61 (47.90)	56.97 (19.26)	263.58 (39.47)
EEG	242.25 (44.16)	191.08 (47.72)	51.17 (16.84)	235.89 (40.03)

Table 2.1: Experiment 1: Grand average trial counts for the analyzed accuracy conditions; standard deviations are in parentheses. Behavioral trial counts show the number of trials used in behavioral analyses; EEG trial counts show the number artifact-free trials used in EEG-based analyses. *Notes: SC=Source Correct; SI=Source Incorrect; CR=Correct Rejection.*

Three participants were excluded from analyses due to either low trial count after eye-movement and eye-blink artifact rejection ($n = 1$), poor behavioral performance ($n = 1$), and not completing the experimental session ($n = 1$). The remaining 36 participants were included in all behavioral and ERP analyses presented below. Behavioral analyses included all relevant trials for the 36 participants, while ERP analyses included only artifact-free trials.

2.2.1 Behavioral results

Collapsing across confidence ratings for "old" and "new" responses, 77.31% ($SEM = 1.90\%$) of the studied items were correctly recognized as old (hits), and 75.31% ($SEM = 1.88\%$) of the new items were correctly identified as new (correct rejections). For the hits, correct source information was identified for 78.2% ($SEM = 1.44\%$) of the items, which is slightly higher than the rates of comparable studies (Cansino et al., 2002; Gruber et al., 2008; Wilding & Rugg, 1996). Of the old items incorrectly identified as "new" (misses), correct source information recognition was at chance (49.6%, $SEM = 1.0\%$) [$t(35) = 0.37, p = .71$].

To assess recognition performance more thoroughly, discrimination (d_a) and response bias (c, for *criterion*) were calculated for item and source information by comparing hits to false alarms. d_a was used instead of d' because it provides a more appropriate measure of discrimination in experiments with confidence judgments (Macmillan & Creelman, 2005). These measures were calculated independently for item and source memory, as is done in studies of source memory (e.g., Murnane & Bayen, 1996).

For source responses, accuracy was calculated such that the Right source is the target distri-

	HR / SC	FAR / SI	d_a	zROC slope	c
Item	0.77 (0.02)	0.25 (0.02)	1.52 (0.09)	0.59 (0.02)	-0.03 (0.04)
Source	0.78 (0.01)	0.22 (0.01)	1.76 (0.10)	1.11 (0.08)	0.004 (0.04)

Table 2.2: Experiment 1: Item and source recognition means; standard errors in parentheses in. *Notes: HR=Hit Rate; FAR=False Alarm Rate; SC=Source Correct; SI=Source Incorrect.*

bution (hit: "right" to a Right source item; miss: "left" to a Right source item) and the Left source is the lure distribution (correct rejection: "left" to a Left source item; false alarm: "right" to a Left source item). Here, the designation of the target distribution is arbitrary; the same results would be obtained if the Left source was the target distribution and the Right source was the lure distribution. Average item (or old/new) d_a was 1.52 ($SEM = 0.09$; $zROC\ slope = 0.59$). d_a for source judgments was 1.76 ($SEM = 0.10$; $zROC\ slope = 1.11$) and was conditionalized on getting a recognition hit. Average item c was -0.03 ($SEM = 0.04$) and c for source judgments was 0.005 ($SEM = 0.04$); neither of these was different from zero. These values are summarized in Table 2.2.

Reaction times were measured from the onset of the old–new prompt following the presentation of the test stimulus to the key press indicating the old–new response, and are summarized in Table 2.3. Though these are essentially item recognition judgment RTs, responses are additionally divided into whether the subsequent source judgment was correct or incorrect. Participants' responses for hits ($M = 545.4$ ms) were significantly faster than those for correct rejections ($M = 687.4$ ms) [$t(35) = 5.58, p < .00001$]. Hits when the correct source information was subsequently recognized ($M = 517.1$ ms) were faster than both correct rejections [$t(35) = 5.90, p < .00001$] and hits with source incorrect ($M = 673.2$ ms) [$t(35) = 6.13, p < .000001$]. Reaction times for hits with a subsequent incorrect source responses were not different from those of correct rejections [$t(35) = 0.81, p = .42$].

2.2.2 Electrophysiological results

ANOVA results for the FN400 effect are summarized in Tables 2.4 and 2.5, and those for the parietal old/new effect are in Table 2.6.

Accuracy Condition			
Hit	Hit-SC	Hit-SI	CR
545 (30)	517 (28)	673 (44)	687 (48)

Table 2.3: Experiment 1: Grand average reaction times in milliseconds for recognition old/new judgments for item recognition judgment; standard errors are in parentheses. *Notes: SC=Source Correct; SI=Source Incorrect; CR=Correct Rejection.*

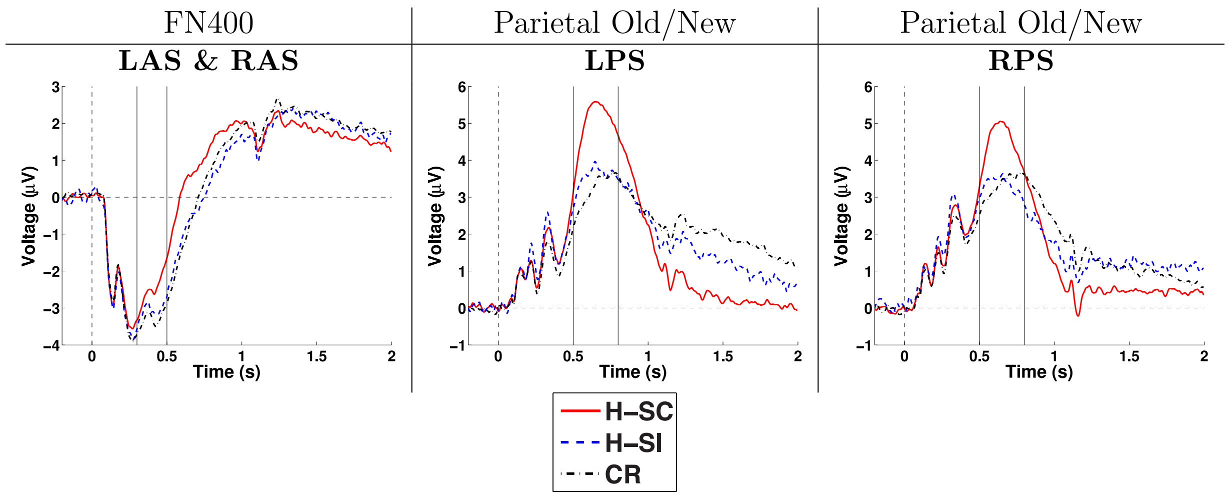

Figure 2.3: Experiment 1: ERP waveforms for the three conditions of interest. The first plot is averaged across the left and right anterior-superior ROIs. The other two plots show the left and right posterior-superior ROIs. Hits with correct source (H-SC) are solid red, hits with incorrect source (H-SI) are dashed blue, and correct rejections (CR) are dash-dotted black.

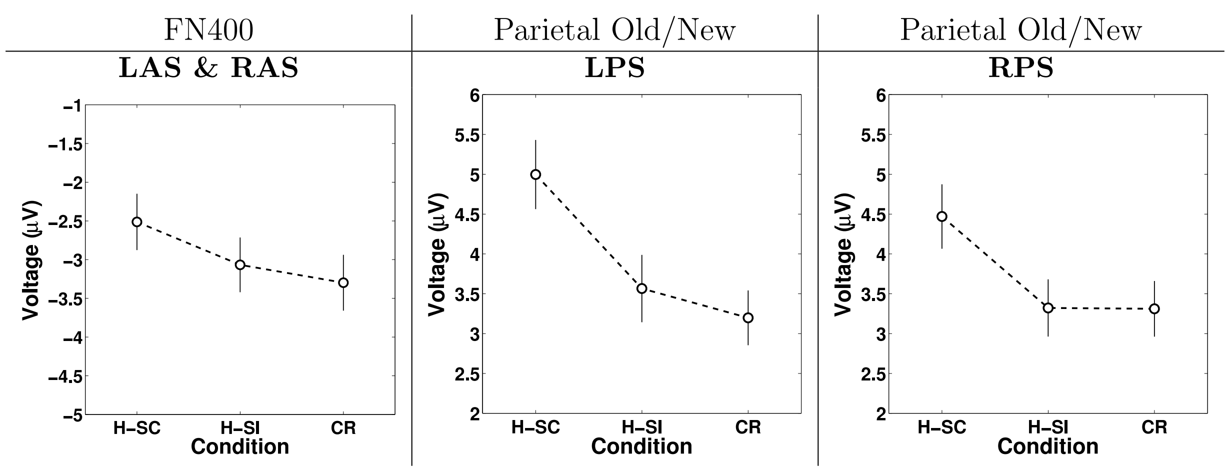

Figure 2.4: Experiment 1: Grand average ERP voltages for the three conditions of interest; error bars are standard errors. The first plot is averaged across the left and right anterior-superior ROIs. The other two plots show the left and right posterior-superior ROIs. *Notes: H-SC=Hits with Correct Source; H-SI=Hits with Incorrect Source; CR=Correct Rejections.*

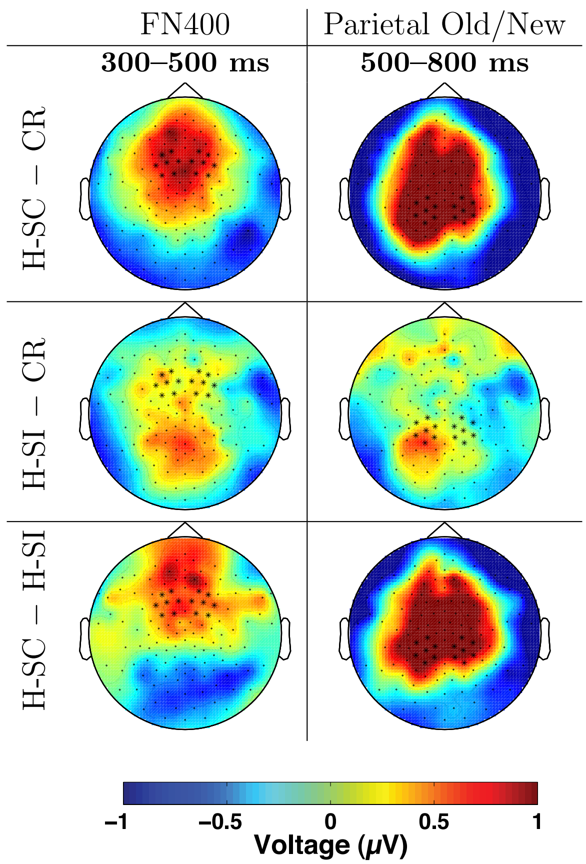

Figure 2.5: Experiment 1: Topographic contrast plots showing the broader distributions of EEG activity. The electrode ROIs in each column are marked with larger asterisks. *Notes: H-SC=Hits with Correct Source; H-SI=Hits with Incorrect Source; CR=Correct Rejections.*

Effect	d.f.	F	M.S.E.	p
Hemisphere	$1, 35$	0.441	1.369	$n.s.$
Hits vs. CRs	$1, 35$	55.307	0.283	$< .0000001$

Table 2.4: Experiment 1: FN400 2 × 2 Repeated Measures ANOVA results for item recognition (300–500 ms, LAS and RAS regions). *Notes: d.f.=degrees of freedom; n.s.=not significant; CR=Correct Rejection.*

A typical FN400 effect was found between old and new items. The FN400 effect occurs relatively early over the frontal hemisphere and is thought to be associated with familiarity processes; this is essentially the canonical item memory contrast comparing old to new items (Curran, 2000). To compare the conditions in the FN400, we conducted a two-way repeated measures ANOVA with factors of hemisphere (left and right anterior superior ROIs) and trial accuracy condition (hits and correct rejections). EEG was averaged over 300–500 ms and was averaged within each ROI, each of which consisted of seven electrodes. The ANOVA revealed a main effect of accuracy condition [$F(1, 35) = 55.31, MSE = 0.283, p < .00000011$], but no main effect of hemisphere [$F(1, 35) = 0.19, MSE = 1.37, p = .51$]. This is summarized in Table 2.4. A planned comparison for accuracy condition showed that, averaging across the two ROIs, correct rejections had a more negative voltage ($M = -3.30$ μV) than hits ($M = -2.64$ μV) [$t(35) = 7.44, p < .0000001$].

The FN400 results broken down by source accuracy were not typical such that hits with source correct and incorrect differed. We conducted an additional two-way repeated measures ANOVA comparing correct rejections and the two types of hits using the same ROIs and time window. Again, only a main effect of accuracy condition was seen [$F(1.71, 59.79) = 22.93, MSE = 0.599, p < .000001$]; there was no main effect of hemisphere [$F(1, 35) = 0.383, MSE = 2.018, p = .54$]. This is summarized in Table 2.5. Since there was no main effect of hemisphere, planned comparisons investigating differences between the three accuracy conditions are averaged across the two ROIs. These t-tests revealed that correct rejections were significantly more negative than both hits with correct source ($M = -2.51$ μV) [$t(35) = 8.54, p < .000000001$] and were only marginally more negative than hits with incorrect source ($M = -3.07$ μV) [$t(35) = 1.83, p = .076$]. Finally, hits with incorrect source were significantly more negative than those with correct source [$t(35) =$

Effect	d.f.	F	M.S.E.	p
Hemisphere	$1, 35$	0.383	2.018	$n.s.$
Hits-SC, Hits-SI, CRs	$1.71, 59.79$	22.930	0.599	$< .000001$

Table 2.5: Experiment 1: FN400 2 × 3 Repeated Measures ANOVA results comparing correct rejections and the two types of hits (300–500 ms, LAS and RAS regions). *Notes: d.f.=degrees of freedom; n.s.=not significant; SC=Source Correct; SI=Source Incorrect; CR=Correct Rejection.*

$4.11, p < .001$]. See Figures 2.3 for and 2.4 for plots of grand average ERPs and simplified voltages.

