DISSERTATION

USING A CHANGE-DETECTION TASK TO SIMULATE DIVIDED PERCEPTION AND ITS EFFECTS ON RECOGNITION MEMORY FOR OBJECTS

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY BOGDAN KOSTIC ENTITLED USING A CHANGE-DETECTION TASK TO SIMULATE DIVIDED PERCEPTION AND ITS EFFECTS ON RECOGNITION MEMORY FOR OBJECTS BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

USING A CHANGE-DETECTION TASK TO SIMULATE DIVIDED PERCEPTION AND ITS EFFECTS ON RECOGNITION MEMORY FOR OBJECTS

Déjà vu is defined as high levels of familiarity for objects or situations that are objectively unfamiliar. One theory of déjà vu is that objects viewed under conditions of divided perception can later evoke familiarity. The present study examined whether a change detection task could simulate divided perception and affect later recognition memory performance for changed items. Participants viewed a study list in which one version of a scene alternated once with another version of the same scene, but with one item missing. Participants attempted to determine the location of the change. On a subsequent test list, participants viewed items from the scenes in isolation and made recognition judgments on them. Across five experiments, this task was used to determine how detection status affected familiarity ratings, how stimulus characteristics affect familiarity ratings, and what recognition processes (i.e., recollection and familiarity) drive recognition decisions for undetected items. Overall, these experiments show that simulated conditions of divided perception do affect recognition memory, which is a first step towards investigating déjà vu directly.

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Introduction

A recognition decision is a judgment of prior occurrence—it is determining whether an item or event had been encountered before (Mandler, 1980). Dual-process theories of recognition memory (Yonelinas, 2002) state that recognition can take place by way of two separate processes: recollection and familiarity. Recollection is the act of bringing to mind specific details about an event. For example, on encountering a person on the street, recalling an instance when that person had been encountered before would help one to determine that the person is an acquaintance. Familiarity is the general feeling one gets that something or someone was encountered before, potentially in the absence of any specific details. On meeting the hypothetical person on the street, even if one cannot recall meeting the person before, the person could be recognized on the basis of just "seeming very familiar."

Déjà vu is a phenomenon characterized by very strong feelings of having been somewhere or done something before, despite evidence to the contrary (Brown, 2004). Some evidence suggests that déjà vu may represent a type of familiarity-based recognition (e.g., Cleary, 2008; Cleary, Ryals & Nomi, 2009).

The purpose of this study is to evaluate the Divided Perception theory of déjà vu by simulating divided perception with the change blindness phenomenon, then measuring familiarity and recognition memory performance for undetected items. There are established laboratory paradigms for studying familiarity, whereas the study of déjà vu in laboratory settings is relatively new. Therefore, a first step toward investigating theories of déjà vu is to investigate whether they apply to familiarity. This approach has been used by other researchers interested in the study of déjà vu (e.g., Brown & Marsh, 2008, 2009).

First, the introduction will review some of the main findings in the area of familiarity-based recognition, and describe how they relate to the déjà vu experience. There will also be a description of the Divided Perception theory of déjà vu, and how it can be tested using existing methods of studying familiarity. Then, in relation to the Divided Perception theory, there will be a section reviewing the findings and theory behind the change blindness phenomenon, focusing on the influence of change detection on later recognition memory. This section will argue that the change-blindness phenomenon presents a means of investigating the Divided Perception theory. Data from five experiments will explore recognition memory performance for items that were or were not detected in a change detection task. The General Discussion will include discussions of what these results mean for change blindness and recognition memory, and their implications for the Divided Perception Theory of déjà vu.

Familiarity and Recognition Memory

In order to examine the role of familiarity in recognition memory, one must isolate familiarity processes from recollection processes. One method of doing this is by using the recognition-without-identification (RWI) paradigm (e.g., Cleary & Greene, 2000; Peynircioglu, 1990). The RWI effect is the finding that participants' familiarity ratings discriminate between old and new stimuli even when participants cannot say what those stimuli are. An example of the procedure starts with participants studying a list of words. A test list immediately follows, in which word fragments appear. Half of the word fragments correspond to studied words, and the other half correspond to unstudied words. After each word fragment appears, participants are asked to attempt to complete the word fragment and then rate its familiarity (i.e., the likelihood that the word fragment corresponds to a studied word). Typical results are that familiarity ratings are significantly higher for studied words than unstudied words, even when participants cannot successfully identify the word fragment. This basic effect has been demonstrated using written words (Cleary & Greene, 2001; Cleary, 2004), spoken words (Cleary, Winfield, & Kostic, 2007), music (Kostic & Cleary, 2009), line drawings (Cleary, Langley, & Seiler, 2004), scenes (Cleary & Reyes, 2009), and analogical relationships (Kostic, Cleary, Severin, & Miller, 2010). Cleary and Greene (2000) performed a "reverse" modification of this procedure in which participants identify word fragments at study rather than test, and participants then attempt to discriminate, via familiarity ratings, between whole test words that appeared as fragments at study and whole test words that did not. RWI in this case is the finding that among test words whose fragments went unidentified at study, ratings are higher at test than for words whose fragments were not studied.

One of the uses of the RWI paradigm is to determine what features of stimuli can be used in familiarity-based recognition decisions. In Cleary's (2004) study, participants received a series of words at study and then test words that shared a common orthography with the study words, but different meanings (e.g., Cheetoh and Cheetah). Even when participants could not recall the similarly-spelled words from study, the test words that orthographically resembled studied words received higher familiarity ratings. Similar findings occurred for test words that shared common phonologies with study words but different orthographies (e.g., Eighty and Lady) as well as test words that shared common meanings with study words but different orthographies and phonologies (e.g., Cheetah and Jaguar). These findings revealed some of the features of words that drive familiarity. The same basic procedure revealed that phoneme features drive familiarity in spoken words (Cleary et al., 2007), geon features drive familiarity in line drawings (Cleary et al., 2004), pitch and rhythm drive familiarity in music (Kostic & Cleary, 2009), and analogical resemblance drives familiarity in word pairs (Kostic et al., 2010).

Another paradigm that has been used to study recollection and familiarity is the Remember-Know procedure (Tulving, 1985). In this procedure, participants provide "Remember" or "Know" responses to items on a recognition memory test. Remember responses indicate recollection of the study episode, while Know responses indicate a sense of familiarity for the item without any accompanying recollection. Tulving showed that participants can understand the distinction and use the terms to report their different bases of recognition decisions. Although one of the major criticisms of this approach is that Remember and Know responses are fundamentally subjective, Gardiner (2001) argues that these responses are still useful to science because their accuracy can be compared against objective recognition decisions. Gardiner also argues that some independent variables (such as levels of processing) affect remembering but not knowing, and other variables (such as study and test modalities) affect knowing but not remembering. Gardiner claims that these results show that the measures are independent and can be experimentally manipulated in different ways, in spite of the fact they are subjective assessments. Diana, Reder, Arndt, and Park (2006) also report a number of dissociations between Remember and Know, and Yonelinas (2002) reported that process dissociations procedures (e.g., Jacoby, 1991) produce proportions of recollection- and familiarity-based responses comparable to what is found using Remember-Know. In other words, the subjective nature of Remember-Know responses were verified with objective measures.

Déjà vu

Cleary (2008) argues that feelings of familiarity in recognition decisions are an integral part of the déjà vu experience. Déjà vu is a commonly-used term, but the nature of this experience is somewhat unclear. Titchener (1928) writes "Most of us, probably, have an occasional acquaintance with what is called paramnesia or wrong recognition: a definite 'feeling that all this has happened before,'…in spite of the fact and the knowledge that the experience is novel" (p. 187). Currently, there is relatively little research on déjà vu in psychology, but when déjà vu is discussed it is often described as an inappropriate feeling of familiarity in a situation that is objectively unfamiliar or new (Brown, 2003, 2004). An example of this would be visiting a foreign country for the first time and feeling as though one had been there before. There are many possibilities for why déjà vu occurs, with the most likely possibility being that déjà vu is a product of recognition memory processes (Cleary, 2008). Brown (2004) states that there is currently no procedure that has been shown to reliably evoke full-blown déjà vu experiences, and that such a procedure may never exist (although see Kovacs et al., 2009, for a possible exception). However, what can be done is to set up conditions like those proposed in different theories and determine whether feelings of familiarity vary in accordance with theory. Because there are established laboratory paradigms for studying feelings of familiarity, testing the effect of various manipulations on familiarity is likely a more productive (if less direct) method of studying déjà vu. Nevertheless, it has been suggested that déjà vu experiences likely range from brief and weak to persistent and strong (Sno, Schalken, & de Jonghe, 1992), so increases in familiarity could perhaps be seen as a type of weak déjà vu experience.

In spite of the fact that déjà vu is poorly understood, there is evidence that the experiences are relatively common. In a review, Brown (2003) reports survey data showing the following characteristics of déjà vu experiences: Two-thirds of people have experienced déjà vu at least once in their lives, and people who have experienced it at least once tend to experience it more than once. A normal experience lasts several seconds. Rates of occurrence vary across individuals; some people experience déjà vu only several times throughout their lives, while other people experience déjà vu several times each month or week. Déjà vu experiences are more common in people with higher levels of education and income. There are no consistent gender differences, although rates of déjà vu do vary across the lifespan. Specifically, the frequency of déjà vu experiences decreases in older adults, but déjà vu experiences are also less common for adults younger than 20.

Déjà vu and familiarity

If a déjà vu experience is characterized by a feeling of familiarity for something that is objectively new, there are a number of recognition memory procedures that produce similar effects. Jacoby, Woloshyn, and Kelley (1989) demonstrated how to make a name "become famous" by manipulating familiarity. Jacoby et al. presented participants with a list of nonfamous names (e.g., Sebastian Weisdorf) under full or divided attention, and later presented participants with another list of names in which both famous and nonfamous names appeared. Some of the nonfamous names appeared earlier, and some were "new" nonfamous names. For each name, participants were asked to judge whether the name was famous or not (as a gauge of familiarity) and also to indicate whether each name on the test list appeared on the study list (a recognition decision). This procedure lead participants to provide more fame judgments for nonfamous names that were presented earlier compared to nonfamous names that did not appear earlier. Also, conditions of divided attention caused participants to be less accurate in their recognition decisions, but fame judgments (familiarity) were not affected. In sum, the fact that nonfamous names can be judged as famous provides one example of how objectively new things can appear familiar in situations when they should not.

Another study relevant to déjà vu is Jacoby and Whitehouse (1989). In several experiments, participants saw a list of study words. Participants later saw a test list in which half the words were studied and half were unstudied, and every test word was preceded by a context word which was either a matching (same) word or a mismatching (different) word. There was also a baseline condition, in which the symbol “xoxoxox” appeared in place of a context word. Finally, presentation duration of the context word/baseline symbol varied as to be fast or slow so that participants would be unaware or aware, respectively, that something appeared before the test word. Participants were simply asked to categorize each word as “old” or “new,” depending on whether it appeared in the study list. Their results were that fast presentation of matching context words lead participants to call new words “old” more often, but the opposite is true for slow presentation of matching context words. Jacoby and Whitehouse interpreted this as showing that a matching context word enhances familiarity of the test word, and if participants are unaware of the source of the familiarity (due to fast presentation of the context word), it will be misattributed to mean that the word appeared earlier. However, if participants are aware of the context word, the familiarity will not be misattributed. (See Huber, Clark, Curran, & Winkielman, 2008, for an alternative interpretation). This procedure provides another demonstration of how participants can experience familiarity for items that are objectively unfamiliar, which Jacoby and Whitehouse related to déjà vu experiences.

More direct investigations of déjà vu include a study by Brown and Marsh (2007) using symbols of low, medium, and high pre-experimental familiarity. Participants were presented with two symbols simultaneously (either Low with Medium or High with Medium) or one symbol (always Medium) and then asked to rate the familiarity of the Medium-Familiarity symbol. (Participants were not told which symbols were low, medium, or high in familiarity). Results showed that when a Medium-Familiarity symbol was paired with a Low-Familiarity symbol, this decreased familiarity ratings compared to when the Medium-Familiarity symbol appeared alone. Likewise, pairing the Medium-Familiarity symbol with a High-Familiarity symbol increased ratings. The authors' interpretation was that the familiarity of one object in a scene can increase or decrease the familiarity of other objects in that scene. Brown and Marsh (2009) again used symbols of high, medium, and low familiarity in a Jacoby-Whitehouse procedure to show that rapidly flashing an identical prime greatly increases the likelihood that participants will indicate that low- and novel-familiarity symbols were encountered prior to the experiment. This provides a means by which objectively unfamiliar symbols can appear familiar. In addition, Brown and Marsh (2009) reported that 79% of their participants were occasionally confused about whether they had encountered the symbols prior to the experiment, and 50% of the participants reported actually experiencing déjà vu.

Brown and Marsh (2008) also examined whether the manipulations similar to those used by Jacoby and collaborators could be used to create feelings of familiarity in an autobiographical context. Participants viewed pictures of a college campus they had never visited. During this first exposure, participants engaged in a shallow level of processing for each photograph which consisted of detecting a cross embedded somewhere in the scene. After a delay of one to three weeks participants were exposed to the photographs again and asked whether they had ever visited each scene at some point in their lives. Upon this second exposure, participants reported experiencing higher familiarity for the pictures of campuses they had never visited, and even caused participants to believe they had visited those campuses before, due to the fact they could not recall having only viewing the scenes. Brown and Marsh again found that nearly half the participants reported experiencing feelings of déjà vu at some point during the experiment.

Cleary et al. (2009) provided compelling evidence that the global configuration of a scene, rather than any individual item in the scene, can produce feelings of familiarity that are likely involved in déjà vu. Cleary et al. presented participants with a study list of line drawings of scenes. On a subsequent test list, participants viewed a test list of all new scenes, half of which shared an overall configuration with a studied scene. As each test scene appeared, participants were asked to recall a study scene with a similar configuration and provide familiarity ratings for each test scene. Participants were also asked to indicate whether they were experiencing any feelings of déjà vu. Results showed that even when participants could not recall a configurally similar study scene, participants gave higher familiarity ratings to test scenes that shared a configuration with a study scene. Participants were also more likely to report being in a déjà vu state while viewing the test scenes that configurally resembled study scenes.

The preceding section suggests several ways in which déjà vu might be related to familiarity-based discrimination, and several studies show evidence of déjà vu-like experiences resulting from laboratory procedures. Cleary (2008) explains how déjà vu could simply be the experience of recognizing a situation as familiar without identifying the source of the familiarity, in ways similar to manipulations of familiarity like those described in this section. Déjà vu could either result from a high degree of overlap with one prior situation, or a lesser degree of overlap with several different situations. The theories in the following section explore this concept in more specific detail.

The Divided Perception Theory of Déjà vu

Brown (2003) suggests several potential explanations for why déjà vu occurs. The different theories range from possibilities involving cognitive processes out of sync to biological dysfunction, but the theories most relevant to familiarity-based recognition are from a class of memory explanations, such as implicitly finding something familiar without explicitly recalling why or how.

One theory of the cause of déjà vu involves attention or perception. Brown (2003) provides a quote by Titchener (1928):

> You are about to cross a crowded street, and you take a hasty glance in both directions to make sure of a safe passage. Now your eye is caught, for a moment, by the contents of a shop window; and you pause, though only for a moment, to survey the window before you actually cross the street….The preliminary glance up and down, which ordinarily connects with the crossing in a single attentive experience, is disjointed from the crossing; the look at the window, casual as it was, has been able to disrupt the associative tendencies. As you cross, then, you think "Why, I crossed this street just now"; your nervous system has severed two phases of a single experience, both of which are familiar, and the latter of which appears accordingly as a repetition of the earlier. (pp. 187–188)

In this example, the feeling of familiarity stems from seeing an object twice—once without consciously attending to it, and a second time while fully attending to it. Brown (2004) suggests this could also be considered a type of split in perceptual experience, caused by external or internal distractions. This distraction then gives the impression that the object was encountered at two separate events. This is called the Divided Perception Theory. It is possible that several factors give rise to déjà vu experiences, or perhaps distinct experiences are collectively grouped as déjà vu. However, the Divided Perception theory can be examined using a methodology that uses a change detection task to simulate[1] the perceptual split described by Titchener and Brown, followed by a recognition test to measure the effects on judgments of familiarity. While Divided Perception may or may not be a viable theory of déjà vu, a first step towards evaluating this possibility is to determine what effect Divided Perception has on familiarity. If Divided Perception can lead to déjà vu, one would expect to see parallel effects on familiarity, such that objects viewed under conditions of divided perception can later evoke feelings of familiarity.

As discussed below, the change blindness phenomenon is a possible means of simulating conditions of divided perception. There has been some prior work involving recognition in change blindness that is relevant to the issue of familiarity and Divided Perception, but there are several gaps in the literature. The next section reviews the theory and background of change blindness effects, and points out several areas in which more work is needed.

Change Blindness

People often feel that they are accurate perceivers of their surroundings, but research has shown that under certain conditions, people perform quite poorly at noticing large-scale changes in a scene. For example, early research explored the phenomenon that one's own eye movements are not easily detected in a mirror, and that the visual world appears stable despite eye movements (Bridgeman, Hendry, & Stark, 1975). In this study, participants were instructed to look at a series of fixation points and then make an eye movement from one fixation point to another. During that time a certain stimulus shifted positions. Results showed that participants were mostly unable to detect the change if it occurred 10ms or less after a saccade. This was an early example of a type of change blindness.

