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Eye-Movement-Based Detection of Relational Memory Despite Attempts to Simulate Memory Impairment

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EYE-MOVEMENT-BASED DETECTION OF RELATIONAL MEMORY DESPITE ATTEMPTS TO SIMULATE MEMORY IMPAIRMENT

by

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ABSTRACT

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by

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Malingering presents a large problem for society in terms of the allocation of resources to those who are truly in need. Memory deficits are commonly malingered after head injury. There has been great effort to develop measures that can reliably identify people who are feigning this type of impairment. In the field of memory, a robust line of research has shown that eye-movement measures are sensitive to relational memory and characteristics of these eye-movement effects have led researchers to suggest that they might represent an obligatory response to the retrieval of a relational memory. The current study investigates the possible utility of these eye movements in detecting when a person is attempting to conceal their memory to feign memory impairment. This study employed an instructional manipulation in which one group was asked to perform an upcoming memory task as though they were feigning memory impairment. This simulator group and a control group then completed a relational memory task while their eye movements were monitored. While simulators were able to conceal their memory with their explicit responses, early viewing patterns revealed their knowledge for the pairs they had studied earlier. This result provides additional support to the idea that eye-movement measures may represent an obligatory measure of relational memory, as well as preliminary evidence that eye-movement based measures could be used to differentiate

between people who truly have memory deficits from those who are merely faking it.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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Malingering, or the feigning or exaggerating of symptoms, is an act that may be done to achieve some kind of gain. This gain could be financial, for example by increasing the chances of successful litigation. It could also be an attempt to gain resources, with people acquiring special accommodations or resources because of their feigned deficits. Either way, malingering presents a problem for society, as those who truly do not need these services or financial settlements receive them unfairly. One common symptom that is often feigned, and is the focus of the current study, is memory dysfunction following a head injury. Memory problems following mild traumatic brain injuries do tend to be fairly common, occurring in approximately half of the patients who experience this type of injury (Fox et al., 1995; Garden & Sullivan, 2010). However, research has also shown that the rate of malingering memory problems is also fairly high. In reviews of legal cases and assessments of clinical samples, base rates of malingering have ranged from about 10% to 60% (Binder & Willis, 1991; Greiffenstein et al., 1994; Schmand et al., 1998; Mittenberg et al., 2002; Slick et al., 2004). Therefore, to make sure that resources are properly deployed to those who truly need them, it is critical that we identify measures that might be sensitive to memory, even when individuals are able to successfully conceal their memory on traditional recognition tests. Past work has indicated that eye movements can be used to index memory indirectly, and that eye-movement-based memory effects are evident across a variety of different paradigms (Hannula et al., 2010). Here we combine eye movement methods with an instructional manipulation encouraging simulated malingering of amnesia to determine whether or not this type of measure could be useful in identifying people who are intentionally aiming to hide their memory.

Eye tracking is a tool that has been used to assess a variety of cognitive processes including language, attention, and most importantly for the current investigation, memory. The way a person views any visual scene is not random and therefore provides us with information both about the characteristics of the scene and of the cognitive processes engaged by the observer. Eye movements are in part guided by the perceptual characteristics of different parts of the scene, in that people tend to look at objects in a scene rather than empty spaces (Buswell, 1935). In addition, characteristics of these objects such as size, hue, and luminance affect a person's gaze pattern (Mackworth & Morandi, 1967). This tendency is likely because the perceptually salient items within a scene may be more likely to provide useful information. Examining participants' viewing of visual stimuli over a period of time also showed that initially people tend to make shorter fixations to these perceptually salient, information-rich areas, whereas later in the trial, longer fixations are spent on the less informative regions of the scene, such as those that are not filled with objects (Antes, 1974). Based on this early research, it appears that a person's eye movements are in part guided by the characteristics of the scene, such that the most perceptually salient regions are likely to be examined the most quickly.

Semantic Memory and Eye Movement Behavior

Importantly for the current investigation, research has shown that in addition to perceptual characteristics of the scene, memory can also have an impact on eye movements. The earliest studies into the effect of memory on eye movements examined how a person's prior knowledge, or their semantic memory, can influence the way they allocate their attention and view a scene in order to gather information. In one early study, participants were presented with a scene titled "An Unexpected Visitor", which depicts a room with various people and items and a man entering through the doorway (Yarbus, 1967). Under free viewing conditions, this study showed the effects of the perceptual characteristics of the scene on viewing patterns. For example, participants tended to look at the people in the room as well as the objects, and spent less time on the empty spaces of the floor and walls. However, this experiment also involved several conditions in which participants were directed to answer specific questions by looking at the picture (e.g. "estimate how long the unexpected visitor has been away from the family"). With each of these questions, participants exhibited different patterns of viewing, spending different amounts of time on the various aspects of the scene. These differences in the pattern of eye movements elicited by these various questions were interpreted as an effect of semantic memory on eye movements. It was suggested that participants had some general world knowledge about what regions of the picture might contain information necessary for answering the question, and this knowledge guided their gaze to these information-rich areas.

A number of other investigations have also shown the effect that semantic memory can have on eye movements and attention (Loftus and Mackworth, 1978; Henderson et al., 1999; Brockmole and Henderson, 2008; Hollingworth, 2009). Two will be discussed in detail here. First, an early study showed that semantic knowledge about the contexts in which certain objects are generally found had an impact on how a person would view a scene (Loftus & Mackworth, 1978). In this study, participants were presented with pictures of scenes that contained contextually consistent objects (e.g. a tractor in a barnyard) or contextually inconsistent objects (e.g. an octopus in a barnyard). As compared to contextually consistent objects, participants tended to fixate earlier in viewing, spend more time viewing, and direct a greater number of fixations toward contextually inconsistent objects. This result suggests that semantic knowledge about objects that would typically be encountered in particular scene contexts impacts visual exploration of scenes. In another experiment investigating the effect of semantic memory on eye movements, the goal was for a participant to locate and determine the orientation of a target object in a scene as quickly as possible (e.g. identify whether a pair of sneakers in a gym scene are at a specific orientation) (Hollingworth, 2009). In each trial, participants saw a target probe, which showed the target object at a specific orientation. Following this probe, participants saw a scene that contained the target object and were asked to indicate whether or not it was in the same orientation that had been seen during the target probe. The manipulation in this experiment was that for some trials, participants saw a preview of the scene they would later explore, while for other trials they did not receive this preview. It was found that when participants were given a brief preview of the scene (10s), even when it did not contain the target object, they fixated on the target object more quickly. Based on this time difference, it was concluded that having a preview of the scene that was going to be presented allowed participants to use their semantic knowledge of where specific objects generally appear within that context to guide their visual search. These studies, and others like them (Henderson et al., 1999; Brockmole and Henderson, 2008), show that it is not only perceptual characteristics of the presented stimuli that influence eye movement behavior, but that the contents of a person's semantic memory can also affect their viewing patterns.

Episodic Memory and Eye Movement Behavior

The previous studies have shown that semantic memory can impact how a person views a visual stimulus. General world knowledge can aid viewers in searching areas of the image that might be useful to accomplish a certain task and lead them to spend more time viewing things that do not conform to their knowledge of the world. While these studies suggest that eye movements are affected by semantic memory, for this type of measure to be useful in identifying people who may be malingering amnesia on typical recognition memory tests, it is more important that eye movements also be influenced by episodic memory. While semantic memory is memory for general world knowledge, episodic memory is memory for past experiences or events (Tulving, 1972).

Several investigations have indicated that eye movement measures can be used to distinguish between novel and previously seen visual stimuli. These studies have investigated how previous exposure to a stimulus affects the way a person will visually examine it when subsequently presented with it. Some of these studies used materials that were familiar to the participants before they entered the experimental context (e.g. famous faces, familiar buildings) and investigated how people viewed these familiar items as compared to novel stimuli (Althoff et al., 1999; Althoff & Cohen, 1999). These studies have shown that participants make fewer fixations and sample fewer regions of pre-experimentally familiar items as compared to unfamiliar items. Althoff et al. (1999) also exposed their participants to the pre-experimentally unfamiliar stimuli several times in order to examine how gaze patterns changed as the participants became increasingly familiar with these images. They found a *repetition effect* in that participants' visual sampling of the stimuli decreased with repeated exposure to the materials, an effect that was present regardless of task demands (i.e. even when participants were asked to do a non-memory task, such as an emotional labeling task). These findings suggest that eye movements represent a sensitive indirect method to index episodic memory and that eye movement measures may be useful in revealing memory for a stimulus even when a person attempts to conceal this memory in their explicit responses, such as in malingering.