Typical left-lateralized parietal old/new differences were found. To examine the parietal old/new effect, we conducted a two-way repeated measures ANOVA with factors of hemisphere (left and right posterior superior ROIs) and trial accuracy condition (correct rejections and the two types of hits). EEG was averaged over 500–800 ms and was averaged across the seven electrodes that made up each ROI. A main effect of condition was seen [$F(1.66, 58.14) = 37.554, MSE = 1.494, p < .000000001$], but there was no main effect of hemisphere [$F(1, 35) = 0.684, MSE = 3.8, p = .41$]. Additionally, the hemisphere × accuracy condition interaction was significant [$F(1.53, 53.63) = 9.285, MSE = 0.26, p < .001$]. Table 2.6 has a summary of these values.

Averaging across the two ROIs, pairwise t-tests revealed that the voltage for hits with source correct ($M = 4.73\ \mu$V) was significantly more positive than that of both hits with source incorrect ($M = 3.44\ \mu$V) [$t(35) = 5.76, p < .00001$] and correct rejections ($M = 3.26\ \mu$V) [$t(35) = 9.06, p < .000000001$]. Hits with incorrect source were not significantly different from correct rejections [$t(35) = 1.16, p = .26$]. Examining the interaction, pairwise t-tests revealed that hits with source correct had a marginally higher positive amplitude over the left hemisphere ($M = 5.0\ \mu$V) than the right ($M = 4.47\ \mu$V) [$t(35) = 1.82, p = .077$], and hits with incorrect source had a higher voltage ($M = 3.57\ \mu$V) than correct rejections ($M = 3.20\ \mu$V) over the left hemisphere [$t(35) = 2.3605, p < .05$], but not the right [$t(35) = 0.05, p = .96$]. See Figures 2.3 and 2.4 for plots of grand average ERPs and simplified voltages.

Effect	d.f.	F	M.S.E.	p
Hemisphere	$1, 35$	0.684	3.800	$n.s.$
Hits-SC, Hits-SI, CRs	$1.66, 58.14$	37.554	1.494	$< .000000001$
Hemisphere × Accuracy condition	$1.53, 53.63$	9.285	0.260	$< .001$

Table 2.6: Experiment 1: Parietal Old/New 2 × 3 Repeated Measures ANOVA results comparing correct rejections and the two types of hits (500–800 ms, LPS and RPS regions). *Notes: d.f.=degrees of freedom; n.s.=not significant; SC=Source Correct; SI=Source Incorrect; CR=Correct Rejection.*

2.3 Discussion

To briefly examine the behavioral results, responses were limited to being made after the object disappeared so that ERP analyses of the test period can be conducted without contamination from responses, and so the reaction time results can be difficult to interpret and will not be discussed here. For accuracy, d_as for both item and source judgments were relatively high, showing that participants performed well in these tasks. Additionally, item recognition hit rates for old items (overall) and for hits with the recognition of correct source information were similar. Because the source recognition hit rate was high, this shows that the encoded source information was a salient feature that could be used advantageously. It is possible that using both color and side as source information allowed participants to maximize the potential effectiveness of familiarity. This is something to follow up on in future experiments, potentially by manipulating the salience of the available source information at study. Finally, participants showed no response biases in item and source judgments.

In the ERP analyses, the pattern of the parietal old/new effect is indicative of a typical recollection process: greater positive amplitude for hits with correct source recognition was seen compared to hits with incorrect source information and correct rejections, the latter two of which were not different from each other. This mimics the results seen in the literature (e.g., Allan et al., 1998; Curran, 2000; Curran & Hancock, 2007).

The FN400 component (averaging across 300–500 ms in the left and right anterior superior regions) showed that voltage for correct rejections was significantly more negative than both hits with source correct and hits with source incorrect. This is to be expected because the typical

FN400 result seen in the literature is that correctly identified new items have a more negative voltage than correctly identified old items. Importantly, an additional finding that meshes with the hypotheses and predictions of this experiment regarding source recognition is that hits with source incorrect were significantly more negative than hits with source correct, indicating a physiological difference between remembering items that only differed behaviorally with respect to whether source information was remembered correctly. There is something happening in the cognitive and neural processes that underlie the FN400 that creates a difference between these two cases. It seems likely that if the FN400 indexes familiarity, then familiarity is contributing to the recognition of correct source information.

A number of studies have labeled spatial location as an extrinsic property of an encoded item, which should not contribute positively to familiarity judgments (e.g., Ecker et al., 2007a, 2007b). However, as demonstrated in this experiment, familiarity can differentiate between cases when the spatially based perceptual source information (i.e., presentation side) was correctly versus incorrectly recognized. This is similar to the FN400 effect demonstrated by Peters and Daum (2009) in which source correct trials differed from those with source incorrect across cases when source information was encoded as three different kinds of sensory information (two visual, one auditory). These authors devoted relatively little discussion to this interesting finding because they focused mainly on the later ERP differences across modalities, but Groh-Bordin et al. (2006) discussed a similar finding of familiarity contributing to perceptual source identification. They posit just this, that the familiarity process can use perceptual (and conceptual) information to successfully recognize items and their attributes, and that the amount that the source information is useful depends at least partially on the task at hand.

Thus, it seems that one of two alternatives has occurred in the present experiment. First, as was reviewed earlier, familiarity can help with source monitoring if the item and source are unitized. It seems unlikely that each object and its presentation side would become bound into a single representation because this is extrinsic information and there were only two possible source locations to encode, meaning that the sources were probably not unique enough to create an associative bond. The second possibility is that familiarity can contribute to the recognition of an extrinsic and perceptually based item property, provided that the attribute is relatively simple and salient enough to be recognized. This falls in accordance with the research reviewed in Chapter 1 that led to the hypothesis being tested by the present experiment. In conclusion, it seems that if there is prominent and relatively simple perceptual source information available to encode, familiarity can play a role in its subsequent recognition.

Chapter 3

Experiment 2

In Experiment 2, source information was defined by the type of question that participants had to answer about each item during the study period. These questions required participants to think about an aspect of the item (a conceptual feature) and did not involve paying attention to perceptual details (see Figure 3.1). During the study period, participants answered one of two questions for each item presented in the center of the screen: (1) whether the item was living or nonliving (the "life" question), or (2) whether the item was bigger or smaller than a shoebox (the "size" question). They were told to remember which question they answered for each item. Thus, the judgment they made, which probed for semantic information about that specific item, was the context or source information that participants needed to encode with the item. It was not necessary to subsequently remember what their answer was, though it seems possible that this aspect of the item might come to mind when recalling the question asked during study (as in non-criterial recollection Yonelinas & Jacoby, 1996). During the test period, participants were shown a randomly intermixed list of old and new items. For each item, they first made an old/new judgment, and for the items called "old", they then answered which type of question they answered for the item during the previous study period. Hayama et al. (2008) previously tested a similar paradigm but they could not test the FN400 effect comparing source correct and source incorrect conditions because of insufficient trial counts; additionally, they used three conceptually based source attributes.

This experiment was motivated by the idea that making semantic classifications about an item could involve accessing intrinsic item information, but prior research has indicated that these types of judgments involve higher-level information that requires a recollective process to encode and recognize. For this reason we predicted that the FN400 will not differentiate between correctly and incorrectly recognizing conceptual source information. Additionally, we used only two conceptually based sources so that there were relatively few sources to encode and retrieve, as in Experiment 1.

3.1 Method

3.1.1 Participants

Twenty-six University of Colorado undergraduates participated in the experiment for either course credit or payment of $15 per hour (ages 18–28, $M = 22.7$; 13 male, 13 female). All participants were right-handed native-English speakers and had normal or corrected-to-normal vision. Informed consent was obtained from each participant, and the study conformed to the Human Research Committee guidelines. Two participants were excluded from analyses due to experimenter error. The remaining 24 participants were included in all analyses presented below.

3.1.2 Materials

The stimulus pool consisted of 452 color images of living and non-living things on square white backgrounds collected from `http://www.clipart.com`, from the stimuli set provided by Brady, Konkle, Alvarez, and Oliva (2008), and through image searching on the Internet. Half of the items were smaller than a shoebox and half of the items were bigger than a shoebox. 113 objects were found for each pairwise combination of categories (i.e., living–bigger, nonliving–smaller, etc.). Despite coming from one of the same sources, there was not considerable overlap in the exact images used here and in Experiment 1; we wanted the objects and things in the images used here to easily fall into the each of the pairwise categories. Each image was resized to 240×240 pixels and the experiment was presented on a 17-inch flat-panel display with a resolution of 1024×768 (60 Hz frame rate) placed 1 m in front of the participants. All portions of the display not occupied

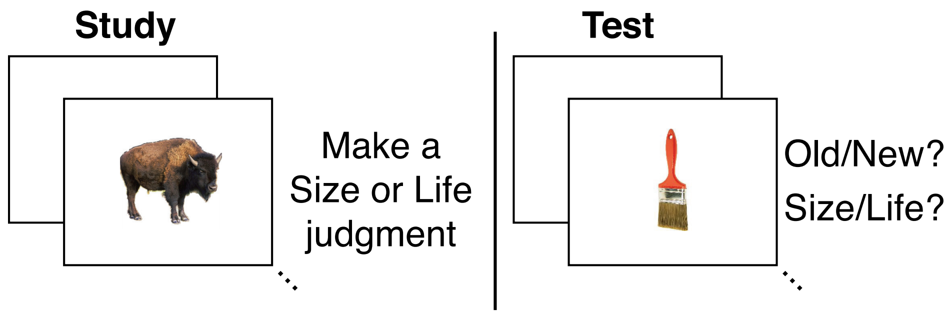

Figure 3.1: An illustration of the study and test tasks used in Experiment 2.

by stimuli or text were filled with black pixels.

3.1.3 Design

The design of the experiment followed that of Gruber et al. (2008). The experiment consisted of three study–test list pairs, with a 15-minute break between study and test. During the break period, the participant could complete Sudoku puzzles, talk to the researchers, or read a book or paper that they brought with them. The entire session lasted approximately 2.5 hours. From the stimulus pool, 96 stimuli were randomly chosen to create each of the three study lists. For each test period, 48 additional stimuli that the participant had not seen were intermixed with the 96 items from the corresponding study period, for a total of 144 stimuli on each test list. The remaining 20 stimuli were used to make a pair of practice study and test lists.

The status of each stimulus was manipulated within subjects, with each participant receiving a different random assignment of objects to the study conditions. Responses were collected using two keys on the bottom row of a standard keyboard (`Z` and `/`), and response assignments for the two keys were randomly determined for each participant at the start of the experiment. EEG was recorded throughout the entire experiment.

3.1.4 Procedure

An electrode cap was applied to each participant's head, and the participants then completed a practice trial to familiarize them with the study and test procedures.

On each trial of the study lists, participants first saw a pair of cue words for 400 ms that indicated how they should judge the object in the upcoming picture. The pair of cue words was either `Living` and `Nonliving` (the `Life` category) or `Bigger` and `Smaller` (the `Size` category), and was randomly assigned to each item such that an equal number of items were paired with each cue category. The cue words appeared on either side of a fixation cross (randomly assigned) in the center of the screen. The `Life` cue indicated that the participant should decide whether the object in the picture is living or nonliving. The `Size` cue indicated that the participant should decide whether the object in the picture is bigger or smaller than an average shoebox. Following the cue, the stimulus then appeared in the center for 700 ms, and after it was removed the participant indicated their response by pressing the corresponding key. A blank inter-stimulus-interval screen, appearing for 700 $\pm$ 200 ms, followed each response.

On each trial of the test lists, participants first saw a fixation cross for 750 $\pm$ 150 ms that was followed by either a stimulus from the previous study list (an old item) or one that they had not seen before (a new item), displayed for 700 ms in the center of the screen. A centered fixation cross then appeared for 800 ms, followed by a blank screen for 900 ms, after which the words `Old` and `New` appeared on either side of a fixation cross (randomly assigned). At this point the participants pressed the corresponding key to indicate whether they thought the item was old or new. If they called it "new", they went on to the next trial. If they called it "old", they were asked what kind of judgment they were asked to make for the item during the preceding study period; here, the words `Size` and `Life` appeared on either side of the cross (randomly assigned), and they pressed the corresponding key to make their memory judgment. A blank inter-stimulus-interval screen, appearing for 1000 $\pm$ 200 ms, followed each response.

3.1.5 Electrophysiological recordings

The procedure for recording electrophysiological data in Experiment 2 was the same as in Experiment 1.

	Accuracy Condition			
	Hits	Hits-SC	Hits-SI	CRs
Behavioral: Overall	219.46 (28.84)	155.67 (31.44)	63.75 (18.50)	125.54 (15.37)
Behavioral: Life	103.0 (3.40)	65.08 (3.80)	37.92 (2.40)	-
Behavioral: Size	114.33 (2.71)	88.92 (3.44)	25.38 (2.31)	-
EEG: Overall	201.08 (40.98)	143.13 (37.60)	57.96 (18.43)	114.54 (18.42)
EEG: Life	94.12 (4.39)	59.92 (4.27)	34.25 (2.32)	-
EEG: Size	104.83 (4.13)	81.54 (3.95)	23.29 (2.20)	-

Table 3.1: Experiment 2: Grand average trial counts for the analyzed accuracy conditions; standard deviations are in parentheses. Behavioral trial counts show the number of trials used in behavioral analyses; EEG trial counts show the number artifact-free trials used in EEG-based analyses. *Notes: SC=Source Correct; SI=Source Incorrect; CR=Correct Rejection.*

3.2 Results

In the results presented below, behavioral analyses included all trials while trials with EEG artifacts were excluded from the ERP analyses.