Examining the conditions under which observers can detect or fail to detect changes in the environment reveals aspects of human perceptual mechanisms as well as the nature of

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[1]The term "simulate" in this context refers to creating conditions similar to divided perception, and does not involve any type of computer simulation or mathematical modeling.

representations of the visual world. Rensink (2002) describes change detection as the ability to report that a change has taken place, as well as identifying what has changed and where the change took place. Change blindness is said to occur when participants cannot successfully perform one or more of these tasks. There are a number of ways to achieve this effect. One method is to make use of a gap or interstimulus interval between a pre-change and post-change stimulus. For example, Rensink, O'Regan, and Clark (1997) developed a flicker paradigm in which two pictures rapidly alternate on a computer screen. The two pictures are identical except for one minor difference, such as an absent object, a moved object, or a color change. When a brief gray screen (a visual mask) appears between the two pictures, identification of the change becomes difficult.

Another method is to take advantage of an observer's own saccades, such as in the Bridgeman et al. (1975) experiment described above. Also, one experiment involved a photograph of two people whose heads were exchanged during a saccade, which observers often missed (Grimes, 1996). One can also simulate a saccade by making a change to an array at the same time as the array shifts position (Blackmore, Brelstaff, Nelson, & Troscianko, 1995); accuracy is considerably less compared to when the change occurs with no shift in position. Similarly, change detection is difficult when the change coincides with an observer's eyeblink (O'Regan, Deubel, Clark, & Rensink, 2000). One can also induce change blindness by making a change at the same time as superimposing "'patches" or "splats" (something like mud splashes on a windshield) on the scene in such a way that they do not occlude the change (Rensink, O'Regan, & Clark, 2000). Change blindness can occur even if the change is gradual, such as an object gradually fading in or out of a scene (Simons, Franconeri, & Reimer, 2000). Finally, change blindness can occur in real-life scenarios as well, such as when the change is occluded. Well-known examples come from Simons and Levin (1998), in which an experimenter asks a pedestrian for directions. As the pedestrian provides directions, confederates walk between the two people while carrying a door and the experimenter switches places with a different person hiding behind the door. Fewer than half of the pedestrians reported noticing that a change had taken place. Similar types of change blindness effects have been well-known to film editors as well, who can disguise discrepancies between scenes by cutting from one camera perspective to another (Simons & Levin, 1997).

One other aspect of change blindness research involves how many times a change appears. “Flicker” paradigms, such as that used by Rensink et al., (1997) involve a change occurring repeatedly. Change detection is typically measured in terms of how many alternations occur or how much time passes until the participant detects the change. There are also “one-shot” paradigms, in which a change occurs only once, and change detection is measured in terms of whether the participant can correctly identify the presence of a change (Levin & Simons, 1997; Simons & Levin, 1998). Response time can also be measured.

Change blindness effects occur across a range of scenarios. They can occur when using simple arrays of symbols (Bridgeman et al., 1975), using 3-D computer-generated images of scenes (Hollingworth & Henderson, 2002), photographs (Rensink et al., 1997), films of real-life interactions (Levin & Simons, 1997), and actual real-life interactions (Simons & Levin, 1998). A key consideration is also whether the change detection task is intentional or incidental (Simons, 2000). For example, in laboratory-based tasks participants may be informed that changes will take place and that their task will be to detect those changes (e.g., Rensink et al., 1997). In real-life tasks, participants may not know that they are in an experiment at all (e.g., Simons & Levin, 1998), and thus would not be on the lookout for changes. This is an important distinction to point out, as it may explain differing findings in different experimental methodologies. For example, Levin, Simons, Angelone, and Chabris (2002) presented participants with a real-life change blindness task and found that when participants failed to detect the change, they only performed at chance levels on a subsequent recognition test of the changing items. Angelone, Levin, and

Simons (2003) performed a very similar procedure in the laboratory and found that participants performed at above chance levels on the same recognition test. Levin et al., suggest that this may be because participants encode fewer features of the stimuli in real-life tasks, but anticipating a change allows participants to attend more closely to the stimuli, even though they did not detect the change.

Theories of Change Blindness

As for why change blindness effects occur, Rensink et al. (1997) argue that this effect is due largely to lack of attention for the changing object. Rensink (2002) points out that the word "attention" has several meanings, and specifies that change detection likely involves "focused attention" which Treisman and Gormican (1988) describe as a sort of spotlight that is directed upon an object to determine its location. In other words, attention is needed to explicitly perceive a stimulus, and without this attention Rensink et al. argue that participants do not retain the representation of a scene that is needed to automatically detect a change. They claim the original representation is simply overwritten or replaced. Evidence in favor of this theory is that the changes are easier to detect when participants receive verbal cues as to where changes will occur—i.e., when participants know where to direct attention. Supporting evidence comes from the finding that when the changing objects are more centrally located and "interesting," observers are faster in detecting the change than when objects are more marginal (Simons, 2000). Simons and Rensink (2005a) also point out that although observers can attend to 4-5 objects at a time, they can only detect changes in one object at a time. In conditions where the change coincides with splats, Rensink et al., (2000) argue that change blindness results from distracting attention away from the areas that change. Rensink (2002) states that in general, changes in the real world are accompanied by motion, but when observers' attention is distracted away from motion, or motion does not accompany changes, changes can be difficult to detect.

However, Simons and Rensink (2005a) discuss that while attention is necessary to detect a change, it may not be sufficient. They report examples of when observers attend to a change but fail to become aware of it, especially when they were not expecting any change (which relates to the difference between real-life and lab-based procedures discussed above). For this reason, change detection has been used as a method to track attention in much the same way as eye tracking (Tse, Sheinberg, & Logothetis, 2003), and Simons and Rensink suggest that this method can be used to determine what aspects of a stimulus (such as shape or color) are receiving attention.

Another explanation for why change blindness occurs is that representations of scenes are never formed in the first place (Noë, Pessoa, & Thompson, 2000). Similar effects, such as the perceptual sense of stability in the world despite saccadic eye movement, suggest that elaborate representations of the world are not created. A similar theory is that representations of pre-change scenes are formed, but they are quickly overwritten or replaced by post-change scenes (Beck & Levin, 2003). Simons and Rensink (2005b) acknowledge that these views are intuitive and popular, but claim that these theories cannot describe many findings. They espouse a different theoretical explanation in which participants do create representations of each scene, and these representations are retained, but change blindness results when participants fail to compare the two representations. In work using real-life incidental change detection tasks, an experimenter asked for directions from a pedestrian while holding a basketball. A group of confederates passed by and took the basketball without the pedestrian noticing. Most of the pedestrians in the study did not report seeing the basketball disappear, but when asked about it they recalled that the experimenter had been holding one and could even describe its colors (Simons, Chabris, Schnur, & Levin, 2002). In a more recent set of experiments, Mitroff, Simons, and Levin (2004) presented participants with simple arrays of objects in which one object changed. Participants would try to detect the change then perform two-alternative forced-choice (2AFC) tests for preand post-change objects. Results showed that even when participants could not detect the change they could still recognize pre- and post-change objects at above chance levels, showing that some representation of the objects remains. Similar evidence comes from Angelone et al., (2003), in which participants viewed motion pictures of people interacting with several changes across scenes. Participants were later assessed for awareness of the changes, and then received 4AFC recognition tests to select the pre-change object. The results showed that even when participants reported not being able to detect the change in the scene, they could still select the correct object at above-chance levels.

One study (Rosielle & Scaggs, 2008) examined change blindness for pre-experimentally familiar scenes. Participants viewed photographs of their own campuses with certain buildings removed, and participants were asked to indicate whether something was absent. Surprisingly, participants failed to detect the absent building over 80% of the time. The authors propose that this is due to a lack of precision in visual long-term memory, but these findings could also be interpreted as failing to compare long-term representations with the current photographs.

Recognition and Change Blindness

As discussed in the previous section, there is some previous work on recognition for critical items in a change blindness task, and it deals with how pre-change and post-change items are represented in memory. One theory is that change blindness occurs because participants do not form a representation of the changed item, and therefore do not notice when it disappears. A competing theory is that participants do form representations of both the pre-change and post-change item, but that change blindness arises from a failure to compare these two representations. In support for the latter theory, Angelone et al., (2003) showed participants a motion picture of two people interacting with several objects changing across scenes. Participants received a questionnaire to determine if they noticed the change, and to select the pre-change picture from a list of four alternatives. The results showed that even when participants reported not being aware of a change in the scene, they could still select the correct picture at above-chance levels.

In contrast, Levin et al., (2002) did not find above-chance performance on recognition tests for critical items in a real-life change blindness tasks. One possibility that Levin et al. suggested is that in real-life tasks, participants may encode fewer features of the objects than in a lab-based task, when participants may be expecting a change and closely attending to stimuli.

Recognition memory has also been tested in change detection tasks when the change occurs gradually. One study (Laloyaux, Devue, Doyen, David, & Cleeremans, 2008) presented participants with pictures of faces that gradually morphed the facial expression or remained unchanged, and participants were later asked to pick the face they had seen on a forced-choice recognition test. When participants saw unchanging pictures, recognition memory performance for the pre-change face was fairly accurate. When participants saw the gradually changed pictures (and did not detect the change), recognition memory performance was much less accurate, with participants being more likely to choose one of the lures, and also being less confident in their choices. These results are counterintuitive, in that they appear to show poor recognition performance for undetected items. However, unlike discrete changes, the gradual changes expose observers to a range of displays, and the authors emphasize that lower accuracy actually reflects retained representations for undetected changes, and claim that this is evidence of how undetected changes can influence recognition memory decisions.

These studies show that participants can recognize changed items even when the change was not detected, but they do not address many aspects of the relationship between change blindness and recognition memory. For example, one shortcoming of these studies is the way in which change detection was assessed. They tended to assess change detection by presenting participants with a questionnaire or survey about whether they noticed any changes or anything unusual, and these questions occurred after the experiment had ended. This could pose a problem, because participants may have noticed something unusual during the procedure but then forgotten it by the end of the experiment. As Rensink (2002) explains, different degrees of change detection can be simply detecting that a change took place, identifying what item changed, or localizing the area of the change. The aforementioned studies only measured whether observers could detect that a change occurred, while a more stringent criteria would have been to measure whether participants could localize the area of the change (likely revealing more instances of change detection than previously suspected; Fernandez-Duque &Thornton, 2000). This bears some similarity to issues of measure awareness of learning in implicit learning paradigms. As Shanks and St. John (1994) point out regarding implicit learning tests, assessing awareness by self-report after a procedure is over could allow for the possibility that participants are aware of a manipulation while it is occurring but then fail to remember it or fail to report it on the final survey. Likewise, in this change blindness task, a post-procedure questionnaire may not be the best way to measure change detection, and change localization may be more accurate.

Another issue is that in the previous studies involving recognition and change blindness, all items on the recognition tests are viewed from different perspectives than on the change detection task. This type of study-test dissimilarity could underestimate performance on the final recognition test, although manipulating similarity between cue and target can increase or decrease recognition performance, and even have no effect at all (Nairne, 2002). Comparisons of items in their original context vs. different contexts would be necessary to determine whether such differences affect recognition performance for undetected items in this task.

Using Change Blindness to Assess Divided Perception Theory

To date, no research has directly tested Divided Perception Theory with regard to déjà vu experiences or feelings of familiarity. Perhaps one reason for this lack of research is the difficulty in creating a task that simulates the experience of viewing a stimulus without always attending to it, and allows the experimenter to keep track of when participants were focusing attention on the stimulus.

There are several established laboratory procedures that examine how much processing is devoted to unattended stimuli. One of the most well-known is the dichotic listening task (Cherry, 1953). In this type of task, participants listen to two streams of auditory information (usually a spoken passage) presented to two separate headphones. Participants are typically asked to "shadow," or repeat the information from one headphone while disregarding the information from the other headphone. Early results showed that very little information presented to the unattended ear reached consciousness, as participants did not report noticing if the unattended message switched languages. One experiment even presented the same word list repeatedly to the unattended ear, which participants did not recognize on a subsequent recognition test (Moray, 1959). There is also a visual analog of dichotic listening, in which participants view two superimposed videos and are instructed to attend to only one (Neisser & Becklen, 1975). Similar to results from dichotic listening procedures, participants are unable to report very much about the unattended video.

Although dichotic listening and "selective looking" tasks are effective at measuring the effects of unattended stimuli across many trials, one issue that makes them inappropriate for examining Divided Perception is that an experimenter would be unable to keep track of when participants surreptitiously shift attention between channels. A typical safeguard would be to eliminate all trials of a dichotic listening tasks when participants fail to correctly shadow the instructed channel, but Jacoby (1991) claims that participants may still be able to switch channels and process the to-be-ignored channel. Posner and Snyder (1975) also claim that participants can still mostly attend to one channel while still switching to the other, so an experimenter could never be completely sure that unattended channels are truly unattended.

Although change detection tasks are also not perfect measures of the focus of attention, they allow for more measurement on a trial-by-trial basis of where participants were attending. It is important to point out that change blindness is not the same construct as divided perception, but they bear enough similarity to allow for change blindness to be used as a simulation of divided perception. For example, a key component of the perceptual split described by Titchener (1928) is two viewings of a scene—the first under diminished attention and the second under full attention. A flicker task is able to re-create the experience of this "double-take," and change detection status can track whether participants had attended to a specific, critical object. In addition, visual stimuli may be more appropriate for this type of investigation, as Brown (2003) reports that déjà vu experiences are more often triggered in response to visual input. In sum, change blindness may not be identical to divided perception, but it presents a useful means of simulating the experience because change blindness and divided perception both result from disruptions to attention and change detection can be used to track the focus of attention. This, in addition to the existing research already on recognition for undetected items, makes a change detection task an effective tool for investigating divided perception.

Overview of Current Experiments

The current experiments built off of change blindness research to examine recognition memory performance for items in a change detection task. Unlike the Angelone et al. (2003) and Levin et al. (2002) studies, the current experiment used a task that allowed participants to immediately localize changes in scenes and obviate problems with post-experiment questionnaires. On a subsequent recognition test, participants were presented with objects from the earlier part of the experiment, and participants provided familiarity ratings or other types of recognition responses. These responses were compared against responses for objects that did not appear earlier in the experiment.

The change detection paradigm is different from standard flicker tasks, such as those used by Rensink et al., (1997). Instead of two pictures alternating back and forth repeatedly, the current flicker task involves one alteration; the first picture is complete and the second picture is lacking the critical object—what Rensink (2002) calls a "one-shot paradigm." This procedure controls for the amount of time that critical objects appear on the screen, which could impact familiarity ratings. Participants are instructed to click on the area where something disappeared, serving as a more sensitive measure of change detection than questionnaire methods used in previous research.

The following experiments also make use of a modification of the RWI paradigm. In typical RWI experiments, participants receive a study list of unaltered stimuli and then a test list of perceptually degraded stimuli. The degraded stimuli can be word fragments, written words embedded in visual noise, spoken word fragments, spoken words embedded in visual noise, fragments of pictures, pictures embedded in visual noise, and so on. Participants are charged with identifying the degraded stimuli and then rating how familiar they seem. Familiarity ratings are then compared between studied and unstudied items when participants could not identify them at test. The current experiment utilized a procedure similar to the reverse RWI manipulation in Cleary and Greene (2000), in which stimulus identification is hindered at study rather than test. Using change blindness as the method of hindering identification, familiarity ratings are compared between studied and unstudied items that participants did not detect changing during *study*.

The first hypothesis of the following set of experiments is that observers are able to demonstrate recognition for undetected items, in accordance with Divided Perception Theory. Although previous research has reported findings of recognition for undetected items (e.g., Angelone et al., 2003), the methods of assessing change detection may have lacked sensitivity, and likely missed instances of change detection. The current studies use a more sensitive measure of change detection that has not yet been used in conjunction with recognition tests. In addition, the current studies employ a different type of recognition test that involves a continuous rating scale of familiarity, as opposed to solely using forced-choice responses, and the flicker task is specifically designed to resemble divided perception. Support for this hypothesis would demonstrate support for the Divided Perception theory of déjà vu, The second hypothesis (investigated in Experiments 1, 2, and 3) is that manipulations to stimulus characteristics, such as location and color, can influence recognition decisions. Prior work (e.g., Brady, Konkle, Alvarez, & Oliva, 2008) has shown that observers can be extremely sensitive to minor variations in the details or position of items in a scene. In contrast, other work has shown that observers can be fairly insensitive to subtle changes (such as mirror reversals) in the details of an object (DiGirolamo & Hintzman, 1997). These experiments will examine the degree to which participants are sensitive to these characteristics in change detection, and perhaps shed light on what types of manipulations might contribute to feelings of déjà vu. The third hypothesis (investigated in Experiments 4 and 5) regards the degree to which recognition for undetected items is determined by recollection vs. familiarity processes. Prior work has only examined whether participants could recognize undetected objects, but not how those objects are recognized. It is predicted that undetected items can be recognized on the basis of familiarity alone, Jacoby (1991) claims that no task relies on only one process, but these experiments can examine the relative contributions of recollection and familiarity to recognition of undetected items. Previous research (Jacoby, 1991; Yonelinas, 2002) suggests that manipulations of attention will affect recollection processes but not familiarity, and the current experiments will examine whether the same pattern occurs in change blindness.