Relational Memory and Eye Movement Behavior

More recent research on the topic of the effect of episodic memory on eye movements has focused on relational memory, and has shown that eye movements can reveal memory for spatial and temporal relations, as well as memory for arbitrary pairings of stimuli (Ryan et al., 2000; Ryan & Villate, 2009; Hannula et al., 2007; Hannula & Ranganath, 2009). Of the studies that use arbitrary pairings, many use a similar scene-face paradigm, which will also be used in the current study due to the robust line of research that has been completed thus far (e.g. Hannula et al., 2007; Hannula & Ranganath, 2009; Williams et al., 2010). In this paradigm participants are first instructed to learn a series of scene-face pairs. Subsequently, these participants are shown three previously studied faces superimposed on a previously studied scene. There are several variations of this testing phase, but in general, participants are asked to identify the face that had been previously paired with the presented scene via button press. In these studies, eye movement measures have revealed that people show disproportionate viewing towards this matching face over the other two faces in the display, despite the fact that all three faces were presented equally often during the encoding phase. This pattern of viewing reflects memory for learned scene-face relationships, and is an example of an eye-movement-based relational memory effect (Hannula et al., 2007; see Hannula et al., 2010 for review).

In addition to demonstrating that previous experience with stimuli can have an effect on eye movements, several interesting characteristics of these eye movements have also been explored. As a part of their analyses, the previously discussed studies usually involve a time course analysis, which examines the pattern of viewing directed to the stimuli over the duration that they are presented. With these analyses, it has been shown that disproportionate viewing towards the matching face occurs extremely quickly after stimulus onset (i.e. between 500 and 750ms). Response-locked analyses of these viewing patterns also revealed that the eye movement effects precede explicit behavioral responses by about 1000ms. In addition to the rapid appearance of this eye-movement-based relational memory effect, these eye movements also appear to be unaffected by task instructions. The effect was observed not only when participants were actively attempting to identify the face that had previously been paired with the scene, but also when disproportionate viewing towards the target face was counterproductive. For example, in Hannula et al. (2007), when participants were told to study the scene and all three faces for a future recognition test, they still showed preferential viewing towards the face that had been paired with the scene during the encoding phase. As they were instructed that they would be required to remember all three faces, preferentially viewing the face for which they already had a relational memory representation is counterproductive to the goal at hand.

Other paradigms have been used to demonstrate that eye-movement based relational memory effects are present in the absence of awareness. One example of this comes from a study in which participants studied scenes and were subsequently presented with these scenes after some sort of manipulation had been performed (i.e. an object was deleted, added, or moved from one location to another). When such manipulations were made to these studied scenes, participants' gaze was drawn to locations that had been manipulated (e.g. for an object moving manipulation, the region that the object has been moved to and the region it was moved from). This pattern of eye movements was observed even when participants were unable to explicitly report the change (Ryan et al., 2000). Despite the sensitivity of this method, individuals with documented memory impairments do not show evidence of any relational memory-based viewing patterns. Work with such patients will be described in the next section. Overall, these three pieces of evidence (i.e. rapid expression, resistance to differences in task instructions, and occurrence in the absence of conscious awareness) suggest that these memory-based viewing effects may occur involuntarily. In the current investigation, these qualities make eye movement measures a good candidate for identifying people feigning amnesia. The aim is to evaluate whether or not these eye-movement based memory effects will reveal participants' memory for previously studied arbitrary pairs, even when they are able to successfully hide this memory through their explicit behavioral response.

Eye Movement Behavior in Memory-Impaired Populations

In order to claim that eye movements are a valid measure for identifying people malingering amnesia, it is vital to know about the eye movement patterns during similar tests for individuals with documented memory impairments. Because eye movements are able to provide a sensitive, indirect measure of memory in patient populations who may have difficulty explicitly reporting their memories (see Hannula et al., 2010 for review), several investigations have examined eye movement behavior in memory-impaired populations. Such studies have found that eye-movement-based memory effects differ from those of controls when examining healthy older adults (Ryan et al., 2007), adults with MCI (Crutcher et al., 2009), patients with Alzheimer's disease (Daffner et al., 1999), patients with neurological damage to the medial temporal lobe (Hannula et al., 2007; Lee & Rudebeck, 2010; Ryan et al., 2000), and patients with schizophrenia (Hannula et al., 2010; Williams et al., 2010). Two of these studies that used the scene-face paradigm described previously and used in the current study will be described below (Hannula et al., 2007; Williams et al., 2010).

Using the scene-face paradigm described previously, Hannula et al. (2007) tested both participants with hippocampal amnesia and non-impaired controls. They found that not only did the hippocampal amnesic patients show significantly worse, chance-level performance for identifying the matching face, they also did not exhibit the typical disproportionate viewing towards this matching face that the control participants showed. In fact, even when the hippocampal amnesic patients correctly identified the target face, they still did not show disproportionate viewing towards this face like controls do. This result confirms that even when the patients managed to respond correctly, their choices were not guided by memory. Another special population that has been tested with this paradigm is schizophrenics who were suspected to have disproportionate relational memory deficits (Williams et al., 2010). This study confirmed that these patients do seem to have a relational memory impairment with decreased ability to select the face that had been paired with the scene. In addition, although these participants did exhibit the eye-movement-based relational memory effects, they were reduced in magnitude and occurred significantly later after stimulus onset relative to control data (approximately 4-6 seconds after stimulus onset as compared to 500-750ms in control participants). These two studies suggest that when using the scene-face paradigm, robust differences can be found in the eye movement patterns between participants who have documented memory impairments and non-impaired populations. In contrast, in the current investigation we expect that participants who are feigning a memory impairment will show a similar pattern of early viewing to participants who are completing the task optimally. Therefore, if our hypotheses are confirmed, eye movement measures could be useful in identifying people who are malingering amnesia. In sum, their overt memory reporting may look like that of people who actually have memory deficits, but they would show typical eye-movement-based memory effects that would reveal their deception.

Detection of Memory Malingering

The research discussed thus far has shown that eye movements can reflect the contents of a person's memory, that these eye movements may be obligatory responses to the presentation of previously experienced stimuli, and that they are absent or different in timing and magnitude in populations with actual memory impairments. One question that has not been as fully investigated, and is the focus of the current investigation, concerns the eye movement patterns of people who have intact relational memory abilities, but who are intentionally hiding their memory. As described previously, malingering occurs at significant rates and can make it more difficult for financial and societal resources to be effectively deployed to the people who truly need them (Binder & Willis, 1991; Greiffenstein et al., 1994; Schmand et al., 1998; Mittenberg et al., 2002; Slick et al., 2004). The act of hiding the true contents of one's memory can serve several purposes and so the detection of such deception has both empirical and practical import. One reason for hiding the contents of a person's memory is to feign amnesia for a financial or accommodation-seeking gain. For example, one might pretend to have extensive memory impairment after injury in order to gain advantage in legal proceedings. Another person might feign amnesia in order to gain disability services. One large review of over 30,000 legal cases reported that probable malingering was present in 30% of disability cases, 29% of personal injury cases, 19% of criminal proceedings, and 8% of cases about medical matters (Mittenberg et al., 2002).

Due to these high rates of feigned symptoms, detection of malingering has long been of interest in the neuropsychological and legal fields. Documentation of cognitive deficits in these types of cases is usually completed with a full neuropsychological evaluation, during which it is strongly recommended that at least one assessment of malingering or effort is completed (Bush et al., 2005). Early research noted that normal, healthy individuals were relatively easily able to produce neuropsychological test results that indicated some sort of cognitive deficit (Faust et al., 1998; Heaton et al., 1978). From this observation, the development of Performance Validity Tests (PVTs) began. Early PVTs such as the Digit Memory Test and the Portland Digit Recognition Test were assessments of memory using a two-alternative forced choice format. The benefit of this format is that chance performance is known to be 50%, so if a person scores reliably below this value, it is good evidence that they have some knowledge of the correct answer and are feigning a memory deficit. However, many studies have shown that when healthy participants are asked to feign a memory impairment on these types of tests, only about a third of them score reliably below chance, indicating that the specificity of these assessments is quite poor (e.g. Guilmette et al., 1993; Martin et al., 1993; Greiffenstein et al., 1994). This high percentage of false negatives has led researchers to state that these below-chance criterion PVTs should not be used, especially in isolation, for the detection of malingering (Vickery et al., 2001).