3.2.1 Behavioral results

For item recognition accuracy during the test periods, 76.2% ($SEM = 2.04\%$) of the studied items were correctly recognized as old (hits). 87.2% ($SEM = 2.18\%$) of the new items were correctly identified as new (correct rejections). Of the correctly identified old items, correct source information was identified for 70.7% ($SEM = 1.78\%$) of the items. As in Experiment 1, these rates are comparable to or slightly higher than the rates of similar studies (Cansino et al., 2002; Gruber et al., 2008; Mecklinger et al., 2007; Wilding & Rugg, 1996). Splitting old items intro those that were studied in the Size and the Life tasks, items that were studied with the Size task showed higher accuracy in all cases. More items were correctly recognized as old when studied in the Size condition ($M = 80.02\%, SEM = 1.91\%$) than in the Life condition ($M = 72.27\%, SEM = 2.38\%$) [$t(23) = 6.01, p < .00001$]. Conditionalizing on recognition hits, source information was also identified correctly more often for Size items ($M = 77.59\%, SEM = 2.14\%$) than Life items ($M = 62.58\%, SEM = 2.37\%$) [$t(23) = 5.51, p < .0001$]. These rates are summarized in Table 3.2.

Old/new discrimination, as measured by d', was higher for items in the Size task ($M =$

	HR	FAR	Hit-SC Rate	Hit-SI Rate	d'	c
Item: Overall	0.76 (0.02)	0.13 (0.02)	-	-	2.03 (0.11)	0.27 (0.07)
Source: Overall	-	-	0.71 (0.02)	0.29 (0.02)	1.15 (0.11)	-0.23 (0.04)
Item: Life	0.72 (0.02)	-	0.63 (0.02)	0.37 (0.02)	1.91 (0.11)	0.33 (0.07)
Item: Size	0.80 (0.02)	-	0.78 (0.02)	0.22 (0.021)	2.18 (0.12)	0.20 (0.07)

Table 3.2: Experiment 2: Item and source recognition means; standard errors are in parentheses. *Notes: HR=Hit Rate; FAR=False Alarm Rate; SC=Source Correct; SI=Source Incorrect.*

$2.18, SEM = 0.12$) than in the Life task ($M = 1.91, SEM = 0.11$) [$t(23) = 6.47, p < .000001$]. Comparing the two sources, item d' was greater for the Size task ($M = 2.18$) than for the Life task ($M = 1.91$) [$t(23) = 6.47, p < .00001$]. Source accuracy rates were calculated such that the Size source was the target distribution and the Life source was the lure distribution. Average source d' was 1.14 ($SEM = 0.11$).

Response bias (c) was calculated for item and source collapsed across the two sources, and for item recognition hits for the individual sources. Overall item c was 0.27 ($SEM = 0.07$) and source c was -0.23 ($SEM = 0.04$). The positive item c value means that participants were more likely to say "new" (i.e., be more conservative) to the old/new question, and the negative source c values means that they were more likely to say that items were studied in the Size source. Item c was more positive, or more conservative, for items studied in the Life task ($M = 0.329$) than in the Size task ($M = 0.195$) [$t(23) = 6.47, p < .00001$], meaning they were more likely to give a "new" judgment to items in the Life task. These discrimination values are included in Table 3.2.

The reaction times (RT) reported here (see Table 3.3) were measured from the onset of the old–new prompt following the presentation of the test stimulus to the key press indicating

	Accuracy Condition			
Study Condition	Hit	Hit-SC	Hit-SI	CR
Overall	458 (34)	440 (31)	507 (49)	459 (32)
Life	471 (40)	450 (32)	509 (60)	-
Size	445 (30)	429 (30)	501 (38)	-

Table 3.3: Experiment 2: Grand average reaction times in milliseconds for recognition old/new judgments for item recognition judgments; standard errors are in parentheses. *Notes: SC=Source Correct; SI=Source Incorrect; CR=Correct Rejection.*

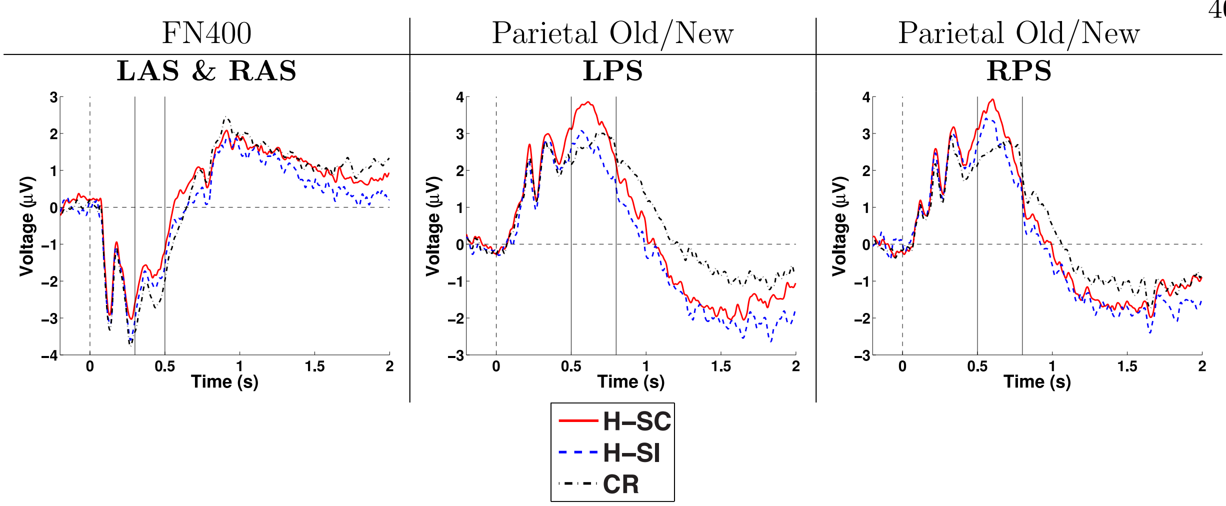

Figure 3.2: Experiment 2: ERP waveforms for the three conditions of interest. The first plot is averaged across the left and right anterior-superior ROIs. The other two plots show the left and right posterior-superior ROIs. Hits with correct source (H-SC) are solid red, hits with incorrect source (H-SI) are dashed blue, and correct rejections (CR) are dash-dotted black.

the old–new response. Though these are essentially item recognition judgment RTs, responses are additionally divided into whether the subsequent source judgment was correct or incorrect. The RTs for the Size and the Life conditions were not significantly different from each other, nor was there an interaction between task and source accuracy; thus, the numbers reported here collapse across the two conditions. The only significant difference observed was that hits when the correct source (M = 440.1 ms) information was subsequently recognized had faster RTs than hits with incorrect source identification (M = 506.8 ms) [$t(23) = 2.80, p < .05$]. Correct rejections (M = 458.8 ms) were not different from hits overall (M = 458.3 ms) [$t(23) = 0.04, p = .97$], nor hits divided up into those with source correct [$t(23) = 1.38, p = .18$] and those with source incorrect [$t(23) = 1.88, p = .07$].

3.2.2 Electrophysiological results

As in Experiment 1, ERP voltages were measured from the onset of the test stimuli, and the same electrode cap and regions of interest were used in Experiment 2. ANOVA results for the FN400 effect are summarized in Tables 3.4 and 3.5, and those for the parietal old/new effect are in

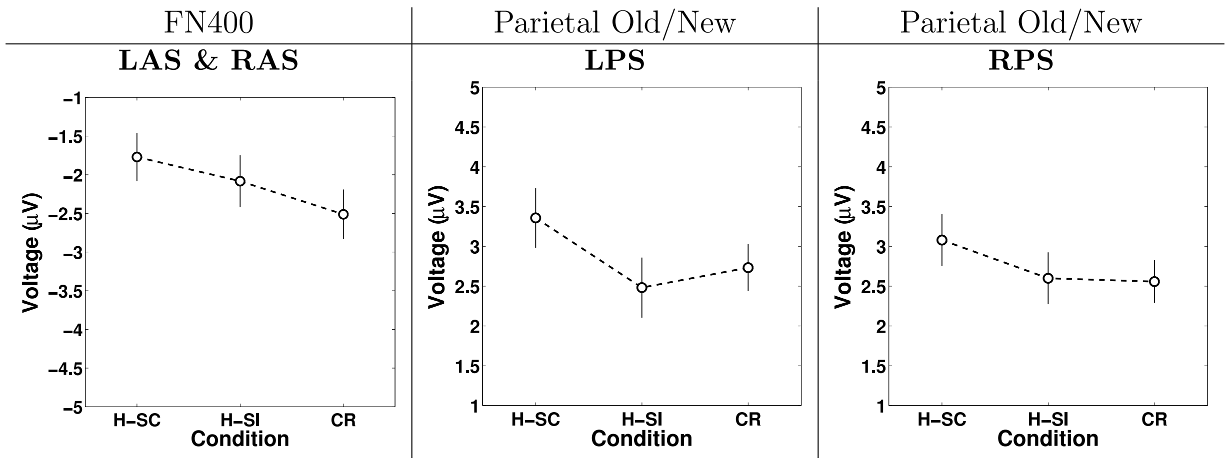

Figure 3.3: Experiment 2: Grand average ERP voltages for the three conditions of interest; error bars are standard errors. The first plot is averaged across the left and right anterior-superior ROIs. The other two plots show the left and right posterior-superior ROIs. *Notes: H-SC=Hits with Source Correct; H-SI=Hits with Source Incorrect; CR=Correct Rejections.*

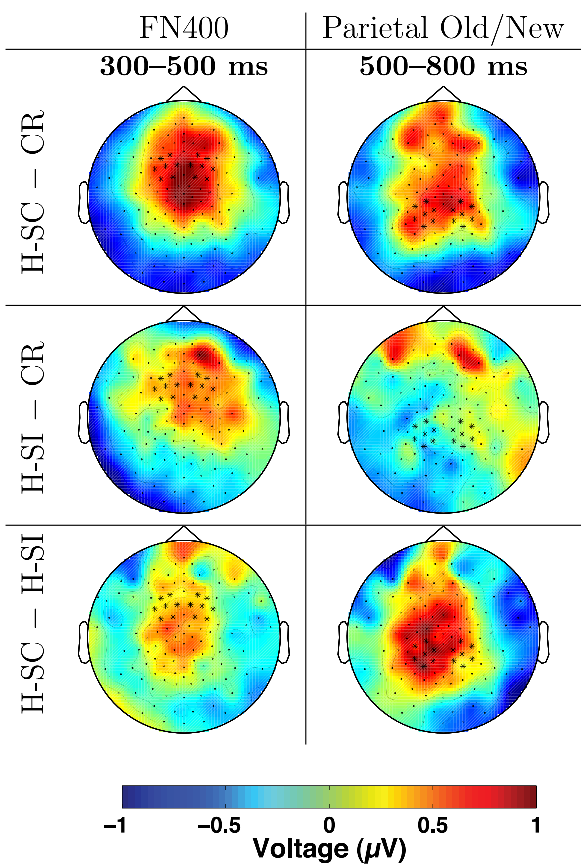

Figure 3.4: Experiment 2: Topographic contrast plots showing the broader distributions of EEG activity. The electrode ROIs in each column are marked with larger asterisks.

Effect	d.f.	F	M.S.E.	p
Hemisphere	$1,23$	0.373	0.718	$n.s.$
Hits vs. CRs	$1,23$	35.358	0.295	$< .00001$

Table 3.4: Experiment 2: FN400 2 × 2 Repeated Measures ANOVA results for item recognition (300–500 ms, LAS and RAS regions). *Notes: d.f.=degrees of freedom; n.s.=not significant; CR=Correct Rejection.*

Table 3.6.

A typical FN400 effect was found between old and new items. To compare the conditions in the FN400 effect, we conducted a two-way repeated measures ANOVA with factors of hemisphere (left and right anterior superior regions) and trial accuracy condition (hits and correct rejections) (see Table 3.4). EEG was averaged over 300–500 ms and was averaged within each ROI, each of which consisted of seven electrodes. This test revealed a main effect of accuracy condition $[F(1,23) = 35.358, MSE = 0.295, p < .00001]$, but no main effect of hemisphere $[F(1,23) = 0.373, MSE = 0.718, p = .55]$. In a planned comparison, correct rejections had a more negative voltage ($M = -2.51$ μV) than hits across the two hemispheres ($M = -1.85$ μV) $[t(23) = 5.95, p < .000005]$.

A typical FN400 effect was found between old items divided by source accuracy and new items. We conducted an additional two-way repeated measures ANOVA using the same ROIs to compare FN400 voltages for correct rejections and the two types of hits in the same temporal window (see Table 3.5). Only a main effect of condition was seen $[F(1.65, 37.96) = 9.823, MSE = 0.82, p < .001]$; there was no main effect of hemisphere $[F(1,23) = 0.582, MSE = 0.967, p = .45]$. Planned pairwise comparisons averaging across the hemispheres revealed that correct rejections were significantly more negative than both hits with correct source ($M = -1.77$ μV) $[t(23) = 5.96, p < .000005]$ and hits with incorrect source ($M = -2.08$ μV) $[t(23) = 2.38, p < .05]$. Hits with correct and incorrect source were not significantly different from each other $[t(23) = 1.63, p = .12]$.

Typical left-lateralized parietal old/new differences were found. To examine the parietal old/new effect, we conducted a two-way repeated measures ANOVA using hemispheres (left and right posterior superior ROIs) and trial accuracy condition (correct rejections and the two types

Effect	d.f.	F	M.S.E.	p
Hemisphere	$1, 23$	0.582	0.967	$n.s.$
Hits-SC, Hits-SI, CRs	$1.65, 37.96$	9.823	0.820	$< .001$

Table 3.5: Experiment 2: FN400 2 × 3 Repeated Measures ANOVA results comparing correct rejections and the two types of hits (300–500 ms, LAS and RAS regions). *Notes: d.f.=degrees of freedom; n.s.=not significant; SC=Source Correct; SI=Source Incorrect; CR=Correct Rejection.*

of hits) as factors (see Table 3.6). EEG was averaged over 500–800 ms and was averaged across the seven electrodes that made up each ROI. A main effect of condition was seen [$F(1.74, 40.07) = 4.619, MSE = 1.589, p < .05$]; there was not a main effect of hemisphere [$F(1, 23) = 0.283, MSE = 1.595, p = .60$]. Planned pairwise comparisons revealed that the voltage for hits with source correct ($M = 3.22$ μV) was significantly more positive than that of both hits with source incorrect ($M = 2.54$ μV) [$t(23) = 2.45, p < .05$] and correct rejections ($M = 2.65$ μV) [$t(23) = 2.90, p < .01$]. Hits with incorrect source were not significantly different from correct rejections [$t(23) = -0.45, p = 65$].