The purpose of the first experiment was to examine recognition in a change detection task with localization of the change as the measure of change detection. The hypotheses are that participants will demonstrate higher levels of recognition for undetected items than for unstudied items (using a more sensitive measure of change detection than previous research), and that manipulations to the locations of critical items will affect performance on the recognition test (which also uses a different procedure than previous research). At test, critical items either appeared in their studied locations or a standardized location to examine the influence of study-test match on recognition. It is expected that presenting critical items in their studied locations will lead to higher ratings.

Experiment 1

Method

Participants. One hundred forty-two Colorado State University undergraduates participated in exchange for credit in a psychology course.

Materials. The stimuli were 50 photographs of everyday scenes. All scenes contained only inanimate objects. All stimuli were original creations by the experimenter, and there were four versions of each photograph: Unaltered, Object Absent, Studied Position and Centered Position. Figure 1 provides an example of each version of a stimulus. As defined in greater detail below, the Unaltered and Object Absent versions appeared at study, and the Studied Position and Centered Position versions appeared at test.

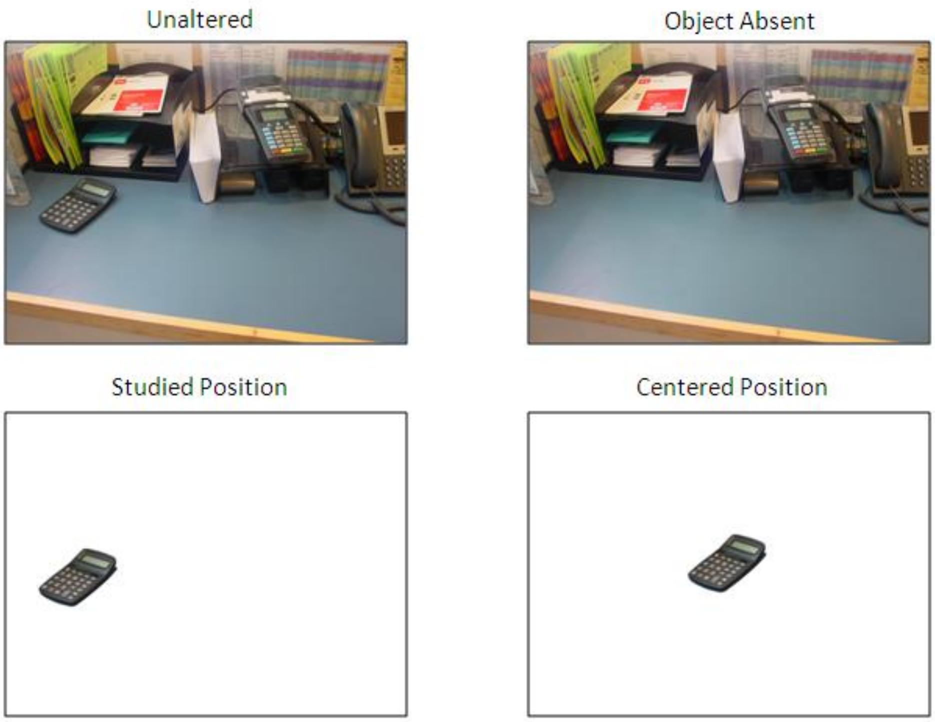

Figure 1. Example of the stimuli that appeared in Experiment 1.

The Unaltered version comprised scenes from everyday life (such as bedrooms, bathrooms, offices, outdoors, etc.). Each scene contained several objects which were appropriate for the scene.

The Object Absent version was identical to the Unaltered version, with the exception that one object was removed from the scene. The object removed from each scene will henceforth be referred to as the "critical object." Each critical object was removed from a scene by taking a second photograph from the same perspective of the first photograph (by use of a tripod) after physically removing one object. The Studied Position version of the photograph contained only the critical object, presented in isolation. This was achieved with Adobe Photoshop by selecting the critical object from the Unaltered version and deleting everything else, leaving a white background. The critical object remained in the same position it occupied in the Unaltered version. The Centered Position version of the photograph also contained only the critical object in isolation, but the critical object appeared in the center of the scene rather than in its studied position.

Procedure. The entire experiment ran on a computer with E-Prime software. The experiment was divided into two parts: the study list, during which participants first viewed the Unaltered and Object Absent scenes while performing a change detection task, and the test list, during which participants rated the familiarity of critical items in the Studied Position or Centered Position conditions.

The following instructions appeared at the beginning of the study list: "In this experiment, you will see pictures of scenes. First you will see the complete scene, then the same scene with something missing. Your job will be to figure out what was missing."

Participants received 25 such trials on the study list. Each trial consisted of two versions of a photograph—the Unaltered version and the Object Absent version. First, a gray screen appeared for 5 seconds with the phrase "Complete scene…" Next, the Unaltered version appeared for 2 seconds. Then another gray screen appeared for 5 seconds with the phrase "Something missing…" Then, the Object Absent version appeared on the screen with a prompt at the top of the screen reading, "Click on where something is missing." At this point, the mouse cursor appeared on the screen. Participants had unlimited time to make the choice, and the experiment continued only after the participant clicked on some part of the screen. Clicking on the screen constituted the "change detection" task in the current set of experiments. Figure 2 represents the timeline of a study trial, in which the Unaltered scene is followed by a gray mask (reading "Something missing…") and the Object Absent scene in which participants attempt change detection.

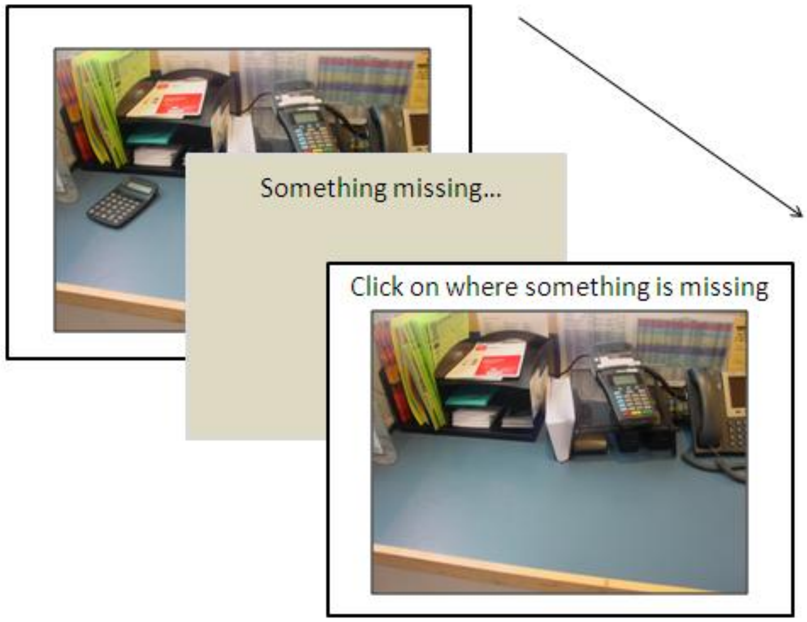

Figure 2. Example of a study trial in Experiment 1.

After participants made the click, the mouse cursor disappeared again and another gray screen appeared with the phrase "Next scene…" for 2 seconds. Participants did not receive feedback as to whether they were correct. Participants received an example with a prominent change before the first trial began. The 25 photographs were randomly selected from the entire set of 50. The 25 photographs appeared in random order.

After the last study trial, the following instructions appeared:

Very good. Now, in the next part of the experiment, you will answer questions about objects that were missing from the scenes.

Each object will appear by itself. Some of them appeared in scenes you saw earlier. You may even have identified them when they were missing. But some of the objects did not appear in scenes you saw earlier--they were not presented at all.

All you have to do is rate how familiar you find each object. Do not worry if you remember seeing it before or if you identified it as missing. Just rate whether you experience any feelings of familiarity.

Then participants began the test trials. There were 50 test trials, in which the critical objects from all 50 photographs appeared in random order. The version that participants received at test (Studied Position or Centered Position) was a between-subjects manipulation and participants were randomly assigned to one of the conditions. There were 71 participants in each condition.

Each test trial consisted of a critical object appearing on the screen. At the bottom of the screen was a rating scale ranging from 1 to 9. On the far left, 1 had the label "Very Unfamiliar." On the far right, 9 had the label "Very Familiar." Figure 3 depicts how each test trial appeared.

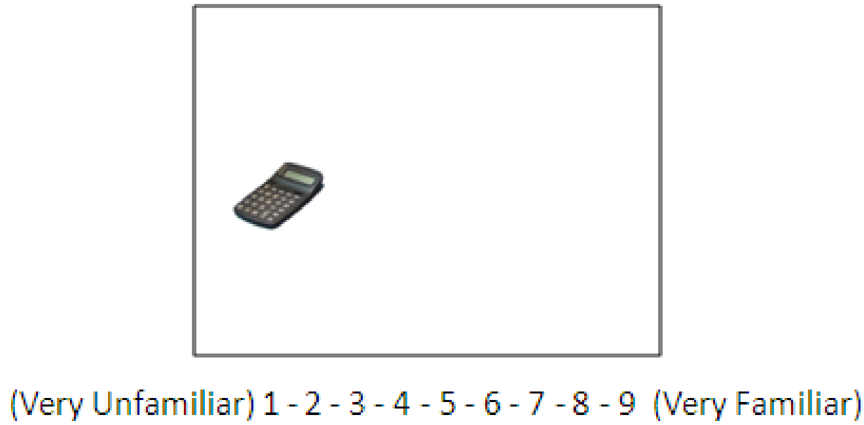

Figure 3. Example of a test trial in Experiment 1.

Participants had unlimited time to make the rating, and the experiment continued only after the participant made a rating. After the rating, a white screen appeared with the phrase "Next object…" for 1 second. After all 50 test trials, a screen appeared to tell the participant that the experiment was over.

Data Scoring. For each change detection response, the program recorded the coordinates of the mouseclick. These coordinates were then compared to a range of coordinates for the critical item. This range of coordinates formed an area in the shape of a rectangle. No critical item was exactly in the shape of a rectangle, so the area of the rectangle was slightly larger than the critical item itself so that the item could be completely covered. If participants clicked anywhere in the area that a critical item had occupied, that trial was labeled "Change Detected." Because the area of the rectangle was slightly larger than the critical item itself, responses were classified as correct somewhat liberally. If participants clicked outside that area, the trial was labeled "Change Undetected."

Results and Discussion

All *t*-tests reported are paired-samples *t*-tests unless otherwise stated. Starting with the change-detection data, participants in both conditions together correctly detected the location of the change 54% of the time (*SD*=14%). Every participant had at least some correct responses (with the lowest performance being at 20%) but no participant was correct on every trial (with the highest performance being at 84%). Participants in the Studied Position condition correctly identified the location of the change 54% of the time (*SD*=14%) and participants in the Centered Position correctly identified the location of the change 53% of the time (*SD*=15%). These conditions had identical study procedures which explains why performance at study is so similar. When participants were incorrect in their responses, they were a mean of 3.78cm (*SD*=1.18) away from the nearest edge of the critical item. Participants' responses were significantly faster when correct (*M*=2.3 s, *SD*=0.96) than when incorrect (*M*=3.94 s, *SD*=1.71), $t(141)=15.43$, *SE*=0.11, $p<.001$. Looking at the stimuli themselves in an items analysis, there is no correlation between the area of the critical item and the likelihood that it will be identified ($r=.00$, $p=.99$), nor was there a correlation between the area of the critical item and the speed with which participants made correct responses ($r=-.08$, $p=.56$) or incorrect responses ($r=.04$, $p=.77$)

The primary data of interest are the familiarity ratings given to items on the test trials. Particularly, critical items at test either appeared on the study list or did not (Studied vs. Unstudied), and of the critical items that did appear at study, participants either detected the change or did not (Detected vs. Undetected). This creates three different conditions at test: Studied/Detected, Studied/Undetected, and Unstudied. (Unstudied items were items that did not appear on the study list, so they never had the opportunity to be detected.) Familiarity ratings are compared for each of these conditions. Another aspect of the data is comparison between familiarity ratings for the different test conditions (Studied Position vs. Centered Position). The term "test conditions" is reserved for this between-subjects manipulation.

Considering both test conditions together, a One-way Repeated-Measures ANOVA compared familiarity ratings for Unstudied items against Studied/Detected items and Studied/Undetected items. Results indicated a significant difference between means, $F(2,282)=443.42$, $MSE=0.66$, $p<.001$, partial $\eta^2=0.76$. Pairwise comparisons using paired-samples *t*-tests revealed that Studied/Detected items received higher familiarity ratings than Studied/Undetected items, $t(141)=13.06$, $SE=.10$, $p<.001$, Cohen's $d= 1.02$, and Studied/Undetected items in turn received higher familiarity ratings than Unstudied items $t(142)=18.37$, $SE=.08$, $p<.001$, Cohen's $d= 1.16$.[2] The comparison between familiarity ratings for Studied/Undetected items and Unstudied items suggests that even when participants fail to detect the critical item in a scene, that items still produces higher familiarity compared to items that never appeared. The mean ratings appear in Figure 4. The pattern shows that although ratings are highest for Detected items, Undetected items still received higher ratings than Unstudied items. In other words, the pattern suggests that participants are able to recognize items despite not detecting them earlier. This supports prior work on change detection, but by using a different procedure and different methods of recognition memory assessment the current experiment is

[2] These effects were replicated in an items analysis.

able to demonstrate that recognition can occur for undetected items using a localization measure, which previous research has shown can reveal more instances of change detection (Fernandez-Duque & Thornton, 2000; Rensink, 2002). Therefore, these results rule out the possibility that recognition may have only been occurring for weakly-detected items, which previous research could not do. This procedure also used a one-shot variation of the flicker task to simulate divided perception, making these results specifically relevant to the evaluation of Divided Perception theory.

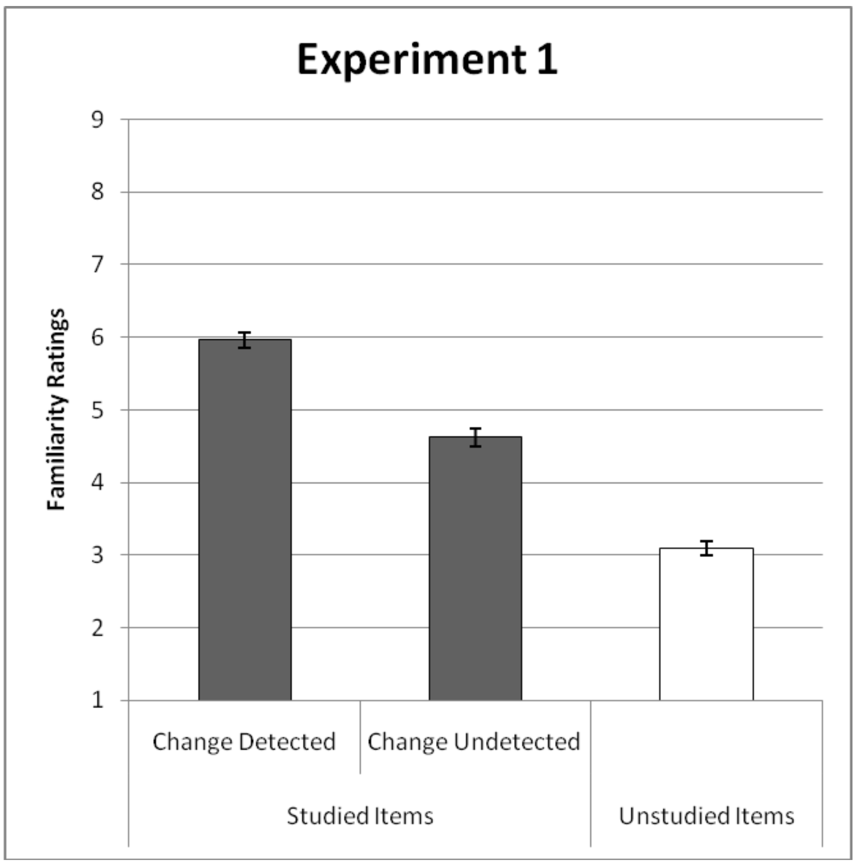

Figure 4. Combined familiarity ratings from both test conditions in Experiment 1. Error bars represent standard error.

One additional dependent measure that can be analyzed is the time in which participants provided the ratings. Previous research has shown that the speed with which participants make recognition decisions can be indicative of recognition processes, with faster responses corresponding to familiarity-based judgments and slower responses corresponding to recollection-based judgments (Yonelinas, 2002). If detection at study leads to recollection at test, one may expect to see slower reaction times in ratings for Detected items, and faster reaction times in ratings for Undetected items. A One-way Repeated-Measures ANOVA revealed a significant difference, $F(2,282)=4.93$, $MSE=106.,90$, $p<.01$, partial $\eta^2=0.03$, with participants providing ratings significantly faster for Studied/Detected items compared to Studied/Undetected items, $t(141)=2.12$, $SE=0.04$, $p<.05$, but there is no significant difference in reaction time between Studied/Undetected and Unstudied items, $t(141)=0.91$, $SE=0.03$, $p=.37$. Figure 5 shows the mean reaction times for each condition, with ratings for Detected items being slightly faster than Undetected and Unstudied items. In several ways, the pattern depicted in Figure 5 is the opposite of the pattern of ratings in Figure 4, which suggests some role of processing differences across Detection/Study status.