With the problems of the below-chance criterion for PVTs, new ways of interpreting the results from these tests were devised. It was proposed that instead of comparing an individual's performance to chance levels, it should instead be compared to the performance of an appropriate clinical normative sample, for example participants with memory impairments who have no incentive to exaggerate their deficits (Guilmette et al., 1993). The logic is that if a person performs significantly below the performance of people with known deficits, they are likely not giving full effort on the assessment. However, unlike performing below chance levels, which indicates that a person has knowledge and is actively avoiding sharing it, there are other factors that could lead a person with true memory dysfunction to perform below the levels of a clinically impaired population, such as poor cooperation or an unusually severe deficit (Vickery et al., 2001). Therefore, if a person's performance is reliably below that of the comparison group, but not reliably below chance, claiming that they are malingering is not an entirely valid conclusion. Furthermore, in a meta-analysis investigating the relative utility of a number of PVTs, using these normative-based cutoffs, the sensitivity of these assessments ranged from 22% to 83%, with an average around 55% (Vickery et al., 2001). Therefore, these assessments are still resulting in a large proportion of false negatives.

Some researchers have aimed to develop PVTs on which truly clinically impaired populations perform similarly to controls, so that it is easier to detect below-normative performance of malingerers. Two of these measures, the Test of Memory Malingering (TOMM; Tombaugh, 1996) and Word Memory Test (WMT; Green, Allen, & Aster, 1996) both appear like many other memory-based neuropsychological measures and rely on the fact that malingerers will continue with their low-effort performance on these measures. The TOMM capitalizes on the fact that simple visual memory is relatively robust in memory-impaired populations. During this assessment a series of 50 line drawings are shown to the participant, which are later tested in a two-alternative forced choice format. Testing conducted with this assessment tool has shown that it is insensitive to neurological memory impairment (Tombaugh, 1996). Validation studies have shown that the TOMM has high sensitivity when used to detect people who are giving sub-optimal effort (Rees et al., 1998). The WMT is a measure of verbal memory that has several different tests including short and long-delay recall and recognition measures. Several of these measures are insensitive to all but the most severe memory impairments and an interpretation of the pattern of performance has been shown to be valid for detecting biased responding (Green et al., 2003; Iverson et al., 1999).

While the TOMM and WMT have shown greater sensitivity and specificity than many other PVTs, their use is still not without problems. One of these problems is that these measures rely on the malingerer not realizing that these effort measures are any different from the other neuropsychological measures, and therefore continuing their low-effort performance. With the easy distribution of information due to the Internet, individuals being tested, as well as their lawyers, have more information than ever about these PVTs, including the name, the appearance, and the measurement and interpretation (Bauer & McCaffrey, 2006). This knowledge of these testing procedures makes it possible that individuals could identify which tests are used to measure effort and simply perform with greater effort selectively on these tests, thus evading detection. In fact, warning individuals as to the presence of PVTs in an assessment battery has been shown to lead to more sophisticated and harder to detect malingering (see Youngjohn et al., 1999, for review). Therefore, the issue of coaching and test security is a potential threat to the utility of these types of PVTs.

Indirect Measures of Memory Deception

Any malingering measure that relies on explicit behavioral responding will be subject to the above coaching concern. Therefore, the current study aimed to investigate the indirect eye-movement measure that could reveal true memory contents for a person who is hiding it with their explicit responses. The use of indirect measures to detect concealed memories is something that has been used in legal investigations where a person hides knowledge of a crime in order to protect themselves or someone else. In order to detect this type of deception, many researchers turn to something known as the Guilty Knowledge Test. In this test, a question is asked with several multiple choice answers and the belief is that a person with the knowledge of the crime will react differently to the correct response, whereas an innocent person will react the same to all of the choices. For example, if asked what kind of gun was used in a crime and given three choices, an innocent person with no knowledge of the crime will have similar responses to all three choices, while a guilty person will react differently to the correct answer (MacLaren, 2001). During this test, the idea is that a guilty person will explicitly deny knowledge of the correct answer, but indirect, physiological measures will be able to reveal their possession of the information. For example, the Guilty Knowledge Test is most commonly administered in combination with skin conductance response (SCR) recordings. SCR increases as a person's emotional arousal increases (MacLaren, 2001) and it is assumed that on the Guilty Knowledge Test the correct responses usually lead to a greater emotional response than the innocuous incorrect responses for a person with knowledge of the crime. On the other hand, for the innocent participant, all choices are equally innocuous and so they should not show a difference in SCR for the critical response.

In addition to SCR, other indirect measures have also been used in the detection of guilty knowledge. Using EEG, the N400 component has been shown to discriminate relatively well between participants with and without crime knowledge when they listened to crime-related sentences with accurate or false completions (Boaz et al., 1991). In addition, a P300-based Guilty Knowledge Test has been developed, capitalizing on the P300's response to rare or meaningful stimuli (Farwell & Donchin, 1991). In this type of test, participants are assigned an arbitrary task where they are asked to respond to some kind of target item and not to all other items. These "other" items consist of crime-relevant items that would only be known by someone who has guilty knowledge of the crime, and irrelevant items. For the innocent participant, the P300 component would be elicited for the target items, due to the meaning assigned to them by the experimenter, but not for any of the other items. For the guilty participant, the P300 would again be elicited for the target items, but also for the crime-relevant items. In this way, the ERPs for the crime-relevant items can distinguish between participants with crime knowledge and those without. Finally, pupil diameter has also been demonstrated as a useful indirect measure for detecting deception (Dionisio et al., 2001; Lubow & Fein, 1996; Bradley &

Janisse, 1981). These studies showed that pupil diameters tend to be larger when someone is concealing information as compared to when they are accurately reporting.

All of these studies indicate that there is the possibility that indirect measures could be of use in detecting someone who is aiming to conceal their memory. However, there are reasons that these three measures might not be ideal for use in neuropsychological assessments of malingering. SCR, as described previously, relies on emotional arousal to particular stimuli, which is why it is useful in Guilty Knowledge Tests where crime-relevant information is thought to be more arousing than other information. In a standard recognition test involving studying information and later being tested, lying on the test items would not necessarily create this autonomic arousal. In addition, some issues with SCR as a valid measure of guilty knowledge exist, because individuals can be taught to evade detection through the imagination of emotional events (Ben-Shakar & Dolev, 1996). The EEG measures capitalize on detection of false statements and rare, meaningful stimuli, which again while useful in the Guilty Knowledge Test, would not be applicable in the standard neuropsychological PVTs, which typically use standardized materials that will not often be particularly meaningful. Finally, pupil diameter measures could be useful in a standard PVT, but, like SCR, pupil diameter is affected by general autonomic arousal as well as cognitive processing load (Bradley et al., 2008; Granholm et al., 1996). Therefore, it could be possible to evade detection by mentally increasing emotional arousal or cognitive processing during the task. These studies of indirect measures of deception do give support for the idea that indirect measures could be useful in detecting malingering during neuropsychological assessment. However, because of the limitations of the measures listed above, the current investigation aims to put forward fixation-based eye movements as a potential measure for detecting malingering.

There has only been one study investigating eye movements as a measure for detecting concealed knowledge (Schwedes & Wentura, 2012). This study referred to the previous research indicating the potential for eye movements to provide an indirect index of memory combined with a Guilty Knowledge Test paradigm. In this study, participants first learned a series of faces, which were either classified as "friends" or "foes". Once the faces were learned to criterion, test trials consisting of lineups of six faces were presented and participants' eye movements were recorded throughout this phase. Participants were instructed that some of the displays would contain one of the studied faces, and that if the lineup contained a "foe" they should select that face to turn them in. If the lineup contained a "friend", they should protect them by selecting one of the other faces. If the lineup did not contain a studied face, they were asked to select any of the six faces. Results showed that participants spent a greater duration of the trial fixated on the faces of foes, which were both known and selected, as compared to the faces of friends, which were known but not selected. The authors classified this as a response intention effect. However, more importantly, this study revealed that participants fixated longer on the faces of friends that were known and non-selected than they fixated on non-selected faces in trials without a friend or foe, which were neither known nor selected. This greater viewing indicated memory for the friend despite the hiding of this recognition through the explicit response. Therefore, this study provides evidence for the current investigation's suggestion that eye movements might be a valuable indirect measure of examining the contents of a person's memory when they are trying to conceal this knowledge.

However, the current investigation extends the findings of Schwedes and Wentura (2012) by applying the use of eye movements to a more standard recognition memory test such as those used in neuropsychological assessment. This will allow for a stronger conclusion that fixation-based eye movement measures could be used to detect not only trial-by-trial concealment of memory as with the other indirect, physiological measures, but also more generalized malingering of memory deficits. In the previous study, participants were told when to tell the truth, on foe trials, and when to conceal their memory, on friend trials. The current study uses a more lifelike malingering scenario where participants are asked to feign a memory deficit but not given specific instructions as to how to accomplish this task. The previous study also only used a fixation duration analysis and an analysis of the location of the first three fixations, which does not allow for a complete analysis of the pattern of viewing that occurs across a trial as a person attempts to conceal their memory. Therefore, the current investigation will employ a time-course analysis to investigate how viewing changes across time when participants are answering items to the best of their ability as compared to when they are feigning memory problems. Lastly, unlike the paradigm in the Schwedes and Wentura (2012) study, the current study utilizes a paradigm with documentation for the performance of truly memory-impaired populations, such as those with hippocampal amnesia and schizophrenia (Hannula et al., 2007; Williams et al., 2010). These patients show viewing patterns that are different from those of healthy controls. This means that if it were demonstrated that simulated malingerers show eye movement patterns similar to healthy controls, there would be greater evidence that eye movements could be useful in distinguishing between those who have true memory impairments and those who are feigning such impairments.