3.3 Discussion

Comparing d' values between Experiment 1 and Experiment 2, it is interesting that item d' was higher (Exp. 1 = 1.52 vs. Exp. 2 = 2.03) and source d' was considerably lower (Exp. 1 = 1.76 vs. Exp. 2 = 1.15) here than in the previous experiment. It seems that encoding an item with a conceptual source allows for better subsequent recognition of the item itself. Perhaps the processing of the items at study that included accessing semantic knowledge about each led to deeper encoding of each item's occurrence (Craik & Lockhart, 1972). Source recognition, on the other hand, was just more difficult when attempting to remember the semantic dimension queried in the study period. To this, consider the fact that every item potentially has a size and an animacy classification,

Effect	d.f.	F	M.S.E.	p
Hemisphere	$1, 23$	0.283	1.595	$n.s.$
Hits-SC, Hits-SI, CRs	$1.74, 40.07$	4.619	1.589	$< .05$

Table 3.6: Experiment 2: Parietal 2 × 3 Repeated Measures Old/New ANOVA results comparing correct rejections and the two types of hits (500–800 ms, LPS and RPS regions). *Notes: d.f.=degrees of freedom; n.s.=not significant; SC=Source Correct; SI=Source Incorrect; CR=Correct Rejection.*

which is the basis of the source information in Experiment 2. During study, assessing items on intermixed queries about size and animacy status might have led to thinking about both dimensions for some of the items, which would make it difficult to subsequently remember the type of judgment, whereas in Experiment 1 each item was presented on a distinct side of the screen that may have remained particularly salient in the context of the study task. A blocked study task design would be appropriate to assess this possibility. Alternatively, during test it might be difficult to remember which of these was the studied source because every item has both source attributes. Additionally, it is an interesting and likely meaningful result that the item and source accuracy rates for the two conditions (Size and Life) were different. Thinking about an item's size led to better recognition of the item and more accurate recognition of source information compared to thinking about whether or not an item is a living thing. Perhaps assessing item size is more of a perceptual task, and thus it is easier to remember this information, or maybe these items are encoded more deeply. These are questions to be answered by future experiments.

To discuss the ERP results, in this experiment, where source information was related to the type of semantically based classification made for each studied object, the parietal old/new effect showed what would be expected for the component thought to reflect recollective processing. Qualitatively, it was much more left lateralized than in Experiment 1, though the effect was still significant when the bilateral regions of interest were averaged together. The FN400 was more negative for correct rejections than for all hits, as was expected. Additionally, and in contrast to Experiment 1, hits with source correct and those with source incorrect did not significantly differ from each other.

The null effect when comparing FN400 voltages of source correct and incorrect trials shows that the familiarity process cannot use conceptually based source aspects to successfully carry out source monitoring, and instead can only differentiate between old and new items. This is the major contrast to the procedure and results of Experiment 1 where source was perceptually defined and familiarity could contribute to successful source monitoring. Previous studies have demonstrated that familiarity based episodic recognition plays a role in source monitoring when the contextual attributes are unitized or bound into a singular representation with the encoded item, though Experiment 1 extends the idea of when familiarity can contribute to source monitoring. These studies have typically used perceptual source attributes (e.g., Diana et al., 2010; Ecker et al., 2007b; Groh-Bordin et al., 2006), but the ones that have shown familiarity bases source recognition have implemented strong unitization as in associative memory paradigms (e.g., Haskins et al., 2008; Quamme et al., 2007). Perhaps, then, familiarity cannot monitor source information when it involves higher-level conceptual associations about the items, and instead a recollection process is necessary to retrieve this information.

Additionally, we can examine the null effect regarding the ways in which the items and their sources were encoded and subsequently retrieved from memory. As mentioned above, it may have been the case that intermixed study questions led participants to encode both source judgments. What seems more likely than this, though, is that during the test period it was difficult to use conceptual information to probe for the type of study judgment made. Thinking in terms of how a global matching model would investigate the studied source information, as discussed in Chapter 1, it may be difficult to correctly differentiate between the familiarity signals after probing with the size and life categories because every item seen during the test period has these properties. Thus, this lack of differentiation means that the familiarity signal might not be strong enough to assist in successful source monitoring (Johnson et al., 1993).

Notably, the significance value for the FN400 comparison between hits with source correct and those with source incorrect is bordering on being considered marginal (p = .12). Though this cannot be answered using the results from the current experiment, it is possible that having relatively few sources to choose from allowed some part of the familiarity process to partake in the recognition of correct source information, but that the effect was not strong enough to be detected in the ERP analysis. An alternative to this is that if the Size task was more perceptually based than the Life task, and familiarity may have contributed more to recognizing the former but the average was brought down by the latter.

In conclusion, the FN400 results support the idea that the familiarity process does not contribute to source recognition when the source attributes are conceptually defined, though the exact reason for this has not been illuminated here. The overall results point toward the a recollective process being involved in encoding and remembering semantic source information, with no contribution from familiarity.

Chapter 4

Experiment 3

Since we are interested in familiarity's contribution to the recognition of source information in relation to the type of source information that was encoded at study, we have investigated this by comparing the FN400 evoked by correct rejections, hits with source correct, and hits with source incorrect. There are limitations in comparing the conditions of Experiments 1 and 2 directly because they differ in multiple dimensions in addition to the perceptual and semantic classification qualities of source information, and instead we have qualitatively compared similarities and differences across the experiments.

To briefly recapitulate, Experiment 1 used perceptually defined sources, while source information in Experiment 2 was based on the conceptual or semantic judgment made at study. The interesting result to examine from these experiments is that the FN400 effect for hits with source correct differed from hits with source incorrect in Experiment 1, whereas this difference was not seen in Experiment 2 . This is inconsistent with the idea that only recollection can support recognizing correct source information, and suggests that familiarity, which is indexed by the FN400, can contribute to perceptual source judgments.

Because of these limitations in comparing Experiments 1 and 2 directly, a third experiment was conducted that combined both perceptually based and conceptually based source information within a single experiment such that all participants saw both types of source information. All conditions other than source type were held constant. Using these more stringent manipulations we predicted that we would find differences in the contribution of familiarity (as indexed by the

FN400) to source monitoring across the types of source information in the same directions that were seen in Experiments 1 and 2.

Specifically, Experiment 3 was run as a within-subjects study designed as a combination of Experiments 1 and 2 (encoding both side/frame color and judgment type) to ensure that the previously described effects are reliable (see Figure 4.1). During each study period in the present Experiment 3, pictures of objects were viewed on the left and right sides of the screen (like in Experiment 1) and participants made size and animacy judgments about each one (like in Experiment 2). Thus, all items had both source dimensions paired with them at study (presentation side and question type). Participants were told to try to remember both the side and question type because they did not know which source dimension would be subsequently tested.

A modified Remember–Know (RK) test paradigm was then used to identify the different ways that participants can remember information. "Remember" (R) and "know" (K) judgments are thought to reflect recollection and familiarity, respectively. This is an appropriate paradigm to use because these ratings will allow us to behaviorally examine the hypothesis that familiarity is more likely to support accurate source recognition in conditions more similar to Experiment 1 than 2. For example, Hicks et al. (2002) had participants differentiate between words that were presented either visually or aurally and found source accuracy for K responses to be equal to R responses, suggesting that a sense of familiarity or partial retrieval of information is sufficient enough to contribute to the identification of correct source information. Thus, we predicted that trials associated with recollection will show above chance accuracy in both source conditions, but trials associated with familiarity will only show above chance accuracy when source in defined by location.

Only one source dimension was queried in each test block. For each test item, participants first made either a source judgment (left/right in a Side test block or size/life in a Question test block) or classified it as new. If the item was given a source, they responded with one of three options using the modified RK procedure: whether they remembered the source information, whether they remembered something other than the source information (i.e., non-criterial recollection, which is explained in more detail below), or whether the item just felt familiar and they could not remember any details. From the results of Experiments 1 and 2, we hypothesize that familiarity might be able to contribute to the recognition of perceptually based (i.e., presentation side) and not conceptually based (i.e., study question) source information.

To briefly motivate the changes in experimental design from the first two experiments, the modified RK procedure was used to gather subjective data regarding whether the source information or some other type of information was remembered at test, or whether the item just seemed familiar and no details about the item were remembered. This modification was made so that the occurrence of recollection of non-source details (i.e., non-criterial recollection Yonelinas & Jacoby, 1996) would not contaminate what would otherwise have been classified as familiarity-based judgments (K judgments in the two-option RK procedure). An example of non-criterial recollection would be remembering at test that studying a picture of an apple made the participant think of how he or she was hungry. Although it is still a subjective measure of recollection, we think that splitting the types of R judgments into source and other categories can eliminate the occurrence of non-criterial recollection trials in both the R and the K judgment categories, and that this type of test procedure is a good compromise between gathering the subjective responses of the RK procedure and being able to investigate the more objective source accuracy.

An additional measure of specificity in participants' answers is the two-tiered test question: source memory is first evaluated to assess recognition success or failure and then the RK judgments are made. Here, because the first answer made during test was a source judgment, item recognition can be implicitly derived based on whether the answer to the test question was one of the sources regardless of source accuracy. The RK judgments then specify what type of information was remembered (source or other) or whether the item just felt familiar.

4.1 Method

4.1.1 Participants

Thirty-three University of Colorado undergraduates participated in the experiment for either course credit or payment of $15 per hour (ages 18–25, $M = 19.2$; 22 male, 11 female). All participants were right-handed native-English speakers and had normal or corrected-to-normal vision. Informed consent was obtained from each participant, and the study conformed to the Human Research Committee guidelines.

4.1.2 Materials

The stimulus pool consisted of 492 color images of living and non-living things on square white backgrounds; they came from the set collected for Experiment 2 and through additional image searching on the Internet. Each image was resized to 240 × 240 pixels and the experiment was presented on a 17-inch flat-panel display with a resolution of 1024 × 768 (60 Hz frame rate) placed 1 m in front of the participants. All portions of the display not occupied by stimuli or text were filled with black pixels.

4.1.3 Design

The design of the experiment was essentially a combination of Experiments 1 and 2. The experiment consisted of four study–test list pairs with a five-minute break between study and test. From the stimulus pool, 76 stimuli were randomly chosen to create each of the four study lists. The two objects at the beginning and end of each study list were not included in the corresponding test list to lessen the possibility of primacy and recency effects. For each test period, 36 additional stimuli that the participant had not seen were intermixed with the 72 items from the corresponding study period, for a total of 108 stimuli on each test list. Two study–test pairs of practice lists were created from the remaining 44 stimuli, with 12 stimuli on each study list, and these plus an additional 8 new stimuli on each test list. One study–test list pair was used to run a practice list

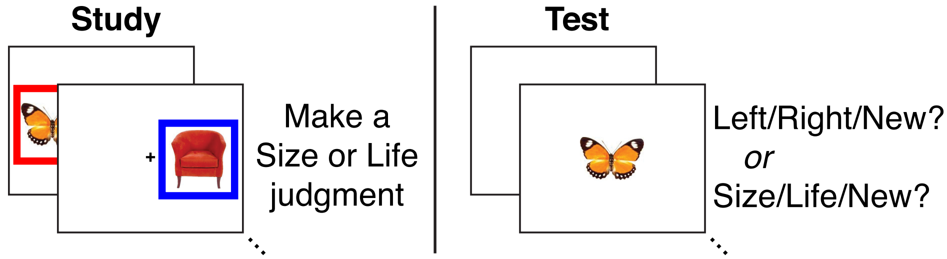

Figure 4.1: An illustration of the study and test tasks used in Experiment 3.

with the side test (from Experiment 1), and the other was used to practice the question test (from Experiment 2).

The status of each stimulus was manipulated within subjects, such that each participant received a different random assignment of objects to the study conditions. Responses were collected using three keys on the bottom row of a standard keyboard, which were pseudo-randomly chosen from the `Z`, `X`, `Period`, and `/` keys. The pseudo-random assignment is described in more detail after the types of responses are described. Response assignments for the keys were determined for each participant at the start of the experiment and were consistent within each participant across study and test periods. EEG was recorded throughout the entire experiment.

4.1.4 Procedure

An electrode net was applied to each participant's head, and the participants then completed a practice trial to familiarize them with the study and test procedures.

The timing of the progression of fixation cross, cues, stimuli, etc., was identical to Experiment 2 and is not reported here. See Figure 4.1 for an example of the procedure described below.

On each trial of the study lists, participants were instructed to fixate on the cross in the center of the screen and observe all on-screen information with their peripheral vision. They first saw the cue words that told them the type of question they had to answer for the upcoming item. Again, the pair of cue words was either `Living` and `Nonliving` (the Life category) or `Bigger` and `Smaller` (the Size category), and were randomly assigned to each item such that an equal number of items were paired with each cue category. Additionally, each item was randomly displayed on either the left or right side of the screen such that half of the items appeared on each side, as in Experiment 1, and no more than three objects in a row could appear on the same side. A 48-pixel colored frame surrounded each object to make location information more salient. The frame colors were red and blue, and color was always redundant with the side; side colors were counterbalanced across participants. Participants were told to attend to both the location of the object and to remember the type of question they answered, because they were not told beforehand which aspect they would be asked to report in the following test period. Following the cue words, an empty black screen was shown, then the stimulus then appeared in the center, and after it was removed the participant indicated their response by pressing the corresponding key. A blank inter-stimulus-interval screen followed each response.