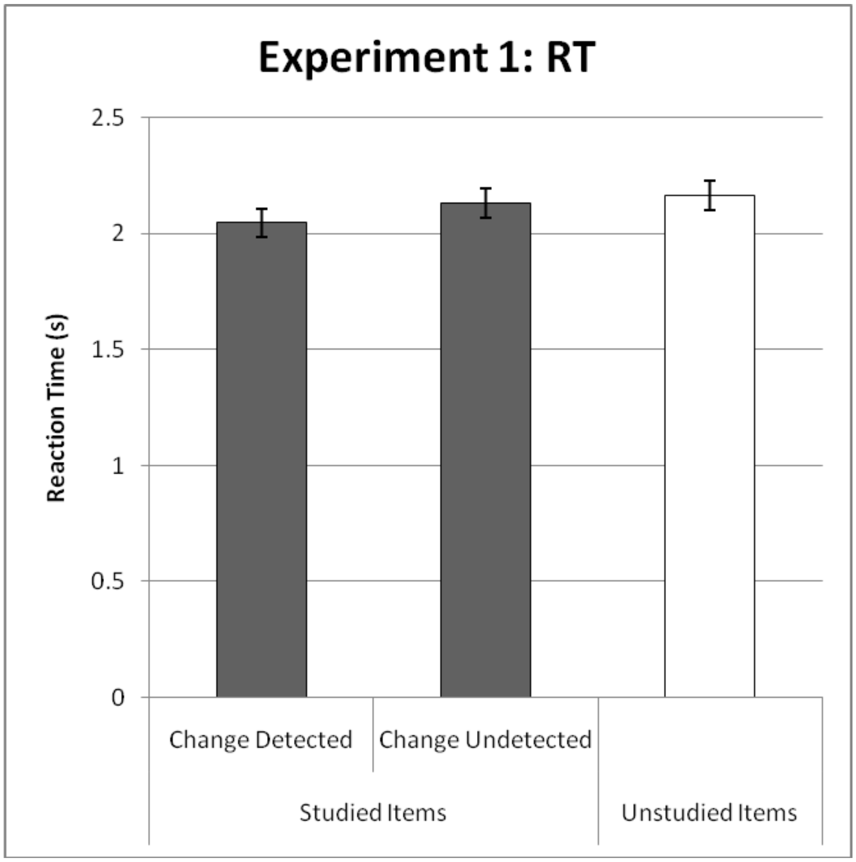

Figure 5. Mean reaction times during the rating task from both test conditions in Experiment 1 combined. Error bars represent standard error.

One potential explanation of this counterintuitive result would be a non-normal distribution, in which one of the conditions (most likely Undetected) contained trials in which participants responded quickly and slowly. An analysis of the distribution of mean reaction times can indicate whether this is a possibility. Figure 6 presents a frequency distribution of mean reaction times of ratings for Detected, Undetected, and Unsudied items to examine whether differences in the variance of rating speed for each type of item could explain the unexpected pattern in Figure 5.

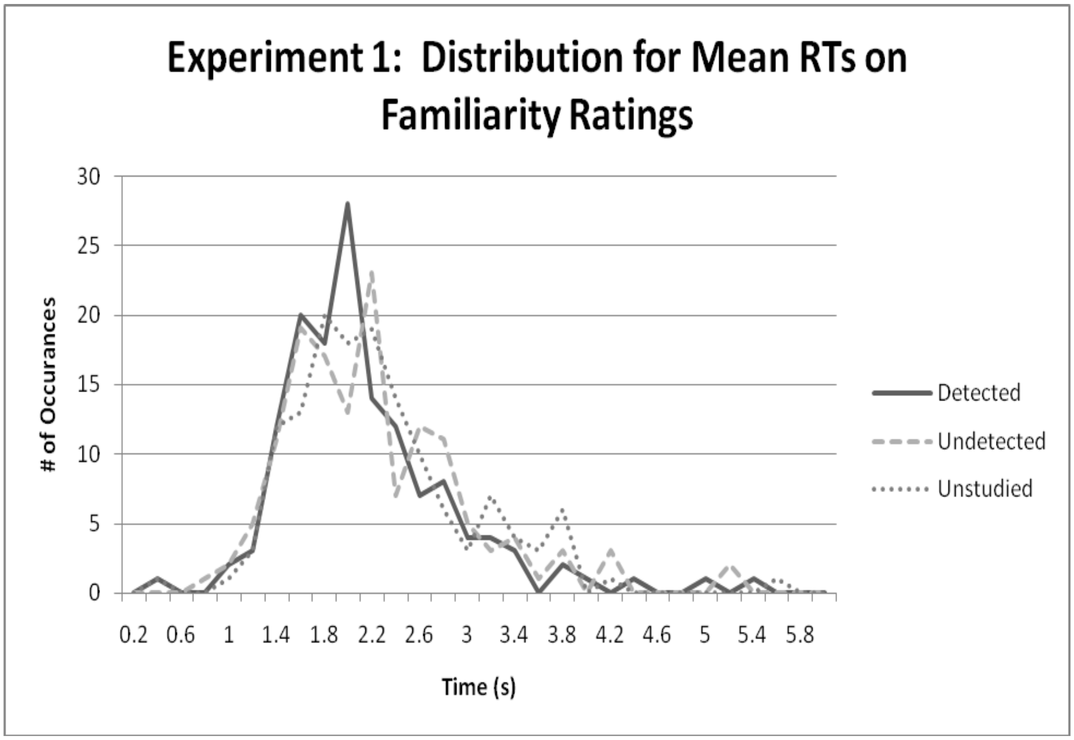

Figure 6. Frequency distribution for reaction times in Experiment 1, from both test conditions combined.

The distributions for Detected, Undetected, and Unstudied reaction times may all have a slight positive skew. The Undetected distribution appears somewhat bimodal, which suggests the variance may be different from other distributions. Indeed, Mauchly's Test of Sphericity indicated a significant difference (p=.04), indicating that variances may not be equal across all levels. A *t*-test on the mean of the standard deviations from each condition show that there was significantly higher variability in the Unstudied condition than Undetected, $t(142)=2.19$, $SE=0.04$, $p<.05$. If individual trials of faster than 0.2 s or slower than 6 s are removed, the tails are somewhat altered but the overall shape of the distributions remains the same, but the difference in standard deviations between Undetected and Unstudied ceases to be significant ($p=.10$) while the difference between Detected and Unstudied becomes significant, $t(142)=2.71$, $SE=0.03$, $p<.01$. In sum, the statistical differences in mean reaction time across study/detection status may be an artifact attributable to the variance. It is also important to point out that participants were not instructed to provide their ratings within a certain response deadline (typically less than one second), which is often the basis by which familiarity processes are isolated (Yonelinas, 2002). Without this response deadline, one cannot be sure that potential differences in reaction time do indeed reflect the use of different recognition processes. Therefore, reaction time data will not be included in future experiments.

Turning back to the familiarity ratings, next is a comparison between ratings for Studied Position test trials to Centered Position test trials. A 2 (Test Condition: Studied Position vs. Centered Position) X 3 (Study/Change-Detect Status: Studied/Change-Detected vs. Studied/Change-Undetected vs. Unstudied) Mixed Factors ANOVA was computed on the familiarity ratings, with Test Condition as a between-subjects variable and Study/Change-Detect Status as a within-subjects variable. This revealed the same main effect of Study/Change-Detection as when the conditions were combined, $F(2,280)=443.29$, $MSE=0.66$, $p<.001$, partial $\eta^2=0.76$. There was also a main effect of Test Condition $F(1,140)=8.75$, $MSE=3.50$, $p<.01$, partial $\eta^2=0.06$, in which the Studied Position items tend to receive significantly higher familiarity ratings than items in Centered Position. Independent-samples *t*-tests show significantly higher familiarity ratings for Studied Position items when Unstudied, $t(140)=2.84$, $SE=0.20$, $p<.01$, Studied/Undetected, $t(140)=2.84$, $SE=0.23$, $p<.01$, and marginally significant for Studied/Detected $t(140)=1.87$, $SE=0.21$, $p=.06$. There was no significant interaction between Test Condition and Study/Change-Detect Status, $F(2,280)<1$, $MSE=0.66$, $p=.38$. Figure 7 depicts the mean ratings, separated by Test Condition (Studied Position vs. Centered Position). The overall pattern of ratings for Detected vs. Undetected vs. Unstudied is the same as in Figure 4, but one can see that the ratings for Centered Position items are consistently lower than ratings for Studied Position.

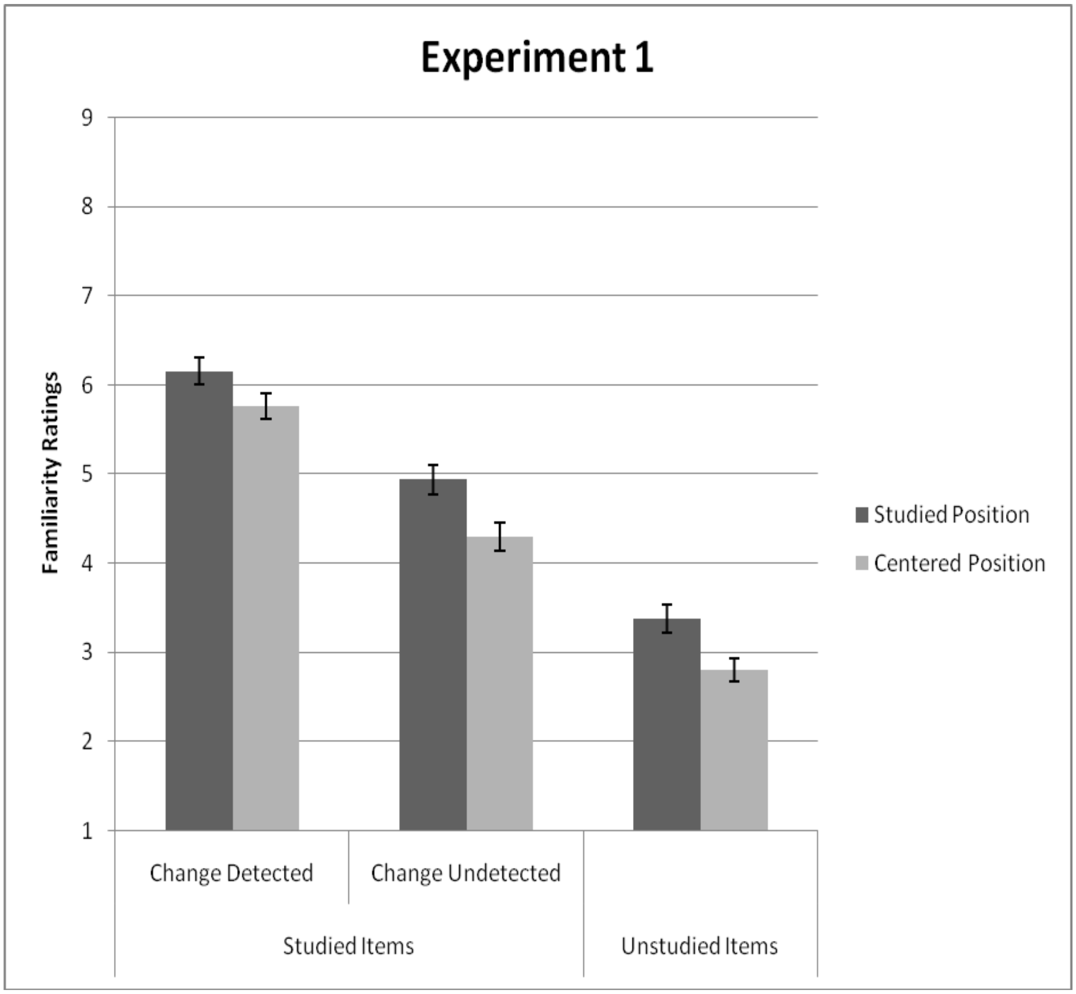

Figure 7. Familiarity ratings in Experiment 1, separated by test condition. Error bars represent standard error.

Finally, it is worth noting that the main results of interest (the difference in familiarity ratings corresponding to Studied/Detected, Studied/Undetected, and Unstudied) result from trials when participants do and do not correctly detect the location of the change. However, to correctly detect the location of the change the participants were required to click inside an area slightly larger than the space formerly occupied by the critical item. This response area was slightly liberal but could still be too strict of a criterion, as participants may have clicked in the general area of the critical item but not exactly where it had been or the slightly larger response area. In the event this happened, the subsequent familiarity rating for the item might be higher than one would expect for an Undetected item, and thus drive the difference in ratings between Undetected and Unstudied. One way to examine this possibility is to enlarge the area which constitutes a correct detection, and see whether the same pattern of familiarity ratings still appears. In a follow-up analysis, the acceptable area for each critical item was expanded, so that mouseclicks in a wider area around the critical item would also constitute correct detections. The expanded acceptable area was four times the original area of the critical item (twice the width and twice the height). In this more liberal coding, participants were correct in their responses 68% of the time (*SD*=14%) instead of 54%. When participants were incorrect in their responses, they were a mean of 5.18cm (*SD*=1.45) away from the nearest edge of the critical item. However, the same pattern of familiarity ratings appeared; Change/Undetected items received significantly lower familiarity ratings than Change/Detected, $t(141)=13.54$, $SE=.12$, $p<.001$, Cohen's $d= 1.13$ and significantly higher ratings than Unstudied, $t(141)=12.34$, $SE=.09$, $p<.001$, Cohen's $d= 0.81$. Even if the acceptable area is expanded to the entire quadrant of the screen in which the critical item appears, the same pattern appears. The rate of correct responses increases to 72% (*SD*=11%) but Change/Undetected items still received significantly lower familiarity ratings than Change/Detected, $t(141)=10.45$, $SE=.13$, $p<.001$, Cohen's $d= 0.91$ and significantly higher ratings than Unstudied, $t(141)=12.38$, $SE=.10$, $p<.001$, Cohen's $d= 0.85$.

The results of Experiment 1 have demonstrated a novel procedure which examines recognition memory performance for items in a change detection task. The hypothesis that participants will demonstrate recognition of undetected objects was supported; the results indicate that correctly detecting the critical item in a change-detection task increases familiarity ratings on a recognition test, but even when participants do not detect the critical item, familiarity ratings are higher than those for unstudied items. In other words, familiarity ratings are higher for studied items even when participants did not detect their earlier absences. This provides initial support for the Divided Perception theory, and presents a means of investigating déjà vu experiences stemming from this type of manipulation. The subsequent experiments in this paper will explore this effect more fully.

Experiment 2

The results from Experiment 1 suggest that the positioning of the critical item on the recognition test also seems to play a role; when the item was in its studied location, familiarity ratings were somewhat higher than when the critical item appeared in the center of the screen. This suggests that previously-published studies' measures of recognition for changed items might have been underestimates, as their recognition tests presented the changed items in different contexts (e.g., Angelone et al., 2003). However, one caveat of this interpretation is that in the Centered Position condition of this experiment (and the Angelone et al. experiments), all test items were presented in a standardized location. The decreased familiarity ratings could have been due to more uniformity among all test trials (which would also explain the significant decrease in familiarity ratings for unstudied items, which should not have been affected). The purpose of Experiment 2 is to determine whether the decrease in familiarity for the Centered Position condition is due to increased uniformity between trials, or if any alteration of the studied position of the critical items will lead to a decrease in familiarity ratings. If ratings are lower for items that appear in non-studied positions, it would suggest that location changes contribute to decreased familiarity. This manipulation is also in line with the way that the RWI paradigm has been used to examine the features that contribute to familiarity. In this experiment, the features being examined are the relative positions of the items and their orientation (either studied orientation or a mirror image).

Method

Participants. Eighty-four Colorado State University undergraduates participated in exchange for credit in a psychology course.

Materials. The stimuli were the same 50 photographs of everyday scenes used in Experiment 1. The Unaltered version and Object Absent version were the same as in the study list of Experiment 1, but the manipulations performed at test were different.

Instead of a Studied Position and Centered Position version for the critical items, the test list presented a Mirror Image version or a Shifted Position version. The Mirror Image version was the mirror image of the Studied Position version, such that the critical object appeared reversed and in the opposite half of the horizontal axis. The Shifted Position version of the photograph was the critical object in isolation, but moved to a different part of the screen. It is different from the Mirror Image version in that the critical item was not reversed.

Procedure. The procedure was identical to Experiment 1. Participants were randomly assigned to the Mirror Image or Shifted Position conditions, whereby participants received only one type of manipulation at test. Forty-two participants were in each condition. Performance in these conditions will ultimately be compared against performance in the Studied Position and Centered Position from Experiment 1, and although assignment to experiments was not truly random, these two experiments ran in overlapping weeks.

Results and Discussion

Again starting with the change-detection data, participants in both conditions together correctly detected the location of the change 52% of the time (SD=13%). Participants in the Mirror Image condition correctly identified the location of the change 51% of the time (SD=10%) and participants in the Shifted Position correctly identified the location of the change 53% of the time (SD=16%). When participants were incorrect in their responses, they were a mean of 4.03cm (*SD*=1.22) away from the nearest edge of the critical item.

Considering familiarity ratings from both test conditions together, a One-way Repeated-Measures ANOVA compared familiarity ratings for Unstudied items against Studied/Detected items and Studied/Undetected items. Results indicated a significant difference between means, *F*(2,166)=245.33, *MSE*=0.64, *p*<.001, partial η^2=0.75. Pairwise comparisons using paired-samples *t*-tests revealed that Studied/Detected items received higher familiarity ratings than Studied/Undetected items, *t*(83)=9.38, *SE*=.12, *p*<.001, Cohen's *d*= 1.06, and Studied/Undetected items in turn received higher familiarity ratings than Unstudied items, *t*(83)=12.71, *SE*=.12, *p*<.001, Cohen's *d*= 1.35. This replicates the main findings from Experiment 1 that familiarity ratings for Studied/Undetected items are significantly higher than those for Unstudied items, showing that participants can experience familiarity for items that were never detected.