Current Experiment

Thus far, two separate lines of research have been discussed. First, eye movements have been shown to be rapid and perhaps involuntary reactions to the presentation of previously studied stimuli, an effect that has been found to be robust in the context of relational memory. Second, the act of concealing the contents of one's memory, and the detection of this deception has been the focus of a large field of research. The current experiment will combine these lines of research to evaluate whether eye movements might index relational memory even when participants successfully hide memory via behavioral responses. In the current study, participants completed the scene-face paradigm used in Hannula et al. (2007) and other studies (Hannula & Ranganath, 2009; Hannula et al., 2010), which has consistently shown eye-movement-based relational memory effects. Novel to this study is that some participants were asked to complete this task as though they were feigning a memory deficit. With this instructional manipulation we had several hypotheses. First, we believed that these simulator participants would be able to successfully feign amnesia and show poorer recognition accuracy through their explicit behavioral responses. We predicted that control participants' accuracy would be significantly greater than chance, while simulators would be closer to chance level performance. We did expect group differences in response times on these test trials, with simulator participants responding more slowly than controls due to the increased cognitive processing that needs to occur to successfully feign memory impairment. Importantly, it is also predicted that eye-tracking measures will reveal the true contents of memory of these simulator participants. While differences in viewing patterns across the entire trial are expected between simulators and controls, equivalent early disproportionate viewing is expected to be directed to the matching face for both control and simulator participants, even on trials for which the simulators' explicit responses are incorrect. Put simply, even when participants fail to explicitly acknowledge the presence of the matching face, their pattern of early eye movements will reveal their memory for the scene-face pair. Finally, on a post-test where simulators are asked to change their strategy and now perform to the best of their ability, we expected to still see poorer performance from the simulator subjects, even though both groups were now instructed to try their best on this test. This prediction stems from previous research showing that suppression of a memory during one retrieval period can impair the ability to subsequently retrieve that memory (Anderson & Green, 2001). We posited that the processes necessary to conceal knowledge of the scene-face pairs and successfully feign memory impairment might lead to this type of suppression-induced forgetting.

With these hypotheses, this study had two main goals. First, if these hypotheses are confirmed, this study will have provided further evidence that eye-movement-based relational memory effects are expressed obligatorily, and perhaps automatically, as they occur even when a person is attempting to conceal their memory. Second, this study could provide preliminary evidence that eye tracking could prove to be a useful tool in identifying people malingering a memory deficit as compared to those who truly suffer from memory impairment. As discussed previously, it has been demonstrated that hippocampal amnesic and schizophrenic patients show patterns of viewing that are very different from healthy controls (either in presence or timing and magnitude of disproportionate viewing). Since our early eye-movement hypothesis predicts that simulators will show similar patterns of viewing as healthy controls, this would mean that it would be different from the pattern seen in those who truly have a memory deficit, which could become a useful way to distinguish between these two groups. This study went beyond previous studies because it allowed for the examination of eye movement patterns in participants who are feigning a memory impairment but who are not given any specific instructions on how to hide their memory from the examiner (e.g. unlike the Schwedes & Wentura study above that directed participants to purposefully not select friends whenever they saw them). Therefore, our procedure is much more similar to how a person might react if they were attempting to feign general memory impairment.

Method

Participants

Thirty-six undergraduate students from the UWM community (18 assigned randomly to the simulator and control groups, respectively) completed this experiment and were compensated with course credit. Additional participants were tested and compensated for their time, but were not included in reported analyses because eye tracking data could not be reliably obtained (n=10), they failed to comply with instructions or reported low effort and motivation on the post-test questionnaire (n=6), or there was experimenter error (n=3). Informed consent was obtained from each participant before testing commenced in a manner approved by the Institutional Review Board at UWM.

Materials & Apparatus

Materials for this investigation included 162 images of scenes (81 indoor and 81 outdoor) and 162 faces (81 male and 81 female). Scenes were sized to 800x600 pixels, while faces were sized to 280x280 pixels and were superimposed on a 300x300 pixel grey background. Eye movement data were recorded using an Applied Science Laboratories R6 Remote Eye Tracker that records participants' eye position every 16.7ms.

Procedure & Design

Participants were randomly assigned either to a control group or to a simulator group, and after obtaining informed consent, one experimenter read the participant the instructions that corresponded to their group membership. Participants in the control group were told that they were about to be given a memory test and that they should complete it to the best of their ability. Participants in the simulator group were read a scenario in which they were instructed to pretend malinger a memory deficit in order to win a lawsuit following a car accident. The scenario used for this experiment was a modified version of the one used in Suhr & Boyer (1999) and can be found, in full, in Appendix A. No specific strategies about how exactly to malinger were provided (e.g., participants were not told to attempt to answer a certain percentage of the items incorrectly or to avoid looking at task relevant materials). Following these instructions, a second experimenter, who was blind to the group assignment, entered the room to administer the experimental protocol, which was identical for both groups of participants.

The memory task included 3 interleaved study-test block sequences. For each of these sequences, 3 study blocks were followed by a corresponding test block. The materials used in each study-test block sequence were not repeated in subsequent blocks. In each study block, 42 scene-face pairs were presented and participants were instructed to try to remember which face was paired with which scene. Each trial consisted of a 2000ms presentation of the scene alone, followed by 4000ms of the same scene presented with the face superimposed on top of it (see Figure 1). As indicated previously, 3 study blocks were followed by a single test block. This means that the same scene-face pairs were presented 3 times in a different random order across blocks. Following the third study block, participants completed 12 trials of the test phase. Here, each trial consisted

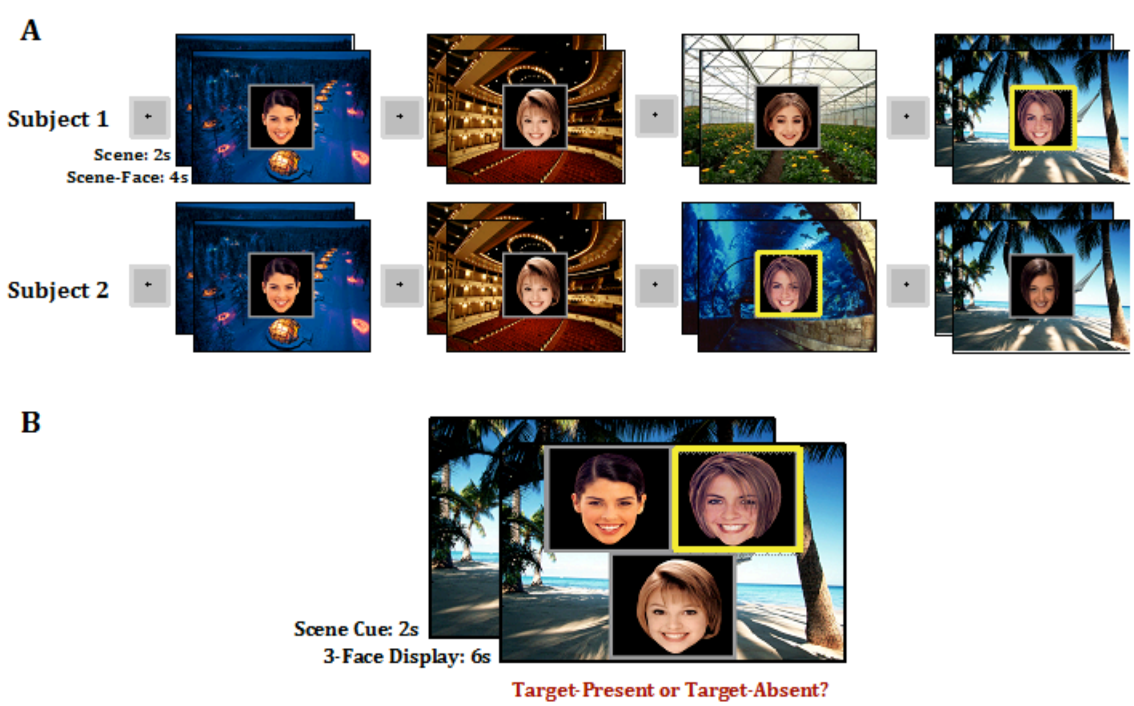

Figure 1. Example study and test trials. A) A series of study trials for two different subjects. B) An example of a test trial that would be seen by both Subject 1 (as a target-present trial) and Subject 2 (as a target-absent trial). The yellow box highlights the critical face for both groups and is for illustration purposes only.

of a studied scene cue for 2000ms, followed by the scene with a three-face display superimposed on top of the scene for 6000ms (see Figure 1). All three of the faces had been previously studied, but in half of the test trials the face that had been previously studied with the current scene was present (i.e. target-present displays) while in the other half it was not present (i.e. target-absent displays). On every test trial, participants were instructed to view the display and to indicate on a button box whether the associated face was present or absent. Control participants were instructed to complete this task to the best of their ability, while simulators were instructed to feign memory impairment.