The test period was blocked such that each test period asked only about either the location in which they saw each object from the preceding study period (the Side, or S, task) or the question type that they answered about each item (the Question, or Q, task). The order of test type was counterbalanced across participants such that 25% of the participants received each of these combinations: S-Q-S-Q, S-Q-Q-S, Q-S-Q-S, Q-S-S-Q. Participants were informed about the type of information they would have to remember at the start of each the test period. After a delay with only a fixation cross, either an old item from the previous study list or a new item appeared, and participants saw either `L R + N` (for Left, Right, fixation cross, New) or `S L + N` (for Size, Life, fixation cross, New), which lined up with their three response keys, to indicate the source information from the study period for each item. If the answer was not “new”, participants then used three-option RK judgments (Remember Source Detail, Remember Other Detail, and Familiar) to identify the subjective feeling that they had about the information that they just reported they had remembered. On the screen they saw either `RQ RO + F` (for Remember Question, Remember Other, fixation cross, Familiar) or `RS RO + F` (for Remember Side, Remember Other, fixation cross, Familiar). If the participant answered “new”, they saw `Maybe + Sure`, to indicate how confident they were about it being a new item.

The key assignments were pseudo-random in that the responses were ordered in a sensible manner for the test task, and equal numbers of participants received each possible key layout. When the initial test source response queried presentation side, the key for a "left" response was always to the left of the key for a "right" response, and these keys were always paired together on one hand while the "new" key was assigned to the far key of the other hand. When the study question type was queried, "new" was on one hand and the "size" and "life" responses were made with the other hand, but no order was set for which key had which of the two source responses. For the RK judgments, the order of keys was always such that the responses went in either ascending or descending memory strength from left to right across the keyboard (with remembering the source being the strongest and familiar being the weakest); F was always assigned to one hand and the RO and RS/RQ responses were made by the other hand.

4.1.5 Electrophysiological recordings

The procedure for recording electrophysiological data in Experiment 3 was the same as in Experiments 1 and 2.

4.2 Results

The Experiment 3 behavioral and ERP data were examined in two ways. We first present the results when dividing trials by response accuracy, followed by the results when dividing trials by RK response type.

4.2.1 Behavioral results by response accuracy

For the response accuracy results, seven participants were excluded from analyses for having trial counts lower than 15 trials in any one accuracy category. Trial count is a critical consideration of ERP analyses, but they were also left out of the behavioral analyses so that the same participants were analyzed in both modalities. This exclusion was performed after ICA-based blink artifact correction and subsequent rejection of events with eye-movement and residual eye-blink artifacts.

	Accuracy Condition			
	Hits	Hits-SC	Hits-SI	CRs
Behavioral: Side	110.30 (17.10)	78.13 (20.58)	32.17 (9.46)	54.22 (11.09)
Behavioral: Question	107.13 (17.31)	69.09 (15.09)	38.04 (12.27)	56.70 (10.30)
EEG: Side	97.87 (22.44)	70.00 (22.31)	27.87 (8.62)	47.70 (12.45)
EEG: Question	93.52 (20.12)	59.96 (16.63)	33.57 (10.90)	49.96 (11.00)

Table 4.1: Experiment 3: Grand average trial counts for the analyzed accuracy conditions; standard deviations are in parentheses. Behavioral trial counts show the number of trials used in behavioral analyses; EEG trial counts show the number artifact-free trials used in EEG-based analyses. *Notes: SC=Source Correct; SI=Source Incorrect; CR=Correct Rejection.*

Three others were excluded from all analyses in this experiment because of either software stability issues ($n = 1$) or experimenter error ($n = 2$). The remaining 23 participants were included in the response accuracy results presented below; behavioral analyses included all trials, while EPR analyses included only artifact-free trials. These trial counts are listed in Table 4.1. Despite excluding a large number of participants, behavioral analyses showed the same qualitative patterns with and without the seven participants who were excluded for having low trial counts.

Item and source recognition rates are summarized in Table 4.2. Collapsing across RK judgments, old/new discrimination, as measured by average d', was 1.56 for the S task and 1.60 for the Q task; item recognition accuracy did not differ between tasks [$t(22) = 0.60, n.s.$]. A source d' comparison between the two tasks showed that participants were better at correctly recognizing presentation side source information than study question source information (side $d' = 1.12$; question $d' = 0.76$) [$t(22) = 3.98, p < .001$].

Measures of item response bias (c) differed such that Q task's c ($M = 0.10$) was more conservative when asked about an item's question type (i.e., more likely to call the item "new") than that of the S task ($M = -.003$) [$t(22) = 2.30, p < .05$]. Source c for S ($M = -0.04$) and Q ($M = -0.02$) did not differ, and all cs were not different from zero.

Responses in the Side task were faster than in the Question task. The reaction times reported in Table 4.3 were measured from the onset of the source–new prompt following the presentation of the test stimulus. Participants were faster to respond to items they correctly recognized as being

	HR	FAR	Hit-SC Rate	d'	c
Item: Side	0.77 (0.03)	0.25 (0.03)	-	1.56 (0.13)	-0.003 (0.08)
Item: Question	0.74 (0.03)	0.21 (0.03)	-	1.6 (0.10)	0.10 (0.08)
Source: Side	-	-	0.70 (0.02)	1.12 (0.14)	-0.04 (0.08)
Source: Question	-	-	0.64 (0.02)	0.76 (0.12)	-0.02 (0.07)

Table 4.2: Experiment 3: Recognition rate averages for item and source judgments; standard errors are in parentheses. *Notes: HR=Hit Rate; FAR=False Alarm Rate; SC=Source Correct; SI=Source Incorrect.*

old (i.e., regardless of source accuracy) when remembering presentation side information ($M =$ 740.7 ms) than when remembering the type of study question ($M = 1033.2$ ms) [$t(23) = 5.25, p <$ .00005]. Additionally, identifying the correct source was faster in the S task ($M = 690.6$ ms) than in the Q task ($M = 989.6$ ms) [$t(23) = 5.15, p < .00005$]; the same pattern is seen when incorrect source information is chosen ($M = 873.0$ ms versus $M = 1126.4$ ms) [$t(23) = 3.13, p < .005$]. Comparing within each task, getting the source correct was significantly faster than getting the source incorrect for both the S [$t(23) = 3.04, p < .01$] and Q [$t(23) = 2.36, p < .05$] tasks.

4.2.2 Behavioral results by response type

In addition to analyzing the trials by source accuracy, we also divided the trials by response type and accuracy. In the case of our modified RK paradigm these response conditions are the "Remember Source" (RS for the S task and RQ for the Q task; called RSrc below), "Remember Other" (RO), "Familiar" (F), and "New" (N) responses. This method allows for estimating source accuracy for old items when responses are based on recollection (RSrc), non-criterial recollection (RO), and familiarity (F). Based on the results of the previous experiments, we predict that trials

	Accuracy Condition			
Study Condition	Hit	Hit-SC	Hit-SI	CR
Overall	883 (61)	830 (58)	1008 (78)	579 (47)
Side	741 (54)	691 (50)	873 (83)	577 (46)
Question	1033 (78)	990 (78)	1126 (93)	581 (54)

Table 4.3: Experiment 3: Grand average reaction times in milliseconds for recognition old/new judgments for item recognition judgments; standard errors are in parentheses. *Notes: SC=Source Correct; SI=Source Incorrect; CR=Correct Rejection.*

	RK Response Condition			
	RSrc	RO	F	N
Behavioral: Side	49.9 (23.6)	33.1 (16.4)	26.6 (15.2)	52.9 (14.4)
Behavioral: Question	52.3 (21.8)	29.9 (17.2)	26.1 (15.3)	56.1 (11.7)

Table 4.4: Experiment 3: Grand average trial counts for the analyzed response conditions; standard deviations are in parentheses. Behavioral trial counts show the number of trials used in behavioral analyses. *Notes: RK=Remember–Know; RSrc=Remember Source response; RO=Remember Other response; F=Familiar response; N=New response.*

associated with recollection will show above chance accuracy in both source tasks, but trials associated with familiarity will only show above chance accuracy when source is defined by location (the S task). Because only behavioral analyses were considered here, only the three participants mentioned earlier were excluded due to technical problems, and 30 participants are included in the analyses. Trial counts are listed in Table 4.4.

The Side task was more accurate than the Question task. Since we are investigating source monitoring for recognition hit items, we compared the accuracy for each of the responses in both test tasks. Based on our predictions, we would expect to see higher source accuracy for F judgments in the S task than in the Q task. Here, we performed a two-way repeated measures ANOVA on the source accuracy rates with factors of task (S and Q) and response (RSrc, RO, F). Source accuracy was calculated within each response for each task (e.g., the proportion of S RSrc responses that had a correct source judgment), and these values are presented in Table 4.5. The effect of task was significant $[F(1, 29) = 11.22, MSE = 0.029, p < .01]$ such that the S task had higher accuracy than the Q task (S = $.67 vs.$ Q = .59). There was also a main effect of response type $[F(1.72, 49.89) = 41.64, MSE = 0.028, p < .000000001]$ such that RS responses ($M = .78$) were

Task	Response Category		
	RSrc	RO	F
Side	.79	.63	.59
Question	.76	.51	.49

Table 4.5: Experiment 3: Average proportion of correct source identification computed within response categories for hits. *Notes: RSrc=Remember Source; RO=Remember Other; F=Familiar.*

more accurate than both RO responses ($M = .58$) [$t(29) = 7.6, p < .0000001$] and F responses ($M = .54$) [$t(29) = 7.2, p < .0000001$], while accuracy rates for RO and F responses were not different from each other [$t(29) = 1.61, n.s.$].

F and RO responses were more accurate for the Side task than the Question task. In light of our current hypotheses, it is informative to do a more pointed examination of the F and RO response accuracies for the two tasks (see Table 4.5). Here, RO responses were significantly more accurate in the S task than the Q task [$t(29) = 2.8, p < .01$], and importantly F responses followed this same pattern [$t(29) = 2.3, p < .05$]. Additionally, testing whether F and RO accuracy rates differ from chance (a rate of .5 give two source choices) is an informative comparison to make regarding familiarity's contributing to source recognition, and is also a comparison about which we had *a priori* notions. Both F and RO responses in the S task were above chance (F: [$t(29) = 2.12, p < .05$]; RO: [$t(29) = 3.92, p < .001$]) while those of the Q task were not different from chance (F: [$t(29) = 0.39, n.s.$]; RO: [$t(29) = 0.4, n.s.$]).

4.2.3 Electrophysiological results by response accuracy

Typical FN400 old/new differences were found for both the Side and Question tasks. A three-way repeated measures ANOVA was performed with factors of hemisphere (left and right anterior superior sites), old/new status (hits and correct rejections), and task type (side and question). The ERPs were averaged over the time window of 300–500 ms. In the ANOVA, there was no main effect of hemisphere [$F(1, 22) = 2.013, MSE = 1.747, p = .17$], but accuracy condition [$F(1, 22) = 6.333, MSE = 1.526, p < .05$] and task type [$F(1, 22) = 8.145, MSE = 0.749, p < .01$] effects were significant. Collapsing across hemispheres, voltages for hits ($-2.67\ \mu$V) were more positive than those of correct rejections ($-3.12\ \mu$V), and responses in the S task ($-2.71\ \mu$V) elicited more positive ERPs than in the Q task ($-3.08\ \mu$V). The ANOVA results are summarized in Table 4.6.

In both test tasks, the FN400 did not differentiate correct from incorrect source recognition. We ran an additional three-way repeated measures ANOVA to compare correct rejections and the two types of hits for the same FN400 spatial and temporal regions. This was demonstrated with a

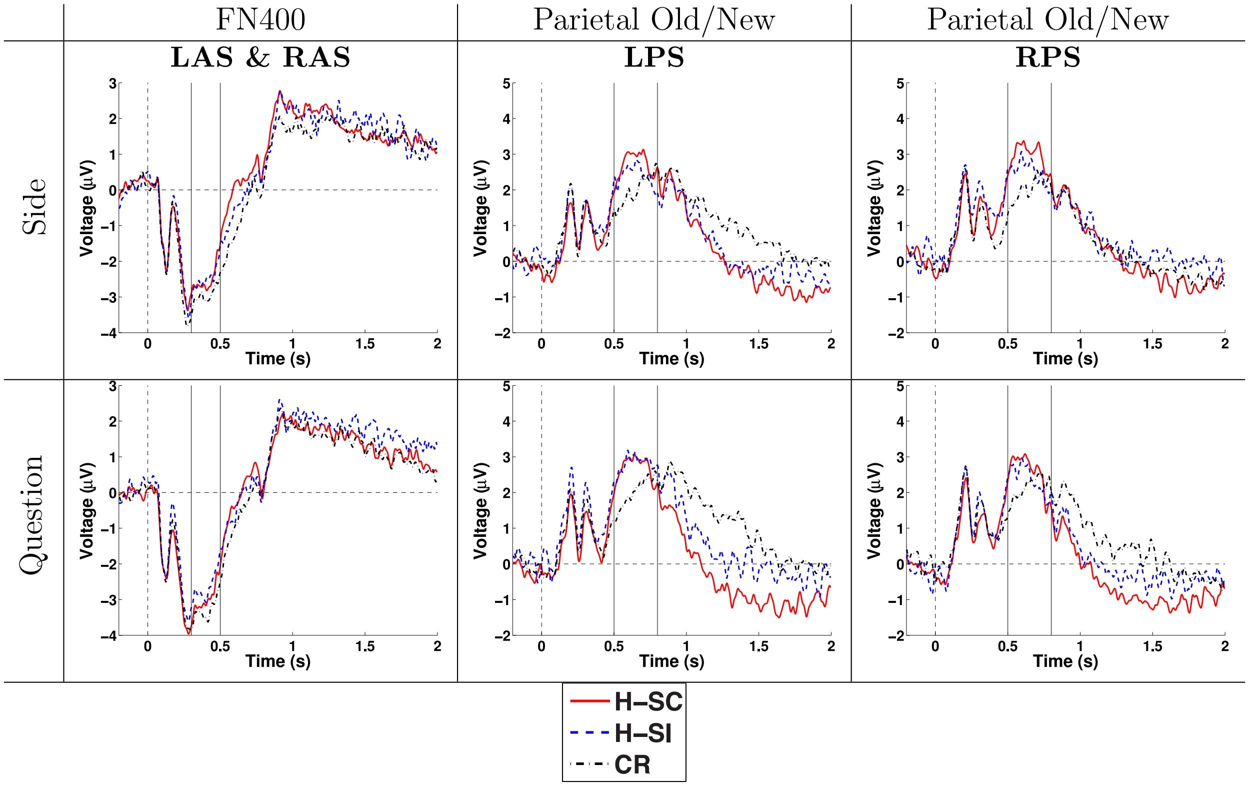

Figure 4.2: Experiment 3: ERP waveforms for the three accuracy conditions of interest. The top row is the Side task and the bottom row is the Question task. The first column of plots is averaged across the left and right anterior-superior ROIs. The next two columns of plots show the left and right posterior-superior ROIs. Hits with correct source (H-SC) are solid red, hits with incorrect source (H-SI) are dashed blue, and correct rejections (CR) are dash-dotted black.