Comparing familiarity ratings from both test conditions separately, a 2 (Test Condition: Mirror Image vs. Shifted Position) X 3 (Study/Change-Detect Status: Studied/Change-Detected vs. Studied/Change-Undetected vs. Unstudied) Mixed Factors ANOVA was computed, with Test Condition as a between-subjects variable and Study/Change-Detect Status as a within-subjects variable. This revealed the same main effect of Study/Change-Detection as when the conditions were combined, *F*(2,164)=245.89, *MSE*=0.64, *p*<.001, partial η^2=0.75. However, unlike in Experiment 1, there was no main effect of Test Condition, *F*(1,82)<1, *MSE*=2.62, *p*=.94, which indicates that the two different test manipulations did not impact familiarity ratings in distinct ways. Figure 8 presents the mean ratings by Detection/Study status, separated by Test Condition. Unlike in Experiment 1, there is no clear trend or significant difference in ratings between test conditions.

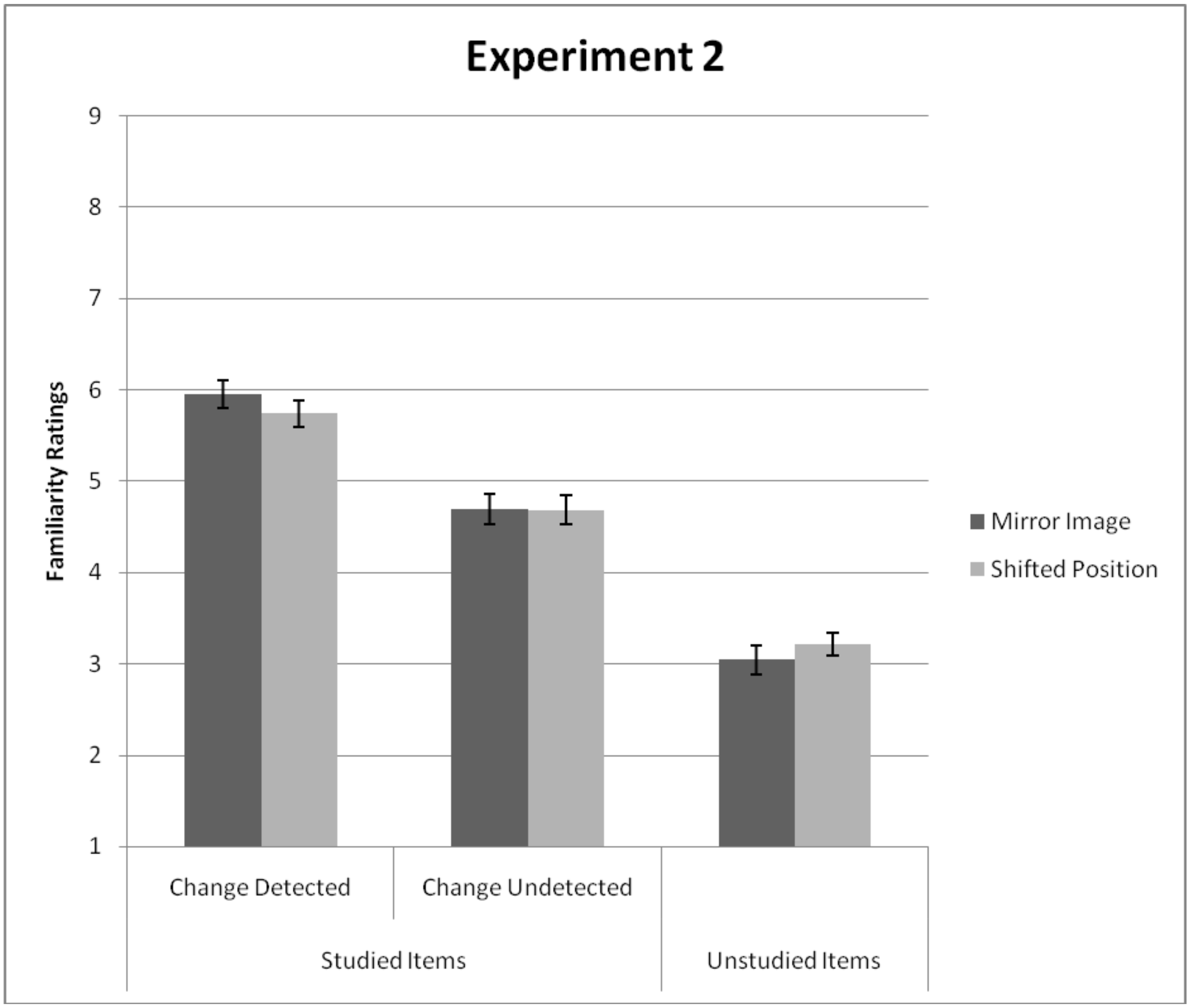

Figure 8. Familiarity ratings in Experiment 2, separated by test condition. Error bars represent standard error.

If the acceptable response is expanded by doubling the width and height of the original response area, the rate of correct detection is increased to 66% (*SD*=13%). When participants were incorrect in their responses, they were a mean of 5.43cm (*SD*=1.40) away from the nearest edge of the critical item. Under the more liberal coding scheme, one participant detected every change, eliminating data for Undetected trials and reducing the degrees of freedom for the following tests. Under this more liberal coding scheme of correct and incorrect detection, Studied/Detected items received significantly higher ratings than Studied/Undetected items, $t(82)=9.30$, $SE=0.14$, $p<.001$, Cohen's $d= 1.11$, and Studied/Undetected items received significantly higher ratings than Unstudied items, $t(82)=9.15$, $SE=0.14$, $p<.001$, Cohen's $d= 1.03$.

However, the ultimate purpose of Experiment 2 is to determine whether any alteration of the critical item's studied position will decrease familiarity, or if uniformity between test trials produced the decrease in familiarity for the Centered Position condition of Experiment 1. To determine this, one must compare from the Mirror Image and Shifted Position conditions of Experiment 2 to the Studied Position and Centered Position conditions of Experiment 1. Although participants were not truly randomly assigned to conditions, the experiments ran in overlapping weeks and had identical procedures. Data from the first 42 participants in each condition were analyzed using a 4 (Test Condition: Studied Position vs. Centered Position vs. Mirror Image vs. Shifted Position) X 3 (Study/Change-Detect Status: Studied/Change-Detected vs. Studied/Change-Undetected vs. Unstudied) Mixed Factors ANOVA, with Test Condition as a between-subjects variable and Study/Change-Detect Status as a within-subjects variable. It revealed no main effect of condition, $F(3,164)=1.45$, MSE=3.19, p=.23, or an interaction between test condition and study/change detection status, $F(3,164)=0.77$, MSE=0.71, p=.52. Looking at the graph of all four conditions together (Figure 9), one can see that the general trend is that shifting the position of the critical items decreased familiarity, but not to the degree that standardizing the position does.

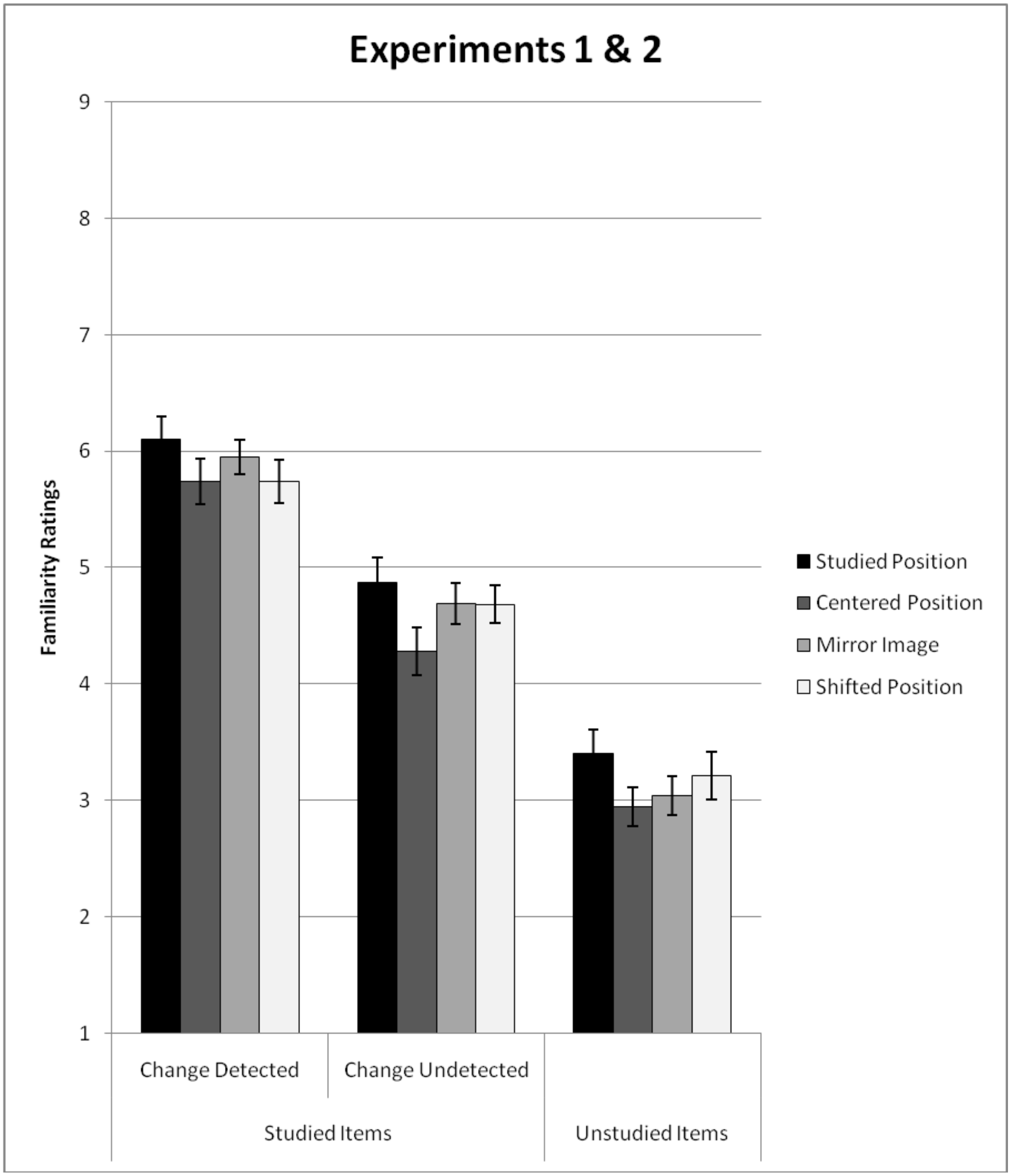

Figure 9. Familiarity ratings from the first 42 participants of Experiments 1 and 2, separated by test condition. Error bars represent standard error.

Experiment 2 replicates the main findings of Experiment 1; familiarity ratings were higher for Studied/Detected items than Studied/Undetected items, which were in turn higher than Unstudied items. However, unlike Experiment 1, Experiment 2 did not find any differences between test conditions, and the hypothesis that location changes could be responsible for decreased ratings was not supported. One possibility is that familiarity ratings are not sensitive to the studied locations of the critical items, as previously suspected, but instead decreased due to increased uniformity between trials. The lower familiarity ratings from Experiment 1 were obtained from items that were all presented in the same location (which also potentially explains the decrease in familiarity ratings for Unstudied items, which should be insensitive to studied vs. different locations). Experiment 3 attempts to answer this question by increasing uniformity between trials in a different way—by presenting critical items in their studied colors or in a standardized grayscale.

Experiment 3

In Experiment 1, critical items appeared in one of two test conditions; they either appeared in their studied relative position in the scene or in a central, standardized location. Results indicated that presenting critical items in the central location tended to decrease ratings, and it was suggested that this could be due to increased uniformity to the trials. Experiment 3 examined whether increased uniformity could also be established by presenting all test items in standardized colors. Just as in Experiment 1, when critical objects appeared at test in either their studied positions or a standardized location, in Experiment 3 the critical objects appeared at test in their studied colors or standardized colors (grayscale). In much the same way that Experiment 2 examined the impact of location on ratings, Experiment 3 also examines the contribution of color information as a potential features used in recognition decisions. Because the previous experiment did not demonstrate any significant effect of manipulating the locations of the critical items at test, an alternative possibility is that increased uniformity caused the decrease in ratings for Center Position items in Experiment 1. Therefore, the hypothesis of the current experiment is that ratings will be lower for critical items presented in grayscale.

Method

Participants. Sixty Colorado State University undergraduates participated in exchange for credit in a psychology course.

Materials. The stimuli were identical to that of Experiment 1, with the following exceptions: All critical objects at test appeared in their studied locations. One group of participants received the critical objects in their studied colors, and another group of participants received the critical objects in grayscale. These test conditions were labeled the "Color condition" and the "Grayscale condition," respectively.

Procedure. The procedure was identical to Experiment 1. Participants were randomly assigned to the Color or Grayscale conditions, whereby participants received only one type of manipulation at test. Thirty participants were in each condition.

Results and Discussion

Participants in both conditions correctly detected the location of the change at study 55% of the time (*SD*=17%). Participants in the Color condition detected the location of the change 55% of the time (*SD*=16%) and participants in the Grayscale condition detected the location of the change 55% of the time (*SD*=19%). When participants were incorrect in their responses, they were a mean of 4.05cm (*SD*=1.25) away from the nearest edge of the critical item.

Considering familiarity ratings from both test conditions together, a One-way Repeated-Measures ANOVA compared familiarity ratings for Unstudied items against Studied/Detected items and Studied/Undetected items. Results indicated a significant difference between means, $F(2,118)=119.84$, $MSE=0.95$, $p<.001$, partial $\eta^2=0.67$. Pairwise comparisons using paired-samples *t*-tests again showed that Studied/Detected items received higher familiarity ratings than Studied/Undetected items, $t(59)=7.29$, $SE=.18$, $p<.001$, Cohen's $d= 0.90$, and Studied/Undetected items in turn received higher familiarity ratings than Unstudied items, $t(59)=7.84$, $SE=.18$, $p<.001$, Cohen's $d= 1.11$. This replicates the main findings from Experiments 1 and 2 that familiarity ratings for Studied/Undetected items are significantly higher than those for Unstudied items, showing that participants can experience familiarity for items that were never detected.

Next is the comparison of familiarity ratings for Color test trials to Grayscale test trials. A 2 (Test Condition: Color vs. Grayscale) X 3 (Study/Change-Detect Status: Studied/Change-Detected vs. Studied/Change-Undetected vs. Unstudied) Mixed Factors ANOVA was performed on the familiarity ratings, with Test Condition as a between-subjects variable and Study/Change-Detect Status as a within-subjects variable. This revealed the same main effect of Study/Change-Detection as when the conditions were combined, $F(2,116)=119.65$, $MSE=0.95$, $p<.001$, partial $\eta^2=0.67$. However, like in Experiment 2 (and unlike in Experiment 1), there was no main effect of Test Condition, $F(1,58)<1$, $MSE=3.78$, $p=.66$, which indicates that the two different test manipulations did not impact familiarity ratings in distinct ways. Figure 10 presents the mean ratings across Detection/Study status, separated by Test Condition. Once again, as in Experiment 2, there is no clear trend or significant difference in ratings between test conditions.

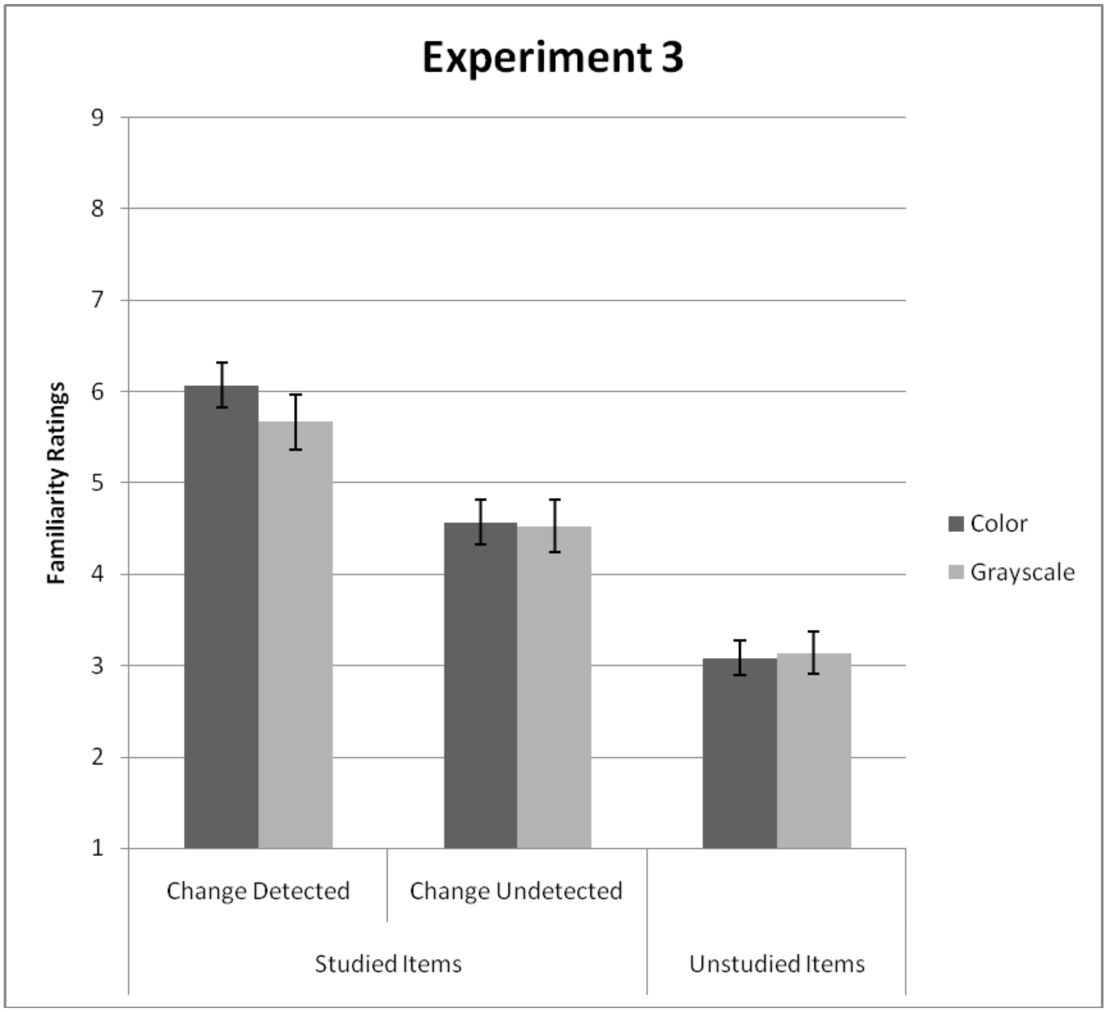

Figure 10. Familiarity ratings in Experiment 3, separated by test condition. Error bars represent standard error.