After all 3 study-test block sequences were administered a post-test was completed. During this post-test, all of the participants were instructed to perform as accurately as possible (i.e. the malingering instructions were removed). The experimenter told participants that this final test would allow us to determine how well they had encoded the materials during the study phase. The 36 trials that comprised the post-test were the same as the 36 test trials seen throughout the experiment. In each post-test trial, the participant was cued for 2000ms by a previously studied scene and then was asked to respond to a 3-face display that was superimposed on top of the scene for 6000ms. They were instructed to select the matching face if it was present using a button box, or to select a face at random if it was not. Then they were asked to indicate verbally whether or not the matching face was present in the display.

Eye movements were recorded throughout all study, test, and post-test block trials. Participants were seated approximately 25in from the computer screen on which the materials were displayed. Calibration was achieved prior to each block using a 9-point calibration screen. Participants were informed about the eye tracking system at the beginning of the experiment and were asked to remain as still as possible while the experiment was in progress, to try not to look away from the computer screen at any time, and to refrain from looking down at their hand when making button press responses.

Finally, after the post-test was completed, all of the participants were asked to fill out a questionnaire. The first question was open-ended and asked participants to describe, in their own words, what their goal during the experiment was. This was to allow us to see if participants in the simulator group understood the instructions to simulate malingering. Following this open-ended question were three questions that required ratings on a 6-point Likert scale (0 = none of the attribute, 5 = a great deal). These three questions asked about the participants' effort, motivation, and confidence, respectively, about completing the previously described goal for the experiment. The simulator group had one additional question about strategies that were used to accomplish the goal and were provided with several options (e.g. answered in a pattern; answered a certain percentage of questions incorrectly; looked purposefully away from task-relevant materials); they were encouraged to report all of the strategies that they used during the experiment in an effort to comply with task instructions. There was also a space for them to indicate any strategies they used that were not in the list of available strategies. The full post-test questionnaire can be found in Appendix B. Following the post-test questionnaire, all participants were fully debriefed.

Counterbalancing

Scenes and faces were randomly assigned to lists, which rotated across experimental conditions. Faces and scenes from respective lists were paired randomly for each participant, and the order in which pairs were presented during each study block was randomized.

Individual participants assigned to each group were yoked – the test displays seen by yoked participants were identical, but because of differences in encoding history, the same display was target-present (i.e. contained the studied associate) for one participant and target-absent (i.e. did not contain the studied associate) for the other.

Use of this yoking procedure meant that a single critical face could be designated for all of the test trials. This *critical face* was the associate (i.e. the face that had been paired with the scene cue) in target-present displays and was the same face, absent the studied association, for yoked target-absent displays (see Figure 1). Individual participants assigned to the simulator and control groups were also yoked, which meant that corresponding simulators and controls saw the same scene-face pairs in the same order during encoding, and the same 3-face displays assigned to the same experimental conditions and presented in the same order during test. Counterbalancing ensured that across test trials, the critical face appeared equally often in each of the three locations for each experimental condition (i.e. target-present, target-absent).

Data Analysis

Procedures used to evaluate direct (behavioral) measures of memory and indirect (eye-movement-based) indices of memory are described in the sections that follow.

Behavioral Measures. In order to evaluate the accuracy of each participant's present/absent responses, corrected recognition and discriminability (d') measures were calculated. Here corrected recognition was defined as the proportion of hits minus the proportion of false alarms, which has a value of 0 for chance performance. In this study, hits correspond to target-present trials identified as containing the associate, while false alarms correspond to target-absent trials identified as containing the associate. The proportion of hits was determined by dividing the number of hits by the total number of hits and misses and the proportion of false alarms was calculated by dividing the number of false alarms by the total number of false alarms and correct rejections. Group-level corrected recognition and d' scores were compared to each other using an independent samples t-test and to chance performance (0 for both measures) using a one-sample t-test. Response times were also compared for each trial type (i.e. target-present and target-absent) using a repeated-measures ANOVA with group as a between-subjects factor.

Eye movement behavior. Evidence for memory retrieval in eye movement behavior was taken from two classes of eye movement measures: 1) a global viewing time measure, and 2) a time-course measure. In both cases, eye movements to a specific critical face embedded in each 3-face test display were evaluated. The critical face was the face that had been studied with the scene cue for target-present displays, and was the yoked comparison face for target-absent displays (see Figure 1).

Global Viewing Time Analysis: The proportion of total viewing time directed to critical faces was calculated for every trial. Resulting viewing time data were then binned as a function of experimental condition (target-present trials, target-absent trials). Simulator data from target-present trials were further subdivided based on recognition accuracy (i.e. target-present hits, target-present misses), a split that was not performed on control group data because these participants made very few errors (mean=3.28, sd=3.20). Because critical faces embedded in target-absent displays were indistinguishable from foil faces (none of the faces had been studied with the scene cue during encoding), data from these trials were collapsed irrespective of recognition accuracy for both groups. Direct comparisons confirmed that this was appropriate, as there were no differences in the proportion of viewing time directed to critical faces embedded in target-absent displays as a function of accuracy for simulators (correct: M=.33, sd=.10, incorrect: M =.35, sd=.08; $t(17)=-.48$, $p=.64$). Controls made very few errors, which meant that this comparison could not be performed.

Memory-based viewing time comparisons were performed by calculating difference scores for each participant (i.e. viewing directed to critical faces from target-present displays minus viewing directed to critical faces from target-absent displays). Positive scores indicate that memory-based viewing is present, and the magnitude of this difference score indicates how robust these viewing time differences are. An independent samples t-test was used to compare the magnitude of memory-based viewing across groups, while a paired t-test was used to compare the viewing effect across accuracy within the simulator group.

Time-Course Analysis: Because past work has indicated that eye-movement-based memory effects are statistically reliable shortly after display onset (Hannula et al., 2007; Hannula & Ranganath, 2009), evaluation of eye movement data collapsed across the entire test trial may not be especially informative in this study. Therefore, after having evaluated group differences in proportion of *total* viewing time, as described above, the data were separated into consecutive 250ms time bins starting with the onset of each 3-face test display. It was predicted that the magnitude of the eye-movement-based memory effect would be well-matched across groups early in viewing (e.g., within the first 500-750ms of 3-face display onset), but that group differences would emerge thereafter. To evaluate this prediction, difference scores (i.e. proportion of total viewing time directed to critical faces from target-present displays minus proportion of total viewing time directed to critical faces from target-absent displays) were calculated for each participant for each of the first four 250ms time points following stimulus onset. As above, positive values indicate that more time was spent viewing critical faces from target-present than target-absent displays, and index memory for studied scene-face relationships (i.e. the magnitude of the eye-movement-based memory effect). For controls, these difference scores were calculated using correct target-present trials; for simulators, the same scores were calculated separately using correct and incorrect target-present trials. A repeated measures ANOVA with group as a between-subjects factor was used to compare viewing effects across time between controls and simulators was computed. In addition, a repeated measures ANOVA with accuracy as a within-subjects factor was used to compare viewing effects across time between correct and incorrect trials within the simulator group.

Participants were removed from all analyses if their data did not contain at least 4 trials that were considered "well-tracked" (trial time exceeding 65% of the duration of the three-face display) for each of the trial types that were analyzed (correct target-present trials and combined target-absent trials for controls; correct and incorrect target-present trials and combined target-absent trials for simulators). This resulted in the removal of 10 participants because reliable tracking data was not obtained, referred to in the Participants section above.

Post-test analyses. Similar analyses that were conducted on the test blocks in terms of accuracy and response time measures were conducted with the data from the post-test.

Data acquired using the post-test questionnaire were evaluated to ensure that participants understood the instructions, to assess their effort and motivation levels, and to investigate the types of strategies they used to complete the simulated malingering task.