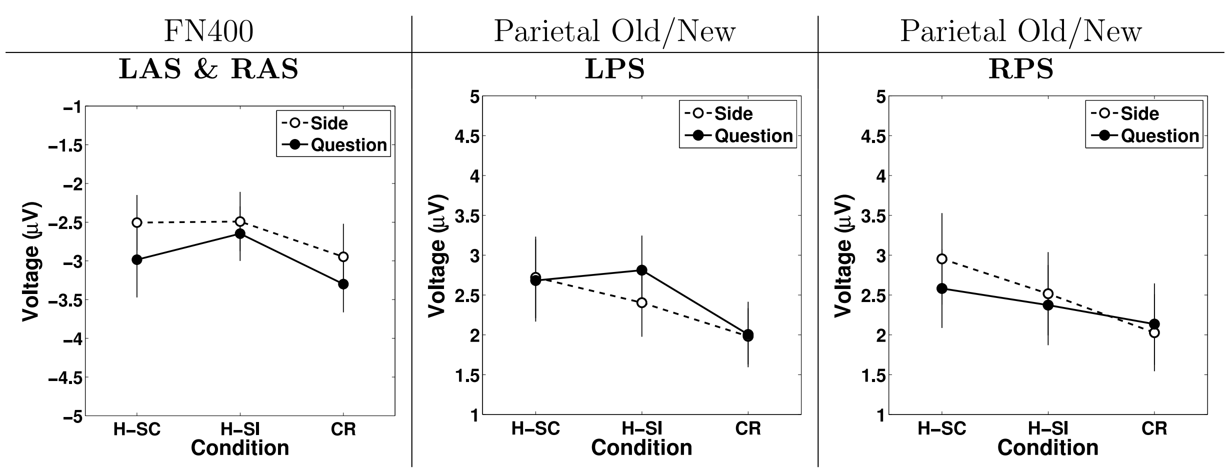

Figure 4.3: Experiment 3: Grand average ERP voltages for the three accuracy conditions of interest; error bars are standard errors. The first plot is averaged across the left and right anterior-superior ROIs. The other two plots show the left and right posterior-superior ROIs. *Notes: H-SC=Hits with Source Correct; H-SI=Hits with Source Incorrect; CR=Correct Rejections.*

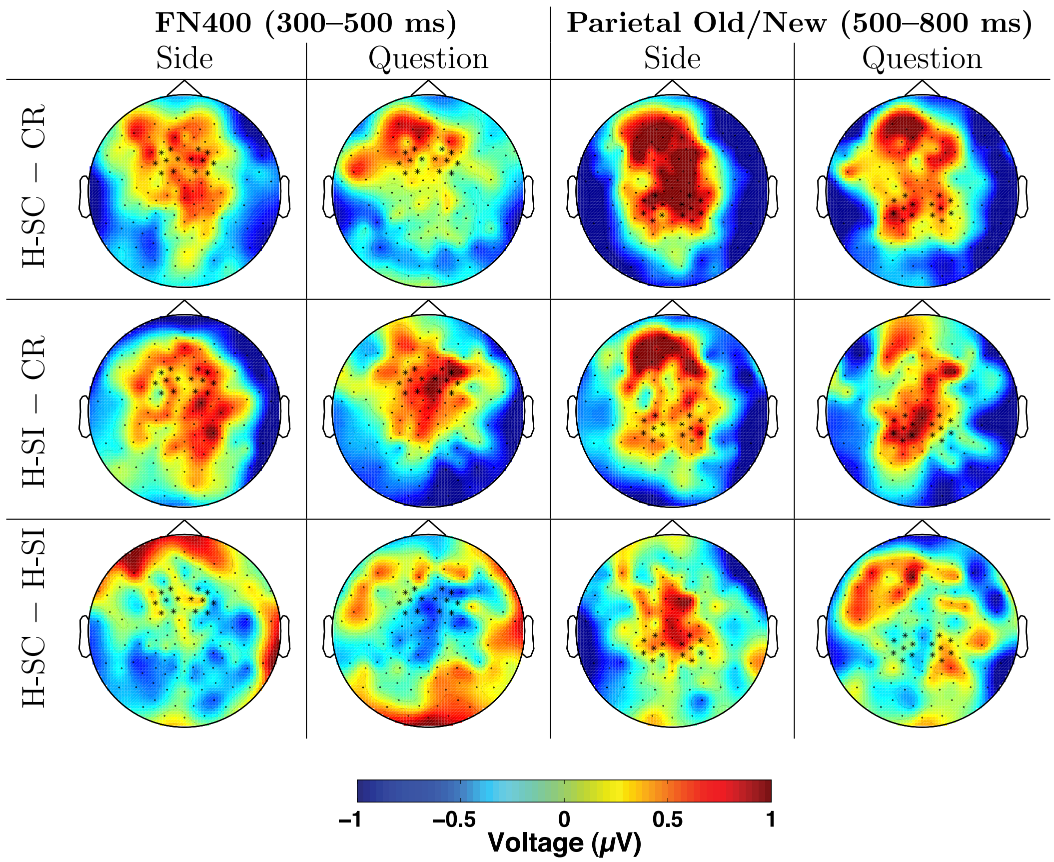

Figure 4.4: Experiment 3: Topographic contrast plots showing the broader distributions of EEG activity. The electrode ROIs in each column are marked with larger asterisks. *Notes: H-SC=Hits with Source Correct; H-SI=Hits with Source Incorrect; CR=Correct Rejections.*

Effect	d.f.	F	M.S.E.	p
Hemisphere	$1, 22$	2.013	1.747	*n.s.*
Hits vs. CRs	$1, 22$	6.333	1.526	$< .05$
Side vs. Question	$1, 22$	8.145	0.749	$< .01$

Table 4.6: Experiment 3: FN400 $2 \times 2 \times 2$ Repeated Measures ANOVA results for item recognition in the two source conditions (300–500 ms, LAS and RAS regions). *Notes: d.f.=degrees of freedom; n.s.=not significant; CR=Correct Rejection.*

Effect	d.f.	F	M.S.E.	p
Hemisphere	$1, 22$	1.553	2.491	$n.s.$
Hits-SC, Hits-SI, CRs	$1.78, 39.27$	3.333	2.474	$= .051$
Side vs. Question	$1, 22$	6.532	1.146	$< .05$

Table 4.7: Experiment 3: FN400 2 × 3 × 2 Repeated Measures ANOVA results comparing hemispheres, accuracy conditions, and the two source conditions (300–500 ms, LAS and RAS regions). *Notes: d.f.=degrees of freedom; n.s.=not significant; SC=Source Correct; SI=Source Incorrect; CR=Correct Rejection.*

hemisphere (left and right posterior superior sites), old/new status (hits with source correct, hits with source incorrect, correct rejections), and task type (S and Q) ANOVA; see Table 4.7. The effect of the source test task was significant with the same pattern as the previous ANOVA (S was more positive than Q) [$F(1, 22) = 6.532, MSE = 1.146, p < .05$]. For the accuracy condition effect, the significance value was just above alpha [$F(1.78, 39.27) = 3.333, MSE = 2.474, p = .051$]. Investigating the differences here showed that while source incorrect responses were more positive (-2.57 μV) than correct rejections (-3.12 μV) [$t(22) = 3.12, p < .01$], hits with source correct (-2.75 μV) did not differ from either of these accuracy conditions.

The parietal old/new effect was not typical in both the Side and Question tasks. We conducted another three-way repeated measures ANOVA to examine the parietal old/new effect (summarized in Table 4.8). The factors here were hemisphere (left and right posterior superior sites), trial accuracy condition (correct rejections, hits with source correct, hits with source incorrect), and task type (side and question). EEG data were averaged over the 500–800 ms time window. Here, only a main effect of accuracy condition was seen [$F(1.87, 41.15) = 3.903, MSE = 3.228, p < .05$], and as with the FN400, the type of source task had no effect on the amplitude of the parietal old/new ERP component. Planned comparisons revealed that ERP voltages for hits with source correct (2.74 μV) were more positive than for correct rejections (2.04 μV) [$t(22) = 2.97, p < .01$]. Unexpectedly, hits with source incorrect responses (2.56 μV) did not differ from either hits with source correct [$t(22) = 0.86, p = .40$] or correct rejections [$t(22) = 1.70, p = .10$].

Effect	d.f.	F	M.S.E.	p
Hemisphere	$1, 22$	0.000	5.026	$n.s.$
Hits-SC, Hits-SI, CRs	$1.87, 41.15$	3.903	3.228	$< .05$
Side vs. Question	$1, 22$	0.000	3.201	$n.s.$

Table 4.8: Experiment 3: Parietal Old/New $2 \times 3 \times 2$ Repeated Measures ANOVA results comparing hemispheres, source recognition success, and the two source conditions (500–800 ms, LPS and RPS regions). *Notes: d.f.=degrees of freedom; n.s.=not significant; SC=Source Correct; SI=Source Incorrect; CR=Correct Rejection.*

4.3 Discussion

Two pieces of evidence from the current experiment suggest that the perceptual side (S) source task was easier to complete than the conceptual question (Q) source task and corroborate with the hypothesis proposed in Experiment 2 (Chapter 3) that the Q task of the second experiment was more difficult than the S task of the first experiment. First, reaction times were faster for remembering presentation side compared to the question answered at study. Shorter reaction times are associated with easier tasks, and more importantly familiarity has been shown to occur earlier than recollection (Hintzman & Curran, 1994). Second, source d' was higher for the S task compared to the Q task. This source d' comparison showed the same pattern as was seen across the first two experiments: d' for remembering side source information in Experiment 1 ($d' = 1.76$) was higher than for remembering the question source of Experiment 2 ($d' = 1.15$). Woroch and Gonsalves (2010) also showed significantly higher source accuracy for a perceptual compared to a conceptual source memory task. Experiments 1 and 2 did not show the reaction time pattern seen in Experiment 3, but this is likely because in the first two experiments old–new judgments were made before source judgments. Additionally, item and source d' were even lower in Experiment 3 and reaction times were higher overall compared to the others. Johnson et al. (1993, p. 5) made a claim that is illuminating regarding the more difficult demands of the current experiment: "Anything that prevents, a person from fully contextualizing information at acquisition (i.e., creating an 'event') will reduce encoding of potentially relevant source information. For example, stress or divided attention may disrupt normal perceptual and reflective processes, resulting in relatively impoverished encoded information from which source could be later derived." It seems likely then that paying attention to and attempting to encode two dimensions of source information is more difficult than one attending to one, and thus the study period encoding task of the present experiment may have been relatively difficult and attention may have been taxed enough to prevent a deep encoding of both dimensions of source information. Despite the increased difficulty compared to the previous experiments, interesting behavioral differences were still found between perceptual and conceptual source monitoring.

Leynes and Phillips (2008) discussed the phenomenon of guessing, and noted that finding a conservative response bias (c) measure shows that people were more likely to guess "new" to an old item (a miss trial) when they were unsure of the source. Thus, the source was either more difficult to encode into memory or was more difficult to retrieve from memory. The present results showed that participants had this conservative bias when tested on question source information, indicating that remembering this type of source was more difficult than remembering side source information. This also supports the idea proposed above and in Chapter 3 that the question task was more difficult than the side task.

When divided by source accuracy, the ERPs were slightly noisy due to the somewhat low number of participants and trial counts, and thus it is difficult to make strong claims about the results regarding electrophysiological differences between the tasks. Overall, the FN400 effect showed the same qualitative patterns as is typically seen for hits and correct rejections, indicating that a familiarity process is working, but there was no differentiation between the two tasks. Regarding the recollection process, if the parietal old/new effect is modulated by the amount of information retrieved (e.g., Vilberg et al., 2006), this may be an explanation for the odd pattern seen above when trials were segmented by source accuracy, which was that hits with correct source responses did not differentiate from those with incorrect source responses. Maybe because the encoding task was difficult (d' values were relatively low), less information was either encoded or recognized than in either of the prior experiments, and thus there was no difference when comparing source correct to source incorrect.

Dividing responses out into RK judgments rather than source accuracy conditions highlighted an interesting effect in this experiment. Examining the behavioral results, it was expected that responses that report feelings of remembering source (RSrc) would be more accurate than responses that report remembering something else (RO) or just having a feeling of familiarity (F), and this is what we found. Importantly, accuracy rates for F and RO responses were both higher for the S task than the Q task and were above chance only in the S task, which shows that feelings of familiarity were able to reliably identify perceptually based source attributes but attempting to remember conceptual source information was no better than guessing randomly.

Chapter 5

General Discussion

The present research tested and supports the hypothesis that familiarity can contribute to successful source recognition. This was observed in both ERPs (Experiment 1) and behavioral results (Experiment 3). In Experiment 1, pictures of objects were encoded as they were presented on one or the other side of a computer display, a perceptual source context. The FN400 ERP component differed between old objects (hits) that had their source correctly recognized and those that had their source incorrectly remembered. This effect shows that in addition to the recollection process, familiarity can reveal when the correct source has been recognized. Experiment 3 combined perceptual and conceptual source dimension encoding and required participants to subsequently remember one or the other. ERP results were relatively substandard due to low numbers in participant and trial counts, but the behavioral results demonstrated familiarity's contribution to perceptual source recognition by showing that responses designating feelings of familiarity had significantly higher accuracy for source judgments when the source was perceptually based than when it was conceptually based. Accuracy was also higher than chance only when source was perceptual. These results further provide some clues regarding the conditions under which familiarity can and cannot contribute to source recognition. When the encoded source information was conceptual in nature, ERP evidence for familiarity based source recognition was not present (Experiment 2), and behavioral evidence of source recognition was weaker than when the source information was perceptually based (Experiment 3). In contrast to the majority of current source memory research, it appears that unitization and/or intrinsic source information is not necessary for familiarity to contribute to source monitoring because it seems unlikely that the perceptual information in the first and third experiments would unitize with or be considered intrinsic properties of the encoded items. Instead, the cases in which familiarity can support source recognition can be broadened to include those in which salient perceptual attributes serve as source information.