If the acceptable response is expanded by doubling the width and height of the original response area, the rate of correct detection is increased to 70% (*SD*=17%). When participants were incorrect in their responses, they were a mean of 5.58cm (*SD*=1.36) away from the nearest edge of the critical item. Under this more liberal coding scheme of correct and incorrect detection, Studied/Detected items received significantly higher ratings than Studied/Undetected items, $t(59)=10.41$, $SE=0.16$, $p<.001$, Cohen's $d= 1.18$, and Studied/Undetected items received significantly higher ratings than Unstudied items, $t(59)=5.31$, $SE=0.19$, $p<.001$, Cohen's $d= 0.74$.

The purpose of Experiment 3 was to examine the influence of standardized color information on familiarity ratings. The overall pattern of ratings for Studied/Detected vs. Studied/Undetected vs. Unstudied replicated from Experiments 1 and 2. However, like in Experiment 2 (but unlike in Experiment 1) the comparisons between test conditions revealed no significant differences, and the uniformity hypothesis was not supported. This suggests that the role of color information has limited importance in this recognition memory task, and that increasing similarity between trials had limited effect, although see the General Discussion for a more thorough interpretation of these findings.

Experiments 2 and 3 have mostly served the purpose of replicating the effects obtained in Experiment 1 and examining the stimulus characteristics that contribute to those effects. Overall, the general conclusions are that stimulus characteristics do not play a large role in recognition memory performance for critical items. Even when a stimulus characteristic does exert a significant influence (such as location, in Experiment 1), the effect size is very small. Therefore, the remaining experiments will focus more on the role of response options at study (such as the availability of a Don't Know response) and test (by providing different assessments of recognition memory performance).

Experiment 4

As discussed earlier, the purpose of the change detection task is to simulate the experience of divided perception and examine its effects on familiarity. However, as of yet the experiments have not explicitly investigated the role of recollection in the recognition decisions. Experiment 4 had two purposes: The first was to add a new response option to assess the role of guessing on change detection, and the second was to examine the basis of the familiarity ratings at test. Regarding the first purpose, one aspect of Experiment 1's procedure is that changes occur on every study trial and participants make a response on every trial. The recorded responses cannot discriminate between trials when participants are merely guessing and trials when participants are incorrect. This is an important distinction to make because a pure guess on the change detection task could reflect a diminished ability to encode aspects of the critical item. If this is the case, it would suggest that there is a limit to the recognition that can stem from divided perception, and that some minimal degree of attention is required during encoding. One potential solution to this issue is to provide a “Don’t Know” option when detecting the change. On prior occasions when participants would otherwise have made blind guesses, the Don’t Know option can be used instead to indicate insufficient encoding to even guess. As several other researchers have suggested (Rensink et al., 1997; Wolfe, Reinecke, & Brawn, 2006), some degree of attention is required to detect changes, and a Don’t Know response would indicate extremely low levels of attention—potentially even lower than when detection attempts were simply incorrect. Therefore, it is predicted that ratings for items labeled Don’t Know will be lower than ratings for Undetected items.

The second purpose of Experiment 4 was to examine how participants made familiarity ratings for critical items. One possibility is that participants were simply experiencing familiarity for the critical item. Another possibility is that seeing the critical item at test could cue participants to recollect it as the changing item from study, even if the change was not correctly localized. If this is the case, it would suggest that participants are able to encode characteristics of the item without detecting the change. This issue can be addressed by including an additional recognition test. In the event that participants could not detect the location of the change, but might still recognize the critical item as such if encountered again, a 2-alternative forced-choice (2AFC) test of was included after the rating procedure. In this 2AFC test, participants were asked to pick the critical item from a scene with the alternative being an item that appeared in the scene but did not disappear. This can determine whether participants can be cued to recognize the critical item even without detecting the change. The hypothesis is that the ratings for Undetected items are based on a feeling of familiarity in the absence of cued recollection, which would predict that 2AFC performance will not be significantly different from chance for Undetected items.

Method

Participants. Thirty-nine Colorado State University undergraduates participated in exchange for credit in a psychology course.

Materials. Materials were the same Unaltered and Object Absent scenes and studied color/studied location critical items from Experiment 1 and 2. In addition, 50 items that appeared in scenes but did not disappear were isolated to serve as alternatives in the rating task and 2AFC test. These items that did not disappear in the Object Absent scene were labeled "non-critical items." Non-critical items that appeared in scenes at study are referred to as Studied Non-critical items, and non-critical items that did not appear in scenes at study are referred to as Unstudied Non-critical items.

Procedure. The study/change detection procedure was identical to that of Experiments 1 and 2, with the exception that when participants attempted to detect the location of the change on each Object Absent scene, a red rectangle appeared at the bottom of the screen with the words "Don't Know" in black letters. Participants were told that they were free to guess, but if they truly did not know where an item disappeared, they were instructed to click on the "Don't Know" rectangle. This constituted a "Don't Know response," as referred to in the results section.

During the rating procedure, all participants received the same condition. (There were no between-groups comparisons.) The 50 non-critical items also appeared on the rating task, so that participants rated 100 items unlike the 50 on previous experiments. Twenty-five of these items were critical items from studied scenes (of which some were correctly detected and others were not). Another 25 items were critical items from non-studied scenes. Twenty-five items were non-critical items from studied scenes, and the final 25 items were non-critical items from non-studied scenes. (The reason for the inclusion of the non-critical items on the rating task is explained below.) Items were randomly assigned to study status and all items appeared in random order.

After the rating procedure ended, participants received 50 trials of a 2AFC test. On this test, a critical item appeared on one half of the screen and a non-critical item appeared on the other half (left vs. right). Whether the critical item appeared on the left or right was counterbalanced across participants, and the order of the trials was random. Participants were instructed to pick which item disappeared earlier, during the study procedure. If participants believed the item on the left was the critical item, they were instructed to push the A key. If participants believed the item on the right was the critical item, they were instructed to push the L key. An A or L label appeared beneath each item. In half the trials, neither the critical item nor the non-critical item appeared during the study procedure, which was used as a control to detect whether participants could pick the critical item at above-change levels even when neither item appeared at study (which would indicate some fundamental difference between critical and non-critical items). Participants had an unlimited amount of time to decide, and there was a one-second interval between trials. This task was included to test the possibility that participants are being cued to recollect the critical item from study, even without being able to detect the location of the change. The reason that the non-critical items also appeared on the rating task earlier in the experiment was to control for recent exposure. If the non-critical items had not appeared on the rating task and only the critical items had, participants may have been able to correctly the pick the critical item simply because they recognized it as familiar from the rating task.

Results and Discussion

Participants correctly detected the location of the change 53% of the time (*SD*=16%). Participants were incorrect 36% of the time (*SD*=17%) and used the Don't Know response 11% of the time (*SD*=11%). Eleven participants did not use the Don't Know response at all. When participants were incorrect in their responses, they were a mean of approximately 3.63cm (*SD*=1.09) away from the nearest edge of the critical item.

Analyses on the familiarity ratings in this experiment are slightly different from previous experiments, as the rating task included non-critical items (which were items that did not disappear from scenes) which were either studied or unstudied. It is important first to see whether there is any difference in familiarity ratings between critical and non-critical items, regardless of detection status. Results show that there is not; ratings for Studied/Critical items were not significantly different Studied/Non-critical items, $t(38)=0.79$, $SE=0.17$, $p=.43$. At first glance, this is a strange finding, as Non-critical items received more exposure than Critical items, and familiarity ratings might be expected to be higher for items with more exposure time. However, factoring in Detection status shows that Detected Critical items received significantly higher familiarity ratings than Studied/Non-critical items, and Undetected/Critical items received significantly lower familiarity ratings than Studied/Non-critical items. The ratings for Detected and Undetected items which were combined for an overall "Studied Critical" group were simply averaging out to create a null difference. There was also no significant difference between Unstudied Critical and Unstudied Non-critical items, $t(38)=0.71$, $SE=0.11$, $p=.48$. This latter result is reassuring in that it shows that familiarity is roughly comparable between critical and non-critical items, which is an important consideration for the analysis of the 2AFC test (reported later). The subsequent analyses of familiarity ratings by detection status will focus only on critical items (as non-critical items were not a component of the detection task).

A One-way Repeated-Measures ANOVA was conducted on the familiarity ratings for critical items that were Studied/Detected, Studied/Undetected, Studied/"Don't Know", and Unstudied. (The Unstudied ratings were only for critical items so that they would represent familiarity for the same items across participants.) This revealed a significant difference between conditions, $F(3,81)=42.41$, $MSE=1.19$, $p<.001$, partial $\eta^2=0.61$. Using paired-samples *t*-tests as pairwise comparisons reveals that ratings for Studied/Detected items were significantly higher than Studied/Undetected, $t(38)=5.05$, $SE=0.24$, $p<.001$, Cohen's $d=0.88$, which replicates the same pattern from previous experiments. Ratings for Studied/Undetected items were also significantly higher than Don't Know items, $t(27)=4.09$, $SE=0.35$, $p<.001$, Cohen's $d=0.80$, and Unstudied items, $t(38)=9.00$, $SE=0.17$, $p<.001$, Cohen's $d=1.11$, which was predicted. However, ratings for Don't Know items were not significantly different from Unstudied items, $t(27)=0.48$, $SE=0.31$, $p=.63$. Figure 11 presents the mean ratings for each type of test item. The pattern of Detected, Undetected, and Unstudied is very much the same as in previous experiments, with the novel finding that Don't Know items receive comparable ratings as Unstudied items.

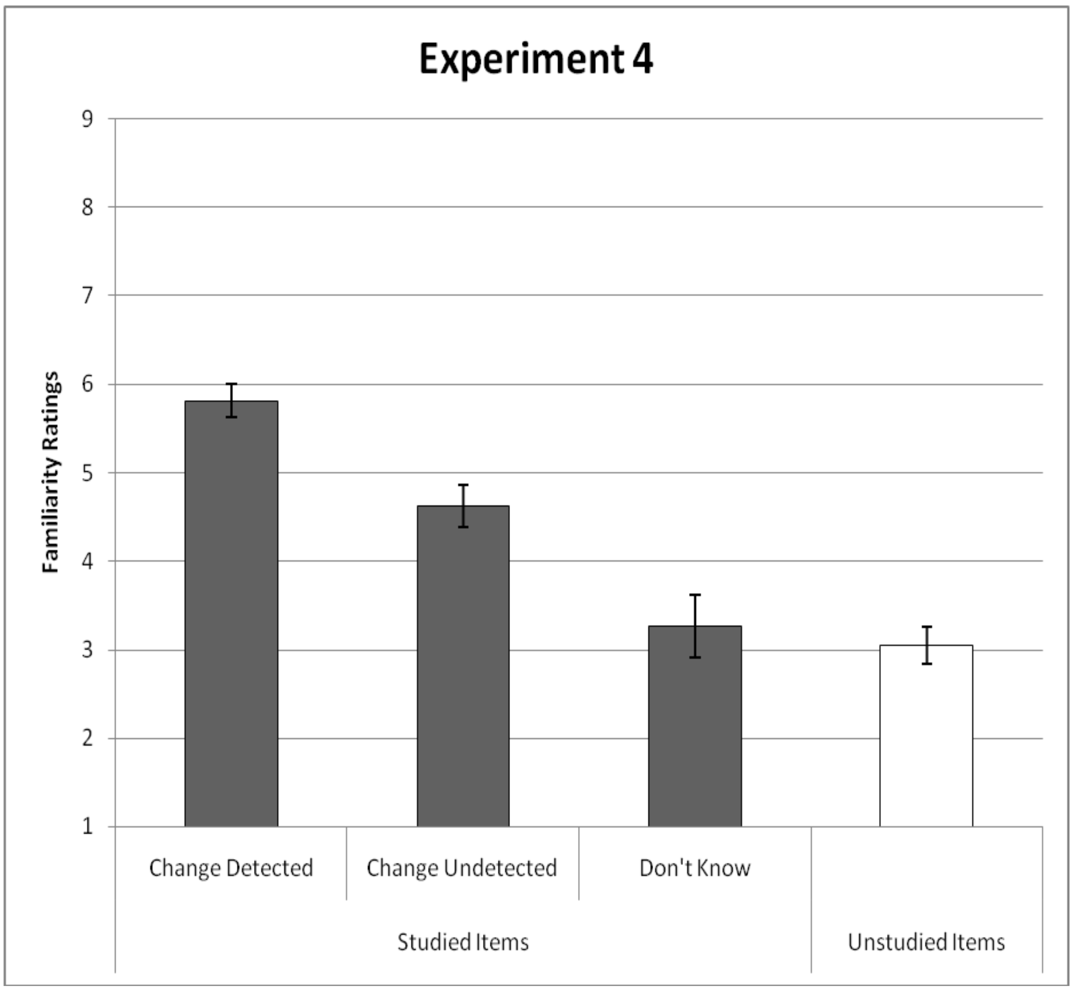

Figure 11. Familiarity ratings for critical items from Experiment 4, separated by Detection/Study status. Error bars represent standard error.

If the area of acceptable response is expanded by doubling the width and height of the original response area, the rate of correct detection is increased to 65% (*SD*=15%) and the incorrect detection rate decreases to 24% (*SD*=14%). The incorrect responses were a mean of approximately 5.33 cm away from the nearest edge of the expanded response area (*SD*=1.91). The rate of Don't Know responses was not affected because the Don't Know response area was separate from the rest of the scene. Under this more liberal coding scheme of correct and incorrect detection, Studied/Detected items received significantly higher ratings than Studied/Undetected items, $t(38)=4.90$, $SE=0.29$, $p<.001$, Cohen's $d=0.92$, and Studied/Undetected items received significantly higher ratings than Don't Know items, $t(27)=2.87$, $SE=0.37$, $p<.01$, Cohen's $d=0.54$, and unstudied items, $t(38)=4.83$, $SE=0.24$, $p<.001$, Cohen's $d=0.69$. Again, the classification of Don't Know and Unstudied is not affected by the area of acceptable response, so that comparison is the same as under the original coding scheme.

Moving on to the results of the 2AFC, the proportions of correct responses are presented in Table 1. The proportions of correct responses seem to present a pattern of results similar to that measured by ratings; participants were reliably better at picking the critical item when it was studied than when it was unstudied, $t(38)=6.89$, $SE=.03$, $p<.001$, and a one-sample *t*-test shows that participants were no better than chance at picking the correct item when it was unstudied, $t(38)=1.76$, $p=.09$. Among studied items, participants were better at picking the critical item when it was Detected than when it was Undetected at study, $t(38)=3.55$, $SE=.03$, $p<.001$, but there was no significant difference in performance between items that were Undetected and Don't Know, $t(27)=0.70$, $SE=.08$, $p=.49$, or between items that were Don't Know and Unstudied, $t(27)=1.17$, $SE=.06$, $p=.25$. Performance for Undetected items was better than Unstudied items, $t(38)=3.38$, $SE=.03$, $p<.01$. Interestingly, performance for Undetected items was significantly better than chance, $t(38)=4.71$, $p<.001$, but performance for Don’t Know trials was not, $t(27)=1.76$, $p=.09$ (although this effect is marginal). The same pattern of results appears when using the more liberal classification of Detected and Undetected.

Table 1

Proportion correct on 2AFC test from Experiment 4.

	Unstudied		Studied (All)		Studied					
					Detected		Undetected		Don’t Know	
	M	*SD*	***M***	*SD*	***M***	*SD*	***M***	***SD***	***M***	***SD***
	.53	*.11*	**.71**	*.11*						
Original Area					**.77**	*.12*	**.65**	*.20*	**.61**	*.33*
4X Area					**.74**	*.13*	**.66**	*.22*	**.61**	*.33*

Note. The Studied and Unstudied proportions are out of all 25 items, and the proportions of Change Detected, Change Undetected, and Don’t Know responses are out of the total number of each type of response during study.