Results

Recognition Accuracy

It was predicted that participants assigned to the control group would successfully distinguished target-present from target-absent displays and outperform participants from the simulator group. This prediction was confirmed when the groups' corrected recognition scores were compared ($t(34)=11.82$, $p<.001$, Cohen's $d=3.94$; see Table 1). This outcome remained the same when group comparisons were performed using d' as a measure of accuracy ($t(34)=10.68$, $p<.001$, Cohen's $d=3.57$; see Table 1). Furthermore, while control group performance was reliably greater than chance (t's(17)≥12.00, p's≤.001), the same could not be said for simulators (t's(17)≤ -.40, p's≥.68 for corrected recognition and d', respectively); collectively, these outcome confirm our behavioral accuracy predictions.

Table 1

Corrected Recognition and d' Means and Standard Deviations of Initial Test Phases

	Corrected Recognition (%)	d'
Controls	81.17(18.87)	3.09 (1.09)
Simulators	2.16(23.19)	0.06(0.61)

Response Times

Because it was expected that completing the memory task while attempting to conceal knowledge of scene-face pairs would be more cognitively demanding than simply completing the task optimally, it was predicted that simulators would make slower present/absent responses than controls. To test this prediction, a repeated-measures ANOVA with the factors Group (Control, Simulator) and Trial Type (target-present, target-absent) was calculated. This ANOVA showed a significant main effect of Group ($F(1,34)=8.964$, $p=.005$), where control participants were faster overall than simulator participants. Target-present trials were also responded to more quickly than target-absent trials ($F(1,34)=16.85$, $p<.001$), however, the Trial Type by Group interaction was not significant ($F(1,34)=.495$, $p=.487$). In sum, control participants responded faster than simulators on both target-present (controls: M=2170.28, sd=462.36, simulators: M=2735.49, sd=662.28) and target-absent trials (controls: M=2406.15, sd=482.40; simulators: M=2902.40, sd=576.97). As above, this pattern of results confirms the predicted outcome.

Eye-Movement-Based Memory Effect

Global Viewing Time Analysis: Due to the robust line of research using this paradigm, it was expected that over the 6 seconds that the three-face display was presented, control participants would show disproportionate viewing towards matching critical faces. Because of the instructional manipulation used in the current study, it was anticipated that the magnitude of this viewing effect would be reduced for simulator participants, particularly on trials for which incorrect responses were made. Therefore, our first analyses compared the overall magnitude of disproportionate viewing, collapsed across the entire six second test trial. Here we first conducted an independent samples t-test comparing the difference scores for control and simulator participants, limited to correctly classified target-present trials. It showed that the magnitude of disproportionate viewing for control participants was reliably greater than for simulator participants, (t(34)=2.83, p=.008; see Figure 2A). This supports the above prediction. We followed up by conducting a one-sample t-test to compare each group's magnitude of disproportionate viewing to 0, which would represent no greater viewing of matching critical faces than critical face from target-absent displays. Greater than chance viewing of the matching critical face was evident for both groups of participants when target-present trials were correctly identified (t's(17) ≥4.28, p's≤.001; see Figure 2A.)

We also conducted a paired samples t-test comparing the magnitude of disproportionate viewing of simulator participants for correctly and incorrectly recognized target-present trials, as we had predicted that an even

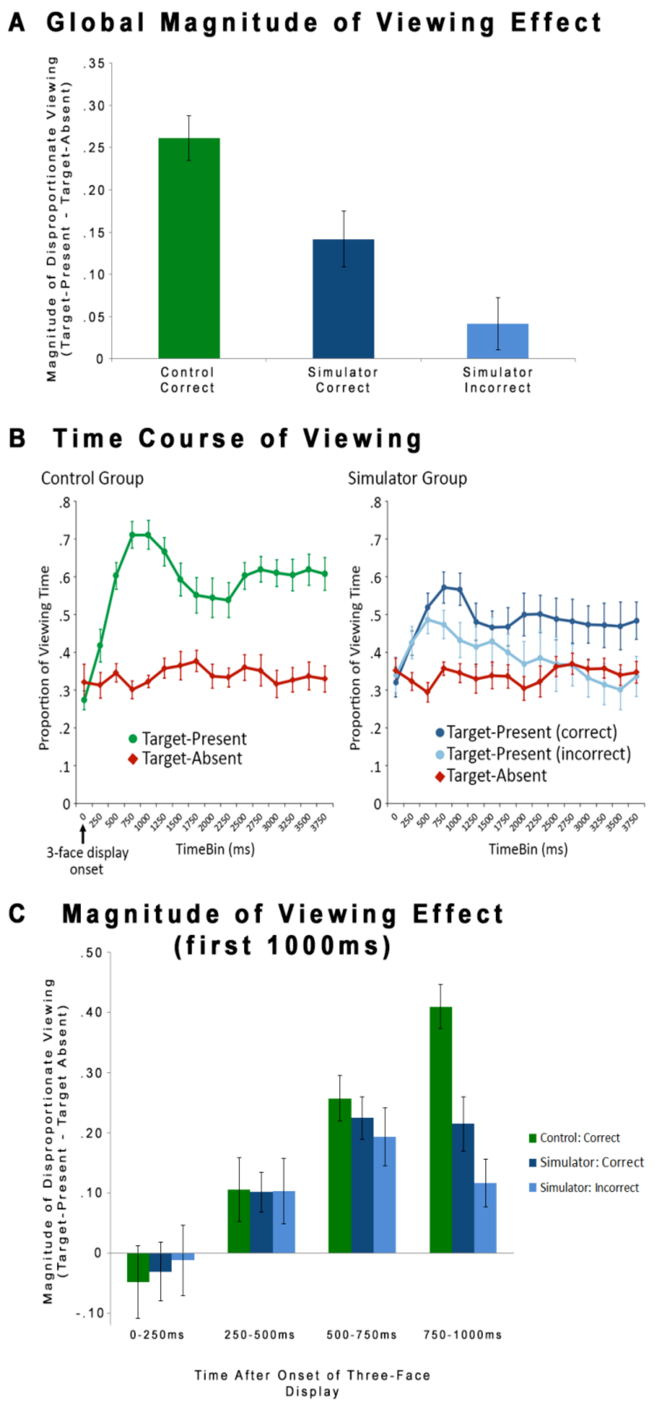

Figure 2. Eye movement based memory effect data. A) Overall magnitude of disproportionate viewing towards matching critical faces. B) Time course of proportion of viewing time directed towards critical faces. C) Magnitude of disproportionate viewing for first 1000ms.

greater reduction in viewing effects would be evident on incorrect trials due to participants' attempts to hide their memory. This t-test showed that the magnitude of disproportionate viewing for correctly recognized trials was reliably greater than for incorrectly recognized trials ($t(17)=3.09$, $p=.007$; see Figure 2A). Again this supports our hypothesis. In addition, we compared the magnitude of disproportionate viewing for incorrectly classified trials to 0, and this time found that for these trials, simulators' disproportionate viewing was not reliably above chance ($t(17)=1.34$, $p=.20$). Therefore, when examining viewing across the whole trial for simulators, the presence of disproportionate viewing appears to coincide with explicit response accuracy.

Time-Course Analysis: Results reported above suggest that eye tracking may be insensitive to detecting concealed memories. However, previous studies have shown that eye-movement based relational memory effects occur very early in viewing. Therefore, it was predicted that viewing measures may be more sensitive to concealed memories shortly after display onset. To evaluate this prediction, a time course analysis was completed (see Figure 2B) and the first 1000ms after display onset was selected for analysis based on previous findings of the timing of eye-movement-based relational memory effects (Hannula et al., 2007). Then, a repeated measures ANOVA with group (simulator, control) as a between-subjects factor and time bin (0-250, 250-500, 500-750, and 750-1000) as a within-subjects factor was calculated using the magnitude scores that were calculated for each time bin (see Figure 2C). Results indicated that the eye-movement-based memory effect became more robust as the trial progressed ($F(3,34)=29.75$, $p<.001$) and that between groups differences emerged across time bins (significant time bin x group interaction: $F(3,34)=2.87$, $p=.04$). The main effect of group was not statistically reliable ($F(1,34)=2.14$, $p=.15$). Planned comparisons showed no significant differences between groups for the 0-250ms, 250-500ms, or 500-750ms time bins (all t's$(34)<.64$, p's$>.05$; See Figure 2C). However, there was a reliable difference between groups for the 750-1000ms time bin ($t(34)=3.47$, $p=.001$), where the control participants showed a greater memory-based viewing effect than the simulators. Follow-up analyses confirmed that the eye-movement-based memory effect was reliably greater than chance for both groups for the 250-500ms, 500-750ms, and 750-1000ms time bins (t's$(17)>2.05$, p's$<.028$); above-chance viewing was not evident from 0-250ms (t's$(17)<-.64$, p's$>.42$). These analyses show that very early in viewing (i.e. between 250-750ms) magnitude of disproportionate viewing is comparable between simulators and controls as we predicted, and that it is only later in viewing that group differences emerge.