To go more in depth, Experiment 1 supports the hypothesis that spatial location is simple and salient perceptually based source information that can be encoded in association with the item. Based on discussion about unitization in other research, the presentation side was probably not encoded as an intrinsic property of the studied items, especially when spatial information has been explicitly described as an extrinsic property (e.g., Ecker et al., 2007a, 2007b). These researchers posit that the intrinsic sensory features of an item (which source information can be encoded as, e.g., an item's surface color) can be used to assess the amount to which the item is familiar, and they specify that being intrinsic to the item is an essential factor in familiarity's processing of the source attributes. When thinking about what might be encoded in Experiment 1, it is important to examine what occurred during the study period. Participants were told that they would need to remember the presentation side for each item, which should automatically make this information relatively salient. Additionally, there was no other task performed during the encoding period, meaning attentional focus would have been on each item and its location. With attention focused in this way, the spatial context was easily associated with the item.

Our results indicate that the relatively simple perceptual nature of the presentation side association was salient enough for familiarity to contribute to its correct identification. Peters and Daum (2009) also showed that the FN400 is sensitive to correct compared to incorrect retrieval of perceptual source information, and though they do not discuss it, it seems that their sources (pictures of scenes, faces, and sounds) are all perceptual in nature and are likely extrinsically associated with the items. Comparable to the results of Experiment 1, these authors showed that source correct trials were more positive than source incorrect trials at frontal sites across a 300–400 ms time window. This provides more support for the idea that familiarity can contribute to the recognition of relatively simple source information and is not limited to remembering only intrinsic properties.

In Experiment 2, we considered a few reasons for why familiarity was not able to contribute to source recognition when the source attributes were conceptually based. First, it is possible that the conceptual source information was not unitized with the item. While the study judgments were based on semantic item information, there is no reason to believe that the type of judgment made would unitize with the item (under the terms in which unitization has been discussed). Evidence for this stems from the experiments in which unitization surely occurred with conceptual source material (e.g., Ford et al., 2010; Haskins et al., 2008; Quamme et al., 2007), but the lack of familiarity effects for non-unitized conceptual sources suggests that unitization is necessary for familiarity to contribute to conceptual source monitoring. Another plausible reason for the null effect is that because every studied and tested item had both a size and an animacy status, the familiarity strength signals (like in a global matching model) produced at test by the recognition process when comparing the items paired with each source did not differentiate enough to be useful. Finally, a third possibility which seems less likely is that though each item was judged on either its size or its animacy status at study, the intermixed judgments led participants to encode the items while thinking about both aspects for each item, and the representation that was later retrieved from memory did not have solid source information associated with it. Whatever the reason for this occurrence, it is clear that familiarity, as indexed by the FN400, does not contribute to conceptual source monitoring, which is an interesting case to compare to the results from Experiment 1.

Experiment 3 seemed to lack the statistical power that the first two experiments had when completing the ERP analyses, and some of the behavioral measures (e.g., d') revealed that encoding both dimensions of source information may have been relatively difficult. Perhaps distributed attentional processing across the two source dimensions prevented familiarity from contributing to successful source monitoring, even when recognizing perceptual source information, or perhaps the low-powered FN400 was not sensitive enough to reflect differences in familiarity processing. Thus, we analyzed the trials based on the subjective response representing the feeling of recognition that participants had; that is, the Remember–Know response type. Critically, source accuracy for responses corresponding to a feeling of familiarity were more accurate for perceptual compared to conceptual source information and were above chance only when remembering perceptual source information and not when remembering conceptual source attributes.

It can be hypothesized that if the trial and participant counts in Experiment 3 were similar to those of the first two experiments, the comparable conditions would show similar ERP results. This remains to be investigated with additional testing. Future experiments should be designed to more precisely delineate the important differences between the conditions in Experiments 1 and 2 such as assessing the effects of overall accuracy, which could either be related to the type of source information encoded during the study period, or is more affected by the difficulty of the encoding task. One of many ways to further investigate the familiarity process would be to force participants to reply more on familiarity during the test period. Speeded responses are thought to induce this behavior because participants have to make a quick judgment, and familiarity is thought to be a relatively early process.

To compare the types of source information used in Experiments 1 and 2, we return to the discussion of modeling evidence introduced in Chapter 1. Elfman et al. (2008) built off of the work by Norman and O'Reilly (2003), integrating the results of behavioral source memory experiments along with dual-process model fits of participant data and complementary-learning-systems model estimates of hippocampal and medial temporal lobe cortex involvement in their perceptually based source memory recognition tasks (source information was screen presentation side). To briefly summarize their results, they showed that correct source information was able to be chosen using what is essentially equivalent to a global matching signal, which they posit is a familiarity-based signal. The model they used stores various features from a study episode in memory. When the authors manipulated the degree of overlap between source details across encoded items, they found that less of an overlap promotes hippocampal involvement (associated with recollection), and an increase in feature overlap leads to less hippocampal involvement and more familiarity-like processing. It seems that the amount that familiarity is involved in recognition decisions in these experiments is determined by the extent to which features of a test item match the initially encoded features. In terms of the work presented here, the present Experiment 1 (see Chapter 2) could be considered to have a high degree of overlap where there were only two source features to encode in addition to the item features. On the other hand, source information in Experiment 2 (see Chapter 3) was richer and the dimensions had more differentiation between them. Two possibilities for familiarity's increased involvement when there is more feature overlap are that either the recollection process is acting more like familiarity in that it uses a graded signal-detection distribution, or that an actual familiarity process is more useful. The present results support and extend the latter possibility because Experiment 1 revealed a FN400 effect that differentiates between whether perceptual source information was correctly identified.

Related to the discussion of FN400 old/new effect is the issue of conceptual priming, which was briefly discussed in Chapter 1 (e.g., Paller et al., 2007). The results of the present experiments, especially Experiment 1, do not support the idea that the FN400 reflects conceptual priming. In the first experiment, a conceptual priming process should not be able to differentiate sources that are defined perceptually because conceptual priming, by definition, should be perceptually insensitive (as was also seen in Groh-Bordin et al., 2006). With respect to Experiment 2, if a conceptual priming process was active and reflected by the FN400, it seems that it would have occurred for remembering the correct conceptual source information but not for getting the source information incorrect. Here, we would have expected to see an FN400 ERP voltage difference between hits with correct source identification to hits with incorrect source identification. However, we did not see a FN400 effect in Experiment 2 for correct versus incorrect source recognition. Thus, our results do not support a link between the FN400 and conceptual priming and add to the recent results by Stenberg et al. (2009) and Stenberg et al. (2010).

In light of the present results, can we conclude that familiarity contributes to source monitoring? If we rely on several measures thought to index familiarity across these experiments (that is, the FN400 in Experiment 1 and the source accuracy results of "Familiar" judgments in Experiment 3) and on results and theories from the source memory literature, the answer seems to be that yes, familiarity can certainly lend a hand in source recognition. What still seems unanswered is exactly when this effect occurs. Examining results from the prior experiments introduced in Chapter 1, the consensus was that unitization must occur between an item and its source for familiarity to be involved in source recognition. However, Experiment 1 demonstrates that familiarity may be able to help with non-unitized source information. Despite this discrepancy, there are hypotheses for what might be occurring. As we have seen, it could be the case that familiarity only supports source monitoring when the source information is perceptual and is relatively easy to access, as source accuracy was quite high in Experiment 1, and was relatively low in Experiment 2. Source accuracy in Experiment 3 was even lower, meaning the task was more difficult, but source accuracy for items judged to be familiar in the perceptual source task was higher than that of the conceptual task, and source accuracy was above chance in the perceptual task while it was not in the conceptual task. Thus, in addition to the cases of unitization from past research, the results of these experiments show that the familiarity process also contributes to source recognition when the information is perceptually based and is particularly salient.

References

Aggleton, J. P., & Brown, M. W. (1999). Episodic memory, amnesia, and the hippocampal-anterior thalamic axis. Behavioral and Brain Sciences, 22(3), 425–444; discussion 444–489.

Aggleton, J. P., Vann, S. D., Denby, C., Dix, S., Mayes, A. R., Roberts, N., et al. (2005). Sparing of the familiarity component of recognition memory in a patient with hippocampal pathology. Neuropsychologia, 43(12), 1810–1823.

Allan, K., Wilding, E. L., & Rugg, M. D. (1998). Electrophysiological evidence for dissociable processes contributing to recollection. Acta Psychologica, 98(2-3), 231–252.

Brady, T. F., Konkle, T., Alvarez, G. A., & Oliva, A. (2008). Visual long-term memory has a massive storage capacity for object details. Proceedings of the National Academy of Sciences of the United States of America, 105(38), 14325–14329.

Cabeza, R., Locantore, J. K., & Anderson, N. D. (2003). Lateralization of prefrontal activity during episodic memory retrieval: evidence for the production-monitoring hypothesis. Journal of Cognitive Neuroscience, 15(2), 249–259.

Cansino, S., Maquet, P., Dolan, R. J., & Rugg, M. D. (2002). Brain activity underlying encoding and retrieval of source memory. Cerebral Cortex, 12(10), 1048–1056.

Clark, S., & Gronlund, S. (1996). Global matching models of recognition memory how the models match the data. Psychonomic Bulletin and Review, 3, 37–60.

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. Journal of Verbal Learning & Verbal Behavior, 11(6), 671–684.

Cruse, D., & Wilding, E. L. (2009). Prefrontal cortex contributions to episodic retrieval monitoring and evaluation. Neuropsychologia, 47(13), 2779–2789.

Curran, T. (2000). Brain potentials of recollection and familiarity. Memory and Cognition, 28(6), 923–938.

Curran, T. (2004). Effects of attention and confidence on the hypothesized ERP correlates of recollection and familiarity. Neuropsychologia, 42(8), 1088–1106.

Curran, T., & Cleary, A. M. (2003). Using ERPs to dissociate recollection from familiarity in picture recognition. Cognitive Brain Research, 15(2), 191–205.

Curran, T., DeBuse, C., & Leynes, P. A. (2007). Conflict and criterion setting in recognition memory. Journal of Experimental Psychology. Learning, Memory, and Cognition, 33(1), 2–17.

Curran, T., DeBuse, C., Woroch, B., & Hirshman, E. (2006). Combined pharmacological and electrophysiological dissociation of familiarity and recollection. Journal of Neuroscience, 26(7), 1979–1985.

Curran, T., & Dien, J. (2003). Differentiating amodal familiarity from modality-specific memory processes: an ERP study. Psychophysiology, 40(6), 979–988.

Curran, T., & Friedman, W. J. (2004). ERP old/new effects at different retention intervals in recency discrimination tasks. Cognitive Brain Research, 18(2), 107–120.

Curran, T., & Hancock, J. (2007). The FN400 indexes familiarity-based recognition of faces. NeuroImage, 36(2), 464–471.

Curran, T., Tepe, K. L., & Piatt, C. (2006). Event-related potential explorations of dual processes in recognition memory. In H. D. Zimmer, A. Mecklinger, & U. Lindenberger (Eds.), Binding in human memory: A neurocognitive approach (pp. 467–492). New York: Oxford University Press.

Diana, R. A., Yonelinas, A. P., & Ranganath, C. (2007). Imaging recollection and familiarity in the medial temporal lobe: a three-component model. Trends in Cognitive Sciences, 11(9), 379–386.

Diana, R. A., Yonelinas, A. P., & Ranganath, C. (2008). The effects of unitization on familiarity-based source memory: testing a behavioral prediction derived from neuroimaging data. Journal of Experimental Psychology. Learning, Memory, and Cognition, 34(4), 730–40.

Diana, R. A., Yonelinas, A. P., & Ranganath, C. (2010). Medial temporal lobe activity during source retrieval reflects information type, not memory strength. Journal of Cognitive Neuroscience, 22(8), 1808–1818.

Dien, J. (1998). Issues in the application of the average reference: Review, critiques, and recommendations. Behavior Research Methods, Instruments, and Computers, 30(1), 34–43.

Dien, J. (2010). The ERP PCA Toolkit: an open source program for advanced statistical analysis of event-related potential data. Journal of Neuroscience Methods, 187(1), 138–145.

Duarte, A., Ranganath, C., & Knight, R. T. (2005). Effects of unilateral prefrontal lesions on familiarity, recollection, and source memory. Journal of Neuroscience, 25(36), 8333–8337.

Duarte, A., Ranganath, C., Winward, L., Hayward, D., & Knight, R. T. (2004). Dissociable neural correlates for familiarity and recollection during the encoding and retrieval of pictures. Brain Research. Cognitive Brain Research, 18(3), 255–272.

Düzel, E., Vargha-Khadem, F., Heinze, H. J., & Mishkin, M. (2001). Brain activity evidence for recognition without recollection after early hippocampal damage. Proceedings of the National Academy of Sciences of the United States of America, 98(14), 8101–8106.

Düzel, E., Yonelinas, A. P., Mangun, G. R., Heinze, H. J., & Tulving, E. (1997). Event-related brain potential correlates of two states of conscious awareness in memory. Proceedings of the National Academy of Sciences of the United States of America, 94(11), 5973–5978.

Ecker, U. K. H., Zimmer, H. D., & Groh-Bordin, C. (2007a). Color and context: an ERP study on intrinsic and extrinsic feature binding in episodic memory. Memory and Cognition, 35(6), 1483–1501.