One possibility these results suggest is that participants are basing their 2AFC decisions for Undetected items on relative familiarity. When an item is Detected, participants are able to make the correct choice because they recollect the critical item from when it was detected at study. When an item is Undetected, participants may have experienced more familiarity for the non-critical item (due to greater exposure time) and then used that familiarity to infer that the other choice was the critical item, allowing participants to correctly pick the critical item at above-chance levels even when the it was undetected. However, results from the familiarity rating task (which occurred before the 2AFC task) show that there was no significant difference between familiarity ratings for Undetected Critical items and Non-critical items in scenes whose

Critical items were undetected, $t(38)=0.65$, $SE=0.32$, $p=.52$. This suggests that the above-chance performance for Undetected items on the 2AFC is not likely due to relative familiarity.

The results of the 2AFC test replicate the results of Angelone et al., (2003), in that participants are reliably better than chance at picking the changing item even when the change was not detected at study. In the context of this experiment, the purpose of the 2AFC test was to determine whether participants might actually be cued to recollecting the critical items during the familiarity rating task, even when the items could not be detected at study. These results seem to suggest that is a possibility, and go against the hypothesis that ratings for Undetected items are made on the basis of familiarity. However, in an additional analysis of trials when participants did not pick the critical item in the 2AFC test, familiarity ratings are still significantly higher for undetected items ($M=3.69$, $SD=2.02$) than unstudied items ($M=2.87$, $SD=1.44$), $t(36)=2.93$, $SE=.28$, $p<.01$. Therefore, this provides support that the ratings can be based on only feelings of familiarity without recollection processes because ratings were still higher for critical items than unstudied items, even when the critical items were neither detected at study nor recollected during the 2AFC task.

The main conclusions from this experiment were that trials when participants were unable to guess the location of the change produced comparable recognition performance (in familiarity ratings and 2AFC responses) as when participants never saw the item at all, as predicted by the hypothesis for Don't Know responses. This suggests that in a state of divided perception, observers must experience a certain minimum level of attention if they are to later recognize the item. In other words, there may be a limit to how "divided" perception can be in order to later experience familiarity for undetected items. This experiment also incorporated the use of a 2AFC test to measure recognition of critical items to examine whether participants may have been cued to recollect the critical item even when they did not detect the change. The results showed that even when participants did not correctly detect the location of the critical item at study, they could still pick the correct item in a 2AFC, which suggests that the higher familiarity ratings for undetected items may have been driven by cued recognition for the critical item during the rating task. However, a subsequent analysis showed that even when participants could not pick the correct item on the 2AFC, and the item was undetected at study, familiarity ratings were still higher than for unstudied items. This supports the hypothesis that ratings can be made only on feelings of familiarity, and also supports the Divided Perception theory in general, because analyses showed that even if participants *can* recognize an item that was not detected on the basis of a cue, they do not always do so, and controlling for this, participants can still experience familiarity for undetected and uncued critical items.

Experiment 5

The results of Experiment 4 suggest that participants may be able to sometimes recollect the occurrence of the critical item at study even when they could not correctly detect the location of its change. Although this does not completely rule out the role of familiarity (the final analysis actually supported the role of familiarity), it opens the question of how much contribution recollection and familiarity each make for recognition of undetected items. In other words, it is not clear how change detection corresponds to recollection vs. familiarity. Experiment 5 investigated this by using a well-studied method of estimating the contributions of recollection and familiarity in recognition judgments--the Remember-Know procedure. The current procedure included a Remember-Know judgment for each critical item at test to measure which items participants recognized on the basis of recollection and which items participants recognized on the basis of familiarity, with Remember responses corresponding to recollection and Know responses corresponding to familiarity. This was aimed at determining whether change detection contributes to later recollection, with the hypothesis being that detection will promote recollection processes while having less effect on familiarity processes. The prediction is that participants provide more Remember judgments for detected items compared to undetected items, and more

Know judgments for undetected items compared to new items (which would suggest familiarity-based discrimination). Unstudied items will likely receive a large proportion of "New" judgments.

Method

Participants. Twenty-nine Colorado State University undergraduates participated in exchange for credit in a psychology course.

Materials. The stimuli were identical to that of Experiment 1, with all stimuli appearing in their studied colors, and all critical objects appearing in their studied locations at test.

Procedure. The procedure was identical to that of Experiment 1, with the exception that instead of rating the familiarity of each critical item at test, participants provided an Old/New judgment for each item. The terms "Old" and "New" correspond to Studied and Unstudied, respectively, such that an Old item appeared in a scene on the study list and a New item did not appear in a scene on the study list. If participants indicated the item was New (by pressing "N"), the next item appeared on the screen. If participants indicated the item was Old (by pressing "O"), they were prompted to indicate how they made the recognition judgment. They were told that if they could specifically remember seeing the object on the study list, they should press "R" for Remember. If they could not specifically remember seeing the object but they knew on some other basis that the item appeared earlier, they should press "K" for Know. The instructions and general procedure were based off of those used by Rajaram (1993).

Results and Discussion

Participants correctly detected the location of the change 52% of the time (*SD*=14%). When participants were incorrect in their responses, they were a mean of 4.02cm (*SD*=1.25) away from the nearest edge of the critical item. When the acceptable response area is increased by doubling the width and height of the original area, the correct detection rate increases to 67% (*SD*=15%), with incorrect responses being a mean of 5.61cm (*SD*=1.37) away from the nearest edge of the critical item. Due to the controversy surrounding the calculation and analysis of Remember-Know data (see Yonelinas, Kroll, Dobbins, Lazzara & Knight, 1998), the proportions of Remember, Know, and New responses were calculated two different ways. The first way followed Rajaram's (1993) method of raw proportions, in which the number of items correctly detected at study was used to calculate the proportion of Studied Remember, Know, or New responses when Detected or Undetected. This was done by dividing the number of Remember, Know, or New responses at test by the number of times each participant detected or failed to detect the change at study. The False Alarm rate was also calculated by dividing the number of items called Old (either Remember or Know) by the number of Unstudied items (which was always 25). The second way addressed the Independence Remember-Know (IRK) assumption proposed by Yonelinas and Jacoby (1995) by calculating conditional probabilities. In this method, the proportion of Studied Remember responses were calculated the same way as before (as the number of Remember responses divided by the number of Detected or Undetected items), but the proportion of Know responses was calculated by the dividing the number of Know responses by the number of Detected or Undetected items, all divided by one minus the proportion of Studied Remember responses. This is to account for the smaller number of trials to which participants can respond Know. To calculate False Alarms, the proportion of Remember responses was calculated by dividing the raw number of Remember responses by the number of Unstudied items (again, always 25), and the proportion of Know responses was calculated by dividing the number of Know responses by 25 over one minus the proportion of Remember responses. Table 2 presents the mean proportions of Old and New responses, as well as the proportions of Remember and Know responses for Old items. Both raw proportions and conditional probabilities are presented for Know responses. False Alarms, appearing on the far right, represent Old and Remember/Know responses for unstudied items. The proportions are presented for items labeled Detected under the original area and the expanded area, although there appear to only be minor differences. The pattern of Old responses again mirrors the pattern of results measured by the 2AFC task as well as ratings, with interesting new insights into the self-described uses of recollection and familiarity processes.

Table 2

Mean proportion of hits and false alarms by response type when items were Detected or Undetected at study in Experiment 5.

	Detected		Undetected		False Alarms	
	M	*SD*	***M***	*SD*	***M***	*SD*
Original Area						
Overall Recognition	**.65**	.17	**.48**	.17	**.24**	.15
Remember	**.51**	.19	**.26**	.15	**.08**	.09
Know (Raw)	**.14**	.13	**.22**	.12	**.16**	.13
Know (Conditional)	**.30**	.20	**.30**	.16	**.18**	.14
4X Area						
Overall Recognition	**.64**	.17	**.43**	.20	**.24**	.15
Remember	**.48**	.19	**.21**	.18	**.08**	.09
Know (Raw)	**.16**	.13	**.22**	.16	**.16**	.13
Know (Conditional)	**.31**	.19	**.28**	.22	**.18**	.14

Starting with the analysis of the raw proportions, A One-way Repeated-Measures ANOVA on proportion of Old responses for Detected, Undetected, and Unstudied items indicated a significant difference, $F(2,90)=107.07$, $MSE=.02$, $p<.001$, partial $\eta^2=0.70$, with Detected items being called Old more frequently than Undetected items, $t(45)=6.67$, $SE=.03$, $p<.001$, Cohen's $d=1.06$, and Undetected items were called Old more frequently than Unstudied items, $t(45)=8.51$, $SE=.03$, $p<.001$, Cohen's $d=1.50$. This replicates the recognition performance from previous experiments. The same pattern of results occurs when using the data from the expanded acceptable response area.

When the recognition data are separated into Remember and Know responses, Detected items received significantly more Remember responses than Undetected items, $t(45)=9.11$, $SE=.03$, $p<.001$, Cohen's $d= 1.46$, while Detected items received significantly fewer Know responses than Undetected items, $t(45)=3.2$, $SE=.02$, $p<.01$, Cohen's $d= 0.64$. In a 2 (Response Type: Remember vs. Know) x 2 (Detection Status: Detected vs. Undetected) Repeated-Measures ANOVA, this manifests itself in a significant interaction, $F(1,45)=56.36$, $MSE=.02$, $p<.001$, partial $\eta^2=0.56$, in which Remember Responses are more likely for Detected items, but Know responses are more likely for Undetected items. Know responses were also significantly higher for Undetected items than Unstudied items, $t(45)=2.26$, $SE=.02$, $p<.05$, Cohen's $d= 0.48$, which suggests a role of familiarity-based discrimination in Undetected items. Remember responses were also more likely for Undetected items than Unstudied items, $t(45)=8.76$, $SE=.02$, $p<.001$, Cohen's $d= 1.50$, which suggests that participants may be able to recollect an item despite failing to detect it (see below for a discussion). The same pattern of results occurs when using the data from the expanded acceptable response area, with the exception that the difference in Know responses between Detected and Undetected items is only marginally significant ($p=.07$), as is the difference between Undetected and Unstudied items ($p=.06$).

Moving on to the conditional probabilities, there is no significant difference in the rate of Know responses between Detected and Undetected items, $t(45)=0.22$, $SE=.04$, $p=.82$, although there was a significant difference in Know responses between Undetected and Unstudied items $t(45)=4.27$, $SE=.03$, $p<.001$, Cohen's $d=0.80$. Remember items were calculated the same was as in the raw proportions, so those comparisons are the same as before. The 2 x 2 (Response Type: Remember vs. Know) x (Detection Status: Detected vs. Undetected) Repeated-Measures ANOVA, still shows a significant interaction, $F(1,45)=29.57$, $MSE=.03$, $p<.001$, partial $\eta^2=0.40$, in which Remember responses are more likely for Detected items, but there is no significant difference in Know responses between Detected and Undetected items. The same pattern of results occurs when using the data from the expanded acceptable response area.

Finally, regarding reaction time data, a 2 x 2 (Response Type: Remember vs. Know) x (Detection Status: Detected vs. Undetected) Repeated-Measures ANOVA showed no difference in the speed with which participants made Remember or Know judgments, p's>.15.

The results of this experiment replicate the findings from previous experiments using a different measure of recognition memory performance. Instead of providing familiarity ratings on a continuous scale, participants provided dichotomous Old/New judgments for each item and specified whether each Old judgment was made on the basis of recollection or familiarity. Participants provided more Old responses for Detected items than Undetected items, which received more Old responses than Undetected items. This follows the pattern obtained using familiarity ratings. Examining the pattern of Remember-Know responses suggests that successfully detecting the location of the change at study leads to a higher likelihood of reporting Recollection at test. However, given the fact that participants gave more Remember responses to Undetected items than Unstudied items, it appears that failure to detect the location of the change at study does not preclude later recollection. This seems to explain the results from Experiment 4, which show that participants could still pick the critical item in the 2AFC test despite not detecting it at study. This supports the hypothesis that detection does seem to promote recollection, as Remember responses were more likely for detected items, but recollection is still possible for undetected items (although less likely). Proportions of Know responses were comparable for Detected and Undetected items, which shows that familiarity is less affected than recollection by varying levels of attention. Similar findings occur in studies for divided attention (Jacoby, 1991; Yonelinas, 2002). Finally, Know responses were more likely for Undetected items than Unstudied items. Taken together, this suggests that participants are more likely to rely on familiarity in the recognition of Undetected items, as predicted. The two methods of calculating Know responses mostly agreed, with the raw proportions suggesting that Know responses are slightly more likely in the Undetected than Detected condition, which would suggest that recognition of Undetected items rely more on familiarity, but this analysis does not hold when using a more liberal classification of detection. In addition, Yonelinas et al. (1998) showed that amnesics appeared to demonstrate enhanced familiarity (according to raw proportions of Know responses) when at best they should only show unimpaired familiarity compared to controls, which was one motivation to calculate conditional probabilities. With this in mind, the conditional proportions probably reflect a more accurate measure of familiarity.

General Discussion

The purpose of this study was to examine whether conditions described by the Divided Perception theory of déjà vu (Brown, 2003, 2004) would allow participants to experience feelings of familiarity for unattended objects. This set of experiments simulated conditions of divided perception by using a change detection task, and found a highly replicable effect in which undetected items evoked higher familiarity ratings than unstudied items. As familiarity is a strong component of déjà vu experiences (e.g., Cleary, 2008), this research is a necessary first step towards showing that divided perception could lead to déjà vu experiences. No prior research has examined the Divided Perception theory, and very few studies in cognitive psychology have investigated the cause of déjà vu experiences. Therefore, the current study represents a potential new direction for this burgeoning field of research.

Overview of Current Experiments

All experiments presented above followed the same general procedure. The stimuli were photographs of everyday scenes containing various objects, and as each scene alternated to an identical scene with one object absent (the critical item), participants were charged with detecting the area in the scene where something disappeared. Later in the experiment, participants took a recognition memory test for items that appeared earlier in the experiment (some of which were successfully detected, some not) and items that did not appear earlier in the experiment.

Experiments 1, 2, 3, and 5 had identical study procedures, and Experiment 4 was different only in providing an option for participants to indicate that they did not know where the change took place. All experiments found that participants successfully detected the location of the change around 50-55% of the time, measured by whether participants could click in the space formerly occupied by the critical item. If a more liberal response area is used, which is four times as large as the original response area, the rate of correct detection increases to around 65-70% accuracy, but this does not alter the results of the recognition tests.

Experiment 1 presented the critical items at test either in their studied locations (where they originally appeared in the study scenes) or in the center of the screen. Results showed that overall, participants gave the highest familiarity ratings to items that were detected. Ratings for undetected items were lower, but still significantly higher than ratings for unstudied items. This established the findings, obtained in all following experiments, that change detection at study enables superior performance on a subsequent recognition test, but participants are still able to recognize an item even without detecting it. Regarding the location of the critical item at test, results showed that familiarity ratings were slightly lower for items presented in the center of the screen. This suggested the possibility that moving the critical item from its studied location, or possibly increasing uniformity between all stimuli, would serve to make each stimulus less familiar. These possibilities were examined in Experiments 2 and 3.

Experiment 2 examined whether location shifts were responsible for the decrease in familiarity ratings in Experiment 1. Critical items at test appeared in a shifted location (somewhere they didn't originally appear at study) or as mirror-reversed images of themselves. These two conditions did not produce significant differences in ratings from each other, nor from the two conditions in Experiment 1 (although the overall pattern of ratings for Detected, Undetected, and Unstudied items was the same as Experiment 1). This provided evidence against the possibility that location differences alone produced the ratings decrease in Experiment 1, and Experiment 3 went on to examine whether the possibility that increased uniformity between stimuli produced the effect.

In Experiment 3, critical items at test either appeared in their studied colors or in a more standardized grayscale. As in Experiment 2, the overall pattern of ratings for Detected, Undetected, and Unstudied was the same, but there were no significant differences in ratings when items appeared in Color or grayscale. This provided evidence against the possibility that uniformity alone produced the ratings decrease in Experiment 1. The most likely conclusion is that some combination of location differences and interstimulus similarity produced the ratings decrease for centrally-located critical items in Experiment 1, and that the effects were small enough to make isolating them difficult.

Overall, Experiments 1-3 examined how stimulus characteristics potentially contribute to recognition of undetected items. Results showed that the stimulus characteristics manipulated in these experiments had weak or inconsistent effects. This is in contrast to previous work that shows participants can be extremely sensitive to minor changes in scenes. Not only are participants capable of recognizing hundreds of images with 90% accuracy at delays of up to a week (Shepard, 1967), but participants can show equally high levels of performance in discriminating between a studied object and the same object in a different pose (Brady et al., 2008).