Also focusing on the first 1000ms, we again conducted an analysis comparing trials of different accuracy within the simulator participants. A repeated-measures ANOVA with accuracy (hits, misses) as a within-subjects factor was used to evaluate the prediction that magnitude of disproportionate viewing would be comparable between correct and incorrect target-present trials early in viewing. Results indicated again that the magnitude of viewing increased across time bins ($F(3,17)=9.62$, $p<.001$), but did not differ as a function of accuracy ($F(1,17)=.69$, $p=.42$). The interaction between time bin and accuracy was also not statistically reliable ($F(3,17)=1.04$, $p=.38$. Planned t-tests for each of the time bins were then conducted. No reliable differences in magnitude of disproportionate viewing between correct and incorrect trials were found for the 0-250ms, 250-500ms, or 500-750ms time bins (all t's$(17)<.29$, p's$>.05$; see Figure 2C). However, there was a reliable difference at the 750-1000ms time bin ($t(17)=2.18$, $p=.04$), where memory-based viewing time differences were greater for correctly recognized target-present trials than incorrectly recognized trials. We also compared the magnitude of disproportionate viewing for incorrect trials for each time bin to 0 and found no reliable disproportionate viewing for the 0-250ms time bin (t(17)=-.21, p=.83), and disproportionate viewing reliably greater than 0 for the 250-500ms, 500-750ms, and 750-1000ms time bins (all t's(17)>1.95, p's<.03). Again, this more focused analysis of early disproportionate viewing supports our hypothesis that simulators show comparable disproportionate viewing towards matching critical faces even when they incorrectly classify these match trials.

Post-test Analyses

On the post-test, all of the participants were instructed to complete the task optimally. Consistent with our predictions, despite this equivalency of instructions, corrected recognition on the present/absent response was greater for controls than simulators (t(34)=2.12, p=.04, Cohen's d=.71; see Table 2). However, when d' was used as a measure of accuracy, this between groups difference was marginal (t(34)=1.27, p=.22, Cohen's d=.10). Accuracy was also assessed by calculating the percentage of target-present trials where participants correctly selected the matching face from the three-face display. Consistent with the corrected recognition outcome above, controls identified the associate more often than simulators although this difference fell just short of the cutoff for statistical reliability (t(34)=2.00, p=.053, Cohen's d=.67). Closer evaluation of the data indicated that this outcome may have been influenced by one control participant who performed more than two standard deviations below the group mean on this post-test measure. When data from this participant were removed, there was a reliable between-groups difference on this measure (t(33)=3.07, p=.005, Cohen's d=1.02). These results appear to indicate that, as predicted, the simulator participants are less successful at retrieving the face-scene pairs during the post-test even though they are now instructed to perform at their best.

Table 2

Correct Recognition, d', and Forced-Choice Accuracy Means and Standard Deviations of Post-Test

	Corrected Recognition (%)	d'	Forced Choice Accuracy (%)
Controls	74.79 (26.14)	2.04 (2.04)	91.30 (13.24)
Simulators	56.17 (26.19)	1.87 (1.13)	82.76 (12.37)

Time required to select the matching face or a random face in the absence of a match during the post-test was also examined. A repeated measures ANOVA with group as a between subjects variable (control, simulator) and trial type as a within subjects variable (target-present, target-absent) was conducted. Here we found a significant main effect of trial type (F(1,34)= 61.71, p<.001), where target-present trials were responded to more quickly (M=2632.77, sd=615.06) than target-absent trials (M=2193.59, sd=613.94). There were no differences in response times between groups (F(1,34)=.95, p=.34), nor was there a significant interaction between group and trial type (F(1,34)=.05, p=.83). Due to presence/absence judgments being made verbally, response times for these judgments could not be analyzed.

The post-test questionnaire confirmed that participants understood the instructions that were given to them. Effort, motivation, and confidence levels were high for both groups (controls: Effort – M=4.56, sd=.62, Motivation – M=4.27, sd=.75, Confidence –

M=4.00, sd=1.03; simulators: Effort – M=4.22, sd=.65, Motivation – M=4.11, sd=.83, Confidence – M=3.83, sd=.71). The most common strategies that simulator participants reported using to complete the malingering task were answering randomly (n=11), looking away from task relevant materials (n=9), and taking longer than necessary to respond to trials (n=8).

Discussion

The above results suggest that, as hypothesized, eye movement based measures are sensitive to relational memory even when a person is attempting to conceal their knowledge. Explicit behavioral responses showed that participants instructed to feign memory impairment were able to do so with their explicit responses, performing much worse than control participants and no different from chance level performance. However, despite this success concealing their memory through their explicit responses, early disproportionate viewing towards matching associates provided evidence for the knowledge of the relationship. This viewing pattern was observed not only for trials in which the participants correctly stated that the matching face was present, but also for those in which the participant concealed their memory by denying the presence of the associate. It is also notable that for this early disproportionate viewing, the magnitude did not differ between groups for correctly answered trials or within simulators between correctly and incorrectly answered trials. This indicates that this effect does not seem to be affected by the instructions to conceal memory generally, or by the decision to conceal memory on a particular trial.

First, it is important to note that this effect is not observable when the entire duration of the display is considered. When the whole six seconds were analyzed, simulator participants only showed disproportionate viewing on trials in which they answered correctly, and the magnitude of the disproportionate viewing for these trials was reduced compared to control subjects. It was only when analyses were restricted to the first 1000ms of viewing that the sensitivity of the eye movement measures were evident. This outcome points to the importance of conducting time course analyses, such as the one we used in this study, when analyzing eye movement measures. The fact that the effect occurs so quickly after stimulus onset replicates previous findings (Hannula et al., 2007; Hannula & Ranganath, 2009), and is consistent with the proposal that this eye-movement-based memory effect is an obligatory reaction to the retrieval of a relational memory. The fact that viewing decreases after this initial effect back to chance levels when simulators make incorrect trials further supports this idea, as it suggests that when participants can consciously control their viewing, they attempt to look away from the matching face in accord with their goal of concealing their knowledge of the scene-face pair. Again, this implies that the early viewing effect may be a non-conscious effect of memory, occurring before task-relevant influences, such as goals, begin to impact viewing (see also Hannula & Ranganath, 2009).

It is also important to note that the pattern of viewing that we observed in our simulator participants differs from previously described viewing patterns of patients with documented relational memory deficits (Hannula et al., 2007; Williams et al., 2010). When tested with a similar paradigm, these patients showed similar decreased behavioral performance as our simulator participants. However, these patients showed viewing patterns that differed from those of controls and from our simulators. Patients with hippocampal amnesia did not show any disproportionate viewing to matching faces on either correctly or incorrectly answered trials, even when analyses were restricted to early viewing (Hannula et al., 2007). Patients with schizophrenia who have documented relational memory deficits showed some disproportionate viewing, but it was of decreased magnitude and occurred later in time than control patterns of viewing (Williams et al., 2010). These differences in viewing patterns between our simulator group and these groups of patients indicate that eye movement measures evaluated early in viewing could be useful in distinguishing between people who truly have memory impairment and those who are malingering this type of deficit. As mentioned earlier, developing measures that can differentiate between these two groups is an important endeavor because malingering is a problem in the allocation of societal resources and because current methods have significant flaws. Obviously, much more work would need to be conducted before eye movement measures could be proposed as a method for clinically determining a person's level of effort. Most importantly, studies would be needed in which both patients and simulators are tested on the same protocol, which would allow for calculations of important indicators of how useful eye movement measures might be, such as sensitivity and specificity.

As just mentioned, current methods of detecting malingering are subject to criticism and have some flaws. One of the biggest criticisms of neuropsychological performance validity testing is that coaching of what these measures look like can undermine their success in detecting malingering. When a person who is attempting to malinger is aware of which tests in the neuropsychological battery are intended to measure effort, they can change their strategy selectively for these measures and circumvent being detected by these tests. This is not just a theoretical concern. In a survey of lawyers, about 50% of attorneys stated that they felt that it was part of their responsibility as a lawyer to inform their clients about the presence of performance validity tests in neuropsychological batteries (Wetter & Corrigan, 1995). A later study showed that around 75% of attorneys spend time preparing clients for neuropsychological examinations including providing descriptions of the types of assessments that will most likely be used and describing the ways that assessors test for malingering (Essig et al., 2001). With test security threatened because of the widespread availability of information on these tests online (Bauer & McCaffrey, 2006), it would not be surprising for a person undergoing a forensic evaluation to be aware of exactly which measures were being used to detect malingering. Furthermore, studies have shown that coached malingerers may show more sophisticated techniques for feigning their impairments (Youngjohn, Lees-Haley, & Binder, 1999).