Ecker, U. K. H., Zimmer, H. D., & Groh-Bordin, C. (2007b). The influence of object and background color manipulations on the electrophysiological indices of recognition memory. Brain Research, 1185, 221–230.

Eichenbaum, H., Yonelinas, A. P., & Ranganath, C. (2007). The medial temporal lobe and recognition memory. Annual Review of Neuroscience, 30, 123–152.

Elfman, K. W., Parks, C. M., & Yonelinas, A. P. (2008). Testing a neurocomputational model of recollection, familiarity, and source recognition. Journal of Experimental Psychology. Learning, Memory, and Cognition, 34(4), 752–768.

Ford, J. H., Verfaellie, M., & Giovanello, K. S. (2010). Neural correlates of familiarity-based associative retrieval. Neuropsychologia, 48(10), 3019–3025.

Gallo, D. A., McDonough, I. M., & Scimeca, J. (2010). Dissociating source memory decisions in the prefrontal cortex: fMRI of diagnostic and disqualifying monitoring. Journal of Cognitive Neuroscience, 22(5), 955–969.

Giovanello, K. S., Keane, M. M., & Verfaellie, M. (2006). The contribution of familiarity to associative memory in amnesia. Neuropsychologia, 44(10), 1859–1865.

Greenhouse, S., & Geisser, S. (1959). On methods in the analysis of profile data. Psychometrika, 24(2), 95–112.

Groh-Bordin, C., Zimmer, H. D., & Ecker, U. K. H. (2006). Has the butcher on the bus dyed his hair? When color changes modulate ERP correlates of familiarity and recollection. NeuroImage, 32(4), 1879–1890.

Groh-Bordin, C., Zimmer, H. D., & Mecklinger, A. (2005). Feature binding in perceptual priming and in episodic object recognition: evidence from event-related brain potentials. Brain Research. Cognitive Brain Research, 24(3), 556–567.

Gruber, T., Tsivilis, D., Giabbiconi, C.-M., & Müller, M. M. (2008). Induced electroencephalogram oscillations during source memory: Familiarity is reflected in the gamma band, recollection in the theta band. Journal of Cognitive Neuroscience, 20(6), 1043–1053.

Haskins, A. L., Yonelinas, A. P., Quamme, J. R., & Ranganath, C. (2008). Perirhinal cortex supports encoding and familiarity-based recognition of novel associations. Neuron, 59(4), 554–560.

Hayama, H. R., Johnson, J. D., & Rugg, M. D. (2008). The relationship between the right frontal old/new ERP effect and post-retrieval monitoring: specific or non-specific? Neuropsychologia, 46(5), 1211–1223.

Hicks, J. L., Marsh, R. L., & Ritschel, L. (2002). The role of recollection and partial information in source monitoring. Journal of Experimental Psychology. Learning, Memory, and Cognition, 28(3), 503–508.

Hicks, J. L., & Starns, J. J. (2006). Remembering source evidence from associatively related items: explanations from a global matching model. Journal of Experimental Psychology. Learning, Memory, and Cognition, 32(5), 1164–1173.

Hintzman, D. L., & Curran, T. (1994). Retrieval dynamics of recognition and frequency judgments: Evidence for separate processes of familiarity and recall. Journal of Memory and Language, 33(1), 1–18.

Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. Journal of Memory and Language, 30(5), 513–541.

Jäger, T., Mecklinger, A., & Kipp, K. H. (2006). Intra- and inter-item associations doubly dissociate the electrophysiological correlates of familiarity and recollection. Neuron, 52(3), 535–545.

Janowsky, J. S., Shimamura, A. P., & Squire, L. R. (1989). Source memory impairment in patients with frontal lobe lesions. Neuropsychologia, 27(8), 1043–1056.

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

Kahn, I., Davachi, L., & Wagner, A. D. (2004). Functional-neuroanatomic correlates of recollection: implications for models of recognition memory. Journal of Neuroscience, 24(17), 4172–80.

Klimesch, W., Doppelmayr, M., Yonelinas, A. P., Kroll, N. E., Lazzara, M., Röhm, D., et al. (2001). Theta synchronization during episodic retrieval: neural correlates of conscious awareness. Brain Research. Cognitive Brain Research, 12(1), 33–38.

Leynes, P. A., & Phillips, M. C. (2008). Event-related potential (ERP) evidence for varied recollection during source monitoring. Journal of Experimental Psychology. Learning, Memory, and Cognition, 34(4), 741–751.

Lucas, H. D., Voss, J. L., & Paller, K. A. (2010). Familiarity or Conceptual Priming? Good Question!: Comment on Stenberg, Hellman, Johansson, and Rosén (2009). Journal of Cognitive Neuroscience, 22(4), 615–617.

Macmillan, N. A., & Creelman, C. D. (2005). Detection theory: A user's guide. Mahwah, NJ: Lawrence Erlbaum Associates.

Mecklinger, A. (2006). Electrophysiological measures of familiarity memory. Clinical EEG and Neuroscience, 37(4), 292–299.

Mecklinger, A., Johansson, M., Parra, M., & Hanslmayr, S. (2007). Source-retrieval requirements influence late ERP and EEG memory effects. Brain Research, 1172, 110–23.

Mitchell, K. J., & Johnson, M. K. (2009). Source monitoring 15 years later: What have we learned from fMRI about the neural mechanisms of source memory? Psychological Bulletin, 135(4), 638–77.

Montaldi, D., Spencer, T. J., Roberts, N., & Mayes, A. R. (2006). The neural system that mediates familiarity memory. Hippocampus, 16(5), 504–520.

Murnane, K., & Bayen, U. J. (1996). An evaluation of empirical measures of source identification. Memory and Cognition, 24(4), 417–428.

Norman, K. A., & O'Reilly, R. C. (2003). Modeling hippocampal and neocortical contributions to recognition memory: a complementary-learning-systems approach. Psychological Review, 110(4), 611–646.

O'Reilly, R. C., Busby, R. S., & Soto, R. (2003). Three forms of binding and their neural substrates: Alternatives to temporal synchrony. In A. Cleeremans (Ed.), The unity of consciousness: Binding, integration, and dissociation (pp. 168–192). New York: Oxford University Press.

Paller, K. A., Voss, J. L., & Boehm, S. G. (2007). Validating neural correlates of familiarity. Trends in Cognitive Sciences, 11(6), 243–250.

Parks, C. M., & Yonelinas, A. P. (2007). Moving beyond pure signal-detection models: Comment on Wixted (2007). Psychological Review, 114(1), 188–201.

Peters, J., & Daum, I. (2009). Frontal but not parietal positivity during source recollection is sensitive to episodic content. Neuroscience Letters, 454(3), 182–186.

Quamme, J. R., Yonelinas, A. P., & Norman, K. A. (2007). Effect of unitization on associative recognition in amnesia. Hippocampus, 17(3), 192–200.

Ranganath, C., Yonelinas, A. P., Cohen, M. X., Dy, C. J., Tom, S. M., & D'Esposito, M. (2003). Dissociable correlates of recollection and familiarity within the medial temporal lobes. Neuropsychologia, 42(1), 2–13.

Ratcliff, R., Van Zandt, T., & McKoon, G. (1995). Process dissociation, single-process theories, and recognition memory. Journal of Experimental Psychology. General, 124(4), 352–374.

Rhodes, S. M., & Donaldson, D. I. (2007). Electrophysiological evidence for the influence of unitization on the processes engaged during episodic retrieval: enhancing familiarity based remembering. Neuropsychologia, 45(2), 412–424.

Rugg, M. D., & Curran, T. (2007). Event-related potentials and recognition memory. Trends in Cognitive Sciences, 11(6), 251–257.

Rugg, M. D., Fletcher, P. C., Chua, P. M., & Dolan, R. J. (1999). The role of the prefrontal cortex in recognition memory and memory for source: an fMRI study. NeuroImage, 10(5), 520–529.

Rugg, M. D., Schloerscheidt, A. M., & Mark, R. E. (1998). An electrophysiological comparison of two indices of recollection. Journal of Memory and Language, 39(1), 47–69.

Scoville, W. B., & Milner, B. (1957). Loss of recent memory after bilateral hippocampal lesions. Journal of Neurology, Neurosurgery, and Psychiatry, 20(1), 11–21.

Senkfor, A. J., & Van Petten, C. (1998). Who said what? An event-related potential investigation of source and item memory. Journal of Experimental Psychology. Learning, Memory, and Cognition, 24(4), 1005–1025.

Skinner, E. I., & Fernandes, M. A. (2007). Neural correlates of recollection and familiarity: a review of neuroimaging and patient data. Neuropsychologia, 45(10), 2163–2179.

Smith, M. (1993). Neurophysiological manifestations of recollective experience during recognition memory judgments. Journal of Cognitive Neuroscience, 5(1), 1–13.

Speer, N. K., & Curran, T. (2007). ERP correlates of familiarity and recollection processes in visual associative recognition. Brain Research, 1174, 97–109.

Squire, L. R., Wixted, J. T., & Clark, R. E. (2007). Recognition memory and the medial temporal lobe: A new perspective. Nature Reviews. Neuroscience, 8(11), 872–883.

Staresina, B. P., & Davachi, L. (2006). Differential encoding mechanisms for subsequent associative recognition and free recall. Journal of Neuroscience, 26(36), 9162–9172.

Staresina, B. P., & Davachi, L. (2008). Selective and shared contributions of the hippocampus and perirhinal cortex to episodic item and associative encoding. Journal of Cognitive Neuroscience, 20(8), 1478–1489.

Stenberg, G., Hellman, J., Johansson, M., & Rosén, I. (2009). Familiarity or conceptual priming: event-related potentials in name recognition. Journal of Cognitive Neuroscience, 21(3), 447–460.

Stenberg, G., Johansson, M., Hellman, J., & Rosén, I. (2010). "Do You See Yonder Cloud?"—On Priming Concepts, A New Test and a Familiar Outcome. Reply to Lucas et al.: "Familiarity or Conceptual Priming? Good Question! Comment on Stenberg, Hellman, Johansson, and Rosén (2009)". Journal of Cognitive Neuroscience, 22(4), 618–620.

Tsivilis, D., Otten, L. J., & Rugg, M. D. (2001). Context effects on the neural correlates of recognition memory: an electrophysiological study. Neuron, 31(3), 497–505.

Tucker, D. M. (1993). Spatial sampling of head electrical fields: the geodesic sensor net. Electroencephalography and Clinical Neurophysiology, 87(3), 154–163.

Unsworth, N., & Brewer, G. A. (2009). Examining the relationships among item recognition, source recognition, and recall from an individual differences perspective. Journal of Experimental Psychology. Learning, Memory, and Cognition, 35(6), 1578–1585.

Vilberg, K. L., Moosavi, R. F., & Rugg, M. D. (2006). The relationship between electrophysiological correlates of recollection and amount of information retrieved. Brain Research, 1122(1), 161–170.

Vilberg, K. L., & Rugg, M. D. (2008). Memory retrieval and the parietal cortex: a review of evidence from a dual-process perspective. Neuropsychologia, 46(7), 1787–1799.

Wais, P. E., Squire, L. R., & Wixted, J. T. (2010). In search of recollection and familiarity signals in the hippocampus. Journal of Cognitive Neuroscience, 22(1), 109–123.

Wilding, E. L. (1999). Separating retrieval strategies from retrieval success: An event-related potential study of source memory. Neuropsychologia, 37(4), 441–454.

Wilding, E. L. (2000). In what way does the parietal ERP old/new effect index recollection? International Journal of Psychophysiology, 35(1), 81–87.

Wilding, E. L., Doyle, M. C., & Rugg, M. D. (1995). Recognition memory with and without retrieval of context: an event-related potential study. Neuropsychologia, 33(6), 743–767.

Wilding, E. L., & Rugg, M. D. (1996). An event-related potential study of recognition memory with and without retrieval of source. Brain, 119, 889–905.

Wilding, E. L., & Rugg, M. D. (1997). Event-related potentials and the recognition memory exclusion task. Neuropsychologia, 35(2), 119–128.

Wixted, J. T. (2007). Dual-process theory and signal-detection theory of recognition memory. Psychological Review, 114(1), 152–176.

Wixted, J. T., & Squire, L. R. (2010). The role of the human hippocampus in familiarity-based and recollection-based recognition memory. Behavioural Brain Research, 215(2), 197–208.

Woroch, B., & Gonsalves, B. D. (2010). Event-related potential correlates of item and source memory strength. Brain Research, 1317C, 180–191.

Yonelinas, A. P. (1999). The contribution of recollection and familiarity to recognition and source-memory judgments: A formal dual-process model and an analysis of receiver operating characteristics. Journal of Experimental Psychology. Learning, Memory, and Cognition, 25(6), 1415–1434.

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. Journal of Memory and Language, 46(3), 441–517.

Yonelinas, A. P., & Jacoby, L. L. (1996). Noncriterial recollection: familiarity as automatic, irrelevant recollection. Consciousness and Cognition, 5(1–2), 131–141.

Yonelinas, A. P., Kroll, N. E., Dobbins, I. G., & Soltani, M. (1999). Recognition memory for faces: when familiarity supports associative recognition judgments. Psychonomic Bulletin and Review, 6(4), 654–661.

Yonelinas, A. P., Otten, L. J., Shaw, K. N., & Rugg, M. D. (2005). Separating the brain regions involved in recollection and familiarity in recognition memory. Journal of Neuroscience, 25(11), 3002–3008.

Yonelinas, A. P., Quamme, J. R., Widaman, K. F., Kroll, N. E. A., Sauvé, M. J., & Knight, R. T. (2004). Mild hypoxia disrupts recollection, not familiarity. Cognitive, Affective, and Behavioral Neuroscience, 4(3), 393–400.

Yovel, G., & Paller, K. A. (2004). The neural basis of the butcher-on-the-bus phenomenon: when a face seems familiar but is not remembered. NeuroImage, 21(2), 789–800.

Zimmer, H. D., & Ecker, U. K. H. (2010). Remembering perceptual features unequally bound in object and episodic tokens: Neural mechanisms and their electrophysiological correlates. Neuroscience and Biobehavioral Reviews, 34(7), 1066–1079.