However, other findings show that participants may recognize objects despite minor changes to location, orientation, or color. For example, Experiment 2 showed that familiarity ratings for mirror-reversed images of critical items were numerically lower but not significantly lower than unaltered items. Hintzman, Curran, and Oppy (1992) discovered a similar effect, in which participants provided frequency judgments for items that had appeared 0-15 times. Frequency judgments increased as actual frequency of presentation increased, but participants also provided greater-than-zero frequency judgments for mirror images of studied items, even though those mirror images never actually appeared earlier. In other words, participants falsely recognized mirror images of studied images. DiGirolamo and Hintzman (1997) even found that memory for an object can be strengthened by repeated presentations of that object's mirror image. The current results are in concordance with prior work suggesting that participants may treat mirror images of objects as more or less interchangeable. Regarding the color manipulation of Experiment 3, prior work has shown that color information may enhance recognition of scenes, but only when the color information is "diagnostic" (Nijboer, Kanai, de Haan, & van der Smagt, 2008). In this context, diagnostic color information may help people to recognize grass, which is always green, but not a cup, which could be any color. Nijboer et al. actually found that for recognition of objects was superior when presented in grayscale, rather than full color, due to a higher false-alarm rate for artificial objects. Overall, these findings may suggest that participants are attending primarily to meaning-based information. Information in visual images can involve size, color, location, and others, but these attributes can be altered without changing the identity of the object (Kostic & Cleary, 2009). Simons (2000) has even pointed out that attending to the meaning of a scene, rather than perceptual details, is one factor that could contribute to the phenomenon of change blindness.

Experiment 4 began investigating different response options at study and test. At study, participants had the option of responding "Don't Know" during the change detection task. In Experiments 1, 2, and 3, participants were required to respond on every trial, which did not allow for comparisons in ratings between trials in which participants thought they were correct and trials in which participants were guessing. Experiment 4's Don't Know response option allowed for these comparisons, which addressed whether presentation of a stimulus under the extremely low levels of attention would still allow the observer to later experience familiarity. Experiment 4 also included a second type of recognition test, after the rating task, as an investigation into whether the higher familiarity ratings for Undetected items compared to Unstudied items could be driven by participants cued to recollect the Critical item even when it was not detected. In a 2-Alternative Forced Choice (2AFC) test, the critical item from one of the scenes appeared next to a non-critical item (one that did not disappear) from that same scene and participants had to pick which of the items disappeared at study. To date, most prior work on recognition in change detection has made use of 2- or 4-AFC, but no studies until this one have compared performance between different types of recognition task. Results replicated the effects from previous experiments; participants provided the highest familiarity ratings for items that were detected at study, and lower familiarity ratings for items that were not detected, although these ratings were still significantly higher than ratings for unstudied items. Interestingly, when participants responded Don't Know, the ratings were not significantly different from when the items were unstudied. In other words, Don't Know trials may correspond to trials when participants were paying very little attention. The results of the 2AFC test corresponded with familiarity ratings; highest accuracy was for items that participants had detected at study, and accuracy was lower for undetected items although performance was still significantly better than chance. Accuracy for Don't Know and Unstudied items was not significantly better than chance. This replicates 2AFC performance from previous studies (e.g., Angelone et al., 2003), but also suggests that the difference in ratings is due to recollection. However, even when participants did not pick the correct item on the 2AFC, familiarity ratings for Undetected items were still significantly higher than Unstudied items, which shows that recollection is not always driving the difference in familiarity ratings. Nevertheless, the results of the 2AFC test show that recollection processes may be involved on the rating task, and Experiment 5 investigated this.

Experiment 5 used a Remember-Know procedure to estimate the contributions of recollection and familiarity processes to performance on the recognition test. After each critical item appeared on the recognition test, participants first responded O or N to indicate if the item was old (studied) or new (unstudied), respectively. If participants responded N, the trial ended and the next critical item appeared on the screen. If participants responded O, they were told to specify how they made the recognition judgment. They were instructed that if they specifically remembered seeing the item earlier, they should push R for Remember (which corresponds to recollection). If they did not specifically remember seeing the item, but they know it appeared, they should push K for Know (which corresponds to familiarity). Although previous studies have examined manipulations of attention on recollection and know processes (Jacoby, 1991), none have examined these processes under conditions of change blindness. Results showed that participants were more likely to press R for detected items than undetected items, which suggests that change detection seems to contribute to later recollection. Furthermore, participants were more likely to press K for undetected items than unstudied items, which shows that even when participants to not recollecting seeing an item before, they are still able to discriminate old from new on the basis of familiarity. However, detection does not always lead to recollection, as not every detected item received an R response. Many undetected items received R responses as well (significantly more than unstudied items), which shows that participants may be recollecting items even without detecting them at study. Nevertheless, this experiment does provide evidence that detection can contribute to later recollection of undetected items, although recollection is less likely to occur for undetected items while familiarity remains constant. This relates well to Divided Perception theory, in that it shows that familiarity is more likely to be used as the basis for recognition decisions when attention was disrupted. Similar findings come from tradition Divided Attention tasks, such as those reported by Jacoby (1991) and others (Yonelinas, 2002). In the first two experiments of Jacoby's study, participants made old-new judgments of words while engaging in a listening task, which consisted of listening to a random sequence of numbers and indicating when three odd numbers were presented consecutively. Results showed that divided attention was more likely to hinder recollection processes more than familiarity processes, and decisions based on familiarity were more or less constant across conditions of full or divided attention (similar to the results of the current paper's Experiment 5). Jacoby also discusses the "factor pure problem" of how no task relies on only one process. This same issue is evident in the current findings that recognition decisions for detected items rely on more than just recollection, and decisions for undetected items rely on more than just familiarity.

Implications for the Present Findings for Theories of Change Blindness

The current results concur with previous work in showing that observers can recognize undetected items, and the current experiments extend prior work using different methods of assessing change detection and recognition performance. Starting with the change detection task, much prior work on change detection (e.g., Angelone et al., 2003, Rensink et al., 1997) has assessed change detection by simply asking participants whether they noticed a change, and sometimes even asking this question after the stimuli are no longer visible. This measure may not be sensitive enough to register all instances of change detection, and allow for the possibility that participants may have noticed a change but forgotten it by the time they were interviewed. Fernandez-Duque and Thornton (2000) claim that verbal reports are a poor measure of change detection, and demonstrate that participants can indicate the location of a change even without being aware that a change took place. For that reason, the current study measured change detection by having participants indicate the location of the change, not the identity of the change or simply whether a change took place. This is in accordance with research that has shown that an important part of change detection is focusing attention on the area in which a change occurs (Rensink et al., 1997; Rensink, 20002). Hollingworth and Henderson (2002) showed that change detection could occur even when participants were not focusing on the object during the change, although participants needed to have focused attention on the object at some point in time (not necessarily during detection). Wolf et al. (2006) found that participants failed to detect color changes in arrays of dots even when cued to the location of the change, if they were not focusing attention on the dot during the change. Having this more accurate means of assessing change detection allows for a more accurate means of assessing recognition, as well. In terms of assessing recognition, the current set of experiments also included the first instance of examining the role of recollection and familiarity processes in recognizing undetected objects. Prior work has only examined whether participants could recognize undetected objects, but not how those objects are recognized.

In addition, the inclusion of different response options in the study procedure (in Experiment 4, below) allows for analysis of the role of guessing. The results of Experiment 4 demonstrate a novel effect in change detection, in that when participants did not feel they could accurately detect the location of the change, later familiarity for that item is comparable to familiarity for items that never appeared. In other words, although previous work has suggested that change detection can be an implicit process (Fernandez-Duque & Thornton, 2000), this work suggests that participants at least have enough explicit knowledge of the representation to indicate when they will not be able to recognize a change, which is in line with other work showing that change detection can be explained through explicit processes (Mitroff, Simons, & Franconeri, 2002).

Finally, a theoretical debate in the change detection literature revolves around whether change blindness occurs because representations are brief and fleeting (Noë et al., 2000) or because observers form representations of pre- and post-change objects but fail to compare them (Simons & Rensink, 2005b). The current set of experiments do not support the theory of brief representations because the participants demonstrated retained representations of pre-change objects over the course of several minutes. Although these results fit better under the failure-to-compare theory, to truly evaluate the theory a better experimental manipulation would be to replace the pre-change object with a post-change object, as performed by Mitroff et al., (2004). However, this manipulation would not be as appropriate at simulating the conditions of divided perception, so it was not included in this study.

Applying the Change Blindness Paradigm to the Study of Divided Perception Theory

As discussed earlier, a change detection task was used in these experiments as a means of simulating conditions of divided perception. Clearly, change blindness is not the same phenomenon as divided perception, but they share similarities. For example, both involve manipulations of attention. While change blindness has been shown to depend heavily on where the observer directs attention (Rensink, 2002), Divided Perception is more similar to being distracted by something. Brown (2004) describes having one's attention quickly drawn away from the object by some internal or external distraction. Thus, both types of tasks prevent the object from fully entering consciousness, and the change detection task incorporates elements from both experiences. Correctly determining the location of the change is a measure of where attention is being focused, while the external distraction is simulated by limiting presentation durations of critical items to 2 seconds.

One difference between change blindness and divided perception is that change blindness merely allows for some degree of encoding of the critical item, although at levels lower than detected items. Divided perception, on the other hand, is supposed to lead to extremely high levels of familiarity—higher than those obtained in the current experiments. Perhaps one reason for this difference is due to source attribution (Johnson, Hashtroudi, & Lindsay 1993). It is possible that in real-life instances of divided perception, the source of the familiarity may be unapparent, so the déjà vu experient attributes the familiarity to some other source (such as a dream). However, in a laboratory-based change blindness experience, even though the participant does not recall seeing the changing object before, it is easy to think of a source for the familiarity—the study list that occurred earlier in the experiment (although the participant may not be aware of the *specific* experimental source). This is in line with Jacoby and Whitehouse's (1989) claim that items are only falsely recognized if the participant is unaware of the source of the familiarity, as well as Whittlesea's discrepancy-attribution hypothesis, that states that fluently-processed items are only interpreted as familiar if the fluency is somehow surprising in that context (Whittlesea & Williams, 2000). A major goal of future work on Divided Perception theory should be to investigate situations that would evoke higher feelings of familiarity for undetected items than detected ones, possibly with uncertainty as to their source (or lead to attributions of familiarity to extra-experimental sources). It is also important to keep in mind that divided perception is currently a theoretical cause of déjà vu, and most of the evidence for it is anecdotal, not empirical. Therefore, demonstrating that divided perception can lead to strong (as opposed to slightly increased) feelings of familiarity is an important future step in supporting Divided Perception theory as a potential explanation of déjà vu. Finally, to ultimately produce déjà vu experiences in a lab setting, a paradigm must evoke high feelings of familiarity accompanied by the sensation that the experience is objectively new.

Alternative Theories of Déjà vu

The Divided Perception theory of déjà vu is not the only theory of why déjà vu occurs. Brown (2003) suggests several alternative potential explanations, ranging from memory-based theories to biologically-based theories.

The Single-Element theory proposes that déjà vu arises when one encounters an object one has seen before in a different context. For example, a man might visit his friend's new house, and the house seems very familiar. The man could not have visited the house before because his friend just moved in. Unbeknownst to the man, his friend bought a new lamp which looks exactly like one the man had seen ten years earlier, and the familiarity from the lamp causes the entire environment to seem more familiar. Brown and Marsh (2007) found support for this theory by showing that the familiarity of one symbol can affect the familiarity of adjacent symbols, such that the familiarity of one item can make other symbols in the area more or less familiar, in the same way that the familiarity from a previously-encountered lamp can diffuse into other parts of the environment.

In contrast, the Global Configuration theory proposes that déjà vu arises when one encounters a similar configuration of a scene, such as a room, in a different context. For example, two rooms may have different colors, different pieces of furniture, and even different styles, but similarities in the arrangements of each room's contents may produce a feeling of déjà vu. Cleary et al. (2009) investigated this possibility by producing line drawings of different scenes that shared similar configurations but different items. Participants studied a list of line drawings with names, and then received a test list of different line drawings in which half the test items shared a configuration with a studied line drawing and half did not. The results showed that when participants could not recall the name of the studied scene that a test scene resembled, familiarity ratings were higher for test scenes that configurally resembled studied scenes than for test scenes whose configurations did not resemble any studied scenes. Participants were even more likely to report being in a déjà vu state in response to test scenes that shared configurations with studies scenes.

A third theory--the Biological Dysfunction theory--invokes a neurological explanation, suggesting that déjà vu arises from a brief change in neural transmission speed. When the brain receives sensory input, those sensory signals can take multiple pathways from the sensory organ to higher-level cortical centers. These multiple pathways may usually take about the same time to reach a destination, or some normal lag between the two identical signals. But if one signal should take longer than usual, when it finally reaches its destination it will have been preceded by an identical signal. The second signal may then be interpreted as familiar, because something exactly the same was perceived milliseconds earlier. It has long been known that déjà vu experiences are associated with the pre-seizure aura in epileptics (e.g., Bowles et al., 2007), and potential support for this theory has come from a study showing that temporal-lobe epileptics experience déjà vu as part of the pre-seizure aura regardless of perceptual input, suggesting that déjà vu experiences can arise purely from anomalous electrical activity in the brain (O'Connor & Moulin, 2008).

Although these theories are all somewhat different from each other, the fact that several disparate theories have been proposed to explain déjà vu does not pose a problem for the theoretical interpretation of the current set of results because the different theories are not mutually exclusive. It is possible that each of the theories could be valid descriptions of different ways to create déjà vu experiences. It is even possible that the set of conditions described in each theory could give rise to a set of subjectively similar experiences that are collectively grouped as déjà vu. There is still much research to be done on these theories, as well as Divided Perception, and in the future one goal can be to evaluate and compare the nature of déjà vu states elicited under different theoretical frameworks.

Limitations of the Current Study

There are a number of shortcomings in the current set of experiments. The largest and most problematic is that the change detection task used in all experiments may not actually produce the intended state of divided perception. This problem is unavoidable, as there is no formal definition of what divided perception is, apart from the descriptions provided by Brown (2003, 2004). However, even if divided perception did have a more concrete definition, there is always a difference between a real-world phenomenon and a lab-based procedure to produce that phenomenon. In spite of the differences, a change detection task has strong potential for creating an appropriate approximation of divided perception because they both involve the role of attention. Brown (2003) notes that divided perception stems from a failure to fully attend to an object, and Rensink et al., (1997, 2000) note that change blindness also results from failure to fully attend to an object. This suggests that change blindness is conceptually similar to divided perception and can be an effective means of creating divided perception in the lab.

Another potential problem is that the description of divided perception takes place in a naturalistic setting, while the current set of experiments sought to re-create the conditions in a lab-based setting. This pertains to the tradeoff between experimental control and ecological validity in research (Banaji & Crowder, 1989), but it also has an added complication regarding the change detection task. Levin et al. (2002) failed to find evidence of recognition for undetected objects in a real-life change detection task, while Angelone et al. (2003) did find evidence of recognition in a lab-based change detection task. The two studies employed similar procedures and even involved the same group of researchers, yet found contrasting results. The explanation offered by Angelone et al. is that anticipation for the change may cause observers to attend to and encode to more details of the scene. As the current set of experiments informed participants that a change would take place on every trial, future research involving real-life or incidental change detection would be needed to confirm the findings, and this would be an essential replication to support the possibility that real-life instances of divided perception could lead to déjà vu.

Finally, this research approaches recognition memory from a dual-process theory, which asserts that recollection and familiarity are two separate processes that can independently lead to a recognition decision (Yonelinas, 2002). An opposing theoretical perspective claims that recognition decisions are based on a single process, in which the strength of a memory signal is compared against a decision criterion for what constitutes a previously-encountered item (Wixted, 2007). The current experiments use procedures and measures derived from dual-process approaches to recognition (Cleary & Greene, 2000), and thus were interpreted under that framework. However, it bears mentioning that the results could potentially be interpreted under a single-process framework, especially as the difference in ratings between Detected, Undetected, and Unstudied items could suggest varying degrees of memory strength. Such an interpretation would not necessarily preclude the possibility that divided perception could lead to déjà vu, but might require modifications to the theoretical explanation of déjà vu.

Future Directions

The current experiments are the first examination of the Divided Perception theory of déjà vu, but as is often the case in science, the conclusions have opened several avenues for future investigations. For déjà vu research, an important next step would be to demonstrate recognition for undetected items under conditions when a change does not occur on every trial, and perhaps even under conditions of incidental change detection or real-life situations. This would be an important step toward determining how déjà vu occurs in natural settings. Toward this end, a very important step would be to show how divided perception can lead to the high levels of familiarity characteristic of déjà vu states. Perhaps this could be accomplished by variations to the change detection task, such as shorter exposure durations or inducing divided attention during change detection. Introducing delays between study and test of a week or longer was part of Brown and Marsh's (2008) procedure for creating feelings of déjà vu, and the same manipulation might increase familiarity under divided perception, as well.

As stated earlier, there are other theories as to why déjà vu occurs. It remains to be seen which of these theories is correct, and if several methods are capable of producing feelings of déjà vu, how they relate to one another. If there are different causes of déjà vu, it would be interesting to examine individual differences in terms of whether an experient is equally likely to experience déjà vu from each cause.

This research also opens the door towards investigating recognition in change blindness from a dual-process approach of recognition memory. The current results suggest the role of two processes, but do not rule out the possibility that a single process could explain the pattern of results, and future research could focus more on *how* observers make recognition decisions for undetected objects.

Concluding Remarks

The current set of experiments used a change detection task to examine recognition memory under conditions of divided perception. The overall conclusions are that observers can experience familiarity for items even without sufficient focused attention to detect the items when they disappeared from a scene. These experiments build off prior work showing recognition of undetected items, in that they show how the processes of recollection and familiarity are involved in the recognition decisions. These results also show support for the possibility that déjà vu can result from conditions of seeing an object without fully attending to it. These results do not show high levels of familiarity normally associated with déjà vu experiences, but they do show that familiarity is possible for unattended objects, and future modifications to this procedure could determine conditions under which high familiarity would result from inattention.

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