Eye movement measures are not necessarily immune to these coaching concerns. Our study did not test how viewing patterns of simulators would change if they were informed ahead of time that their eye movements could reveal their knowledge for the pairs. This is a study that needs to be conducted. However, we would predict that even with this coaching, the pattern of early disproportionate viewing to matching faces would remain the same. Again, this is because we believe that these eye-movement-based memory effects represent an obligatory reaction to the retrieval of the matching face given the scene cue, and therefore the simulator would not be able to prevent it from occurring. Instead, we might predict an even greater decrease in viewing of the matching face after this initial effect, once consciously controlled eye movements come online and the participant attempts to disengage attention to prevent detection.

This disengagement of attention from the matching face, as evidenced by the decrease in viewing directed towards it after the initial effect, is also of interest. It occurs to some degree for correctly answered trials, as the viewing on these trials was lower than for control participants. It is most noticeable, however, in the incorrectly answered trials, in which the viewing of the matching face reduces to the level of viewing of non-matching critical faces in target-absent displays. This indicates that when simulators have decided to conceal their memory by responding incorrectly, they do have some inclination to divert their attention, and their eye movements, away from the matching face. This idea is further supported by the self-reported strategy employed by half of simulator participants to intentionally look away from task-relevant materials. While they were obviously aware that their eye movements were being monitored, they were not instructed as to how they should view the display or told about our expectation for eye movements to reveal their memory. This provides further evidence that the initial memory-based effect might represent an obligatory reaction, as participants seemed to understand that not viewing the matching face was important for success in their goal of simulating malingered amnesia.

We also examined performance on a posttest in which the instructions to simulate malingering were removed for the simulator group. Despite simulator and control participants completing the same task under the same instructions to optimize performance during this part of the experiment, the control participants' accuracy in both identifying the presence of the matching face and selecting the matching face from the three alternatives in the display exceeded that of the simulator participants. There are several reasons that this might have occurred. First, it could be that the simulator participants, knowing that they were going to have to fake a memory impairment, chose not to study the materials as well as controls during the encoding phase. This could be a good strategy, as participants were not warned about the need to accurately recall the pairs on the posttest during the first part of the experiment. However, this does not seem plausible. As mentioned previously the magnitude of the eye-movement based memory effects early in viewing were as robust in simulator participants as in control participants. This appears to indicate that the encoding of the scene-face pair was comparable between groups. This hypothesis could also be tested by informing the simulator participants of the posttest before the encoding phase, so that they would be more motivated to encode the materials. This is something that we are implementing in upcoming studies.

A second explanation for the impairment on the posttest is that the control participants had an extra opportunity to retrieve and strengthen the memory during the test phase, and that the simulator participants missed this opportunity due to their attempts to conceal memory. That is, it is not that the act of malingering harms the memory trace of simulators, but rather the act of *not* malingering allows controls to strengthen their memory for the scene-face pairs. However, this explanation also has some problems. Again, the simulator participants did seem to have some memory retrieval during the test phase, as shown by the eye movement based memory effect. In addition, control participants' performance did not improve from the initial test to the posttest, so it does not seem to be the case that a testing effect is improving their performance and driving the difference between the two groups.

One last explanation for decreased posttest performance among simulators, and the one that seems most plausible, is that the act of concealing memory during the initial test somehow harms subsequent retrieval of the studied pairs. Previous research has shown that attempts to suppress memory retrieval in the presence of a cue decreases the ability to retrieve that memory at a later time, a phenomenon termed suppression-induced forgetting (Anderson & Green, 2001). If the simulator participants were attempting to suppress memory for the face when presented with the scene cue in order to achieve their goal, this suppression-induced forgetting could account for the relatively weaker performance on the posttest by these participants.

The current study is not without its limitations. First, the fact that control participants had very few incorrect trials is both a strength and a weakness. Their near-ceiling performance is a strength in that it allows us to reasonably conclude that the majority of the incorrect responses given by the simulator participants were due to their attempts to conceal their memory rather than simply not remembering the face that had been paired with the scene. However, the fact that we did not have enough incorrect trials to analyze for the control participants is a weakness in that we do not have the ability to compare viewing patterns on incorrect trials across groups as we did for the correct trials. Finding a way to implement this paradigm while increasing the difficulty would allow us to examine the pattern of viewing of participants who are attempting to optimize performance but who miss a matching face in a target-present display and compare this pattern to that of our simulators.

Another limitation of our study is that, although we are attempting to study the phenomenon of malingering, our sample consists of college students instructed to simulate malingering. There are many differences between this group and true malingerers, the most important being the motivation behind the act. Our simulators were performing at the behest of the experimenter, while a person malingering in the real world is often doing so for some kind of personal gain. There is also a difference in the experience level of these two groups. By the time they make it to an evaluation, a true malingerer has likely had a significant amount of time and practice acting out their memory deficit. Our participants were required to perform immediately after receiving the instructions that they needed to hide their memory. These differences could influence the strategies that these two groups use or the manner in which they attempt to conceal their memory. However, it is extremely difficult to gather a sample of people malingering in the real world as these people are usually not willing to admit to their actions, and so the simulation of malingering is likely the best approximation. We simply need to keep in mind that our results might not be identical to what would be found in clinical or forensic settings.

One next step that could be taken with this research is identifying which neural regions contribute to the memory, attention, and cognitive control processes that are required for successful completion of this simulated malingering task. Previous research has shown that hippocampal activity during the scene cue predicts the disproportionate viewing directed towards the matching face during the three-face display (Hannula & Ranganath, 2009). This has been attributed to the pattern-completion processes of the hippocampus, such that when participants are presented with the scene cue, the hippocampus is involved in the retrieval of the face that completes the pairing. This successful retrieval of the relational memory is thought to be what drives the early disproportionate viewing of the matching face. Therefore, we would expect to see this hippocampal activity during the scene cue for both control and simulator participants on trials where they display disproportionate viewing. Based on the findings of the current study, this would include trials in which simulators hide their memory by explicitly responding incorrectly.

While group differences in neural activity would not be expected during the scene cue, we would expect to find significant differences during the presentation of the three-face display. Response times in the current study, where simulator participants were slower to respond to both target-present and target-absent displays, may indicate that the act of simulating malingering is a more cognitively complex task than simply performing optimally. Successfully concealing memory would require cognitive control processes such as conflict monitoring and the disengagement of attention. Therefore, we would expect regions implicated in these processes, such as the anterior cingulate cortex and the lateral prefrontal cortex along with other structures in the dorsal attention network (Anderson et al., 2004; Kerns et al., 2004; Corbetta et al., 2008), to be more active during the presentation of the three-face display in simulator participants than in controls.

Finally, neuroimaging studies could be useful in investigating the question of the impaired posttest performance. As hippocampal activity has been linked to performance on relational memory tasks (Hannula et al., 2009), we would expect that the suppression of hippocampal activity during the three-face display, when simulators are attempting to conceal successful retrieval, would be related to the decreased performance on the posttest. We would also expect that this suppression would be a result of the connections between the hippocampus and the prefrontal cortex due to research that shows that the prefrontal cortex is involved in the selective retrieval of memories that are appropriate for the current context and suppress those that are inappropriate (c.f. Preston & Eichenbaum, 2013). This type of neuroimaging study is currently underway.

In sum, this study added to a robust line of research that shows that eye-movement measures are sensitive to relational memory and that these types of memory effects occur extremely rapidly after stimulus onset. The current study adds to the idea that these eye movements might represent an obligatory response to the retrieval of an episodic memory after being presented with a retrieval cue. These conclusions can be further supported by additional studies implementing the instructional manipulation developed in this study. In addition, this study suggests that eye movement measures could be useful in distinguishing between people who truly have memory deficits and those who are feigning impairment. However, this is one of the first studies looking into this use of eye movement measures. These are preliminary findings and there is much research that would need to be conducted before attempts were made to integrate these types of measures into clinical or forensic settings. That being said, this study provides exciting findings that indicate a potential new use for eye tracking methodology and a potential solution to the problem of detecting malingering that has plagued society for decades.

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Appendix A

Instructions Read to the Simulator Group

"For this experiment I would like you to imagine that you were in a car accident in which another driver hit your car. You were knocked unconscious, and woke up in the hospital. You were kept overnight for observation. The doctors told you that you experienced a concussion. Try to imagine that a year after the accident, you are involved in a lawsuit against the driver of the other car. If you are found to have experienced significant injuries as a result of the accident, you are likely to receive a bigger settlement. You have decided to pretend that you are suffering from a memory disorder as a result of the accident. As a part of the lawsuit, you are required to take a test to determine whether or not you actually have a memory problem. You will complete this test today. If you can successfully convince the examiner that you have a memory deficit, you are likely to get a better settlement. However, it is important that you perform in a way so that the examiner believes that you truly have a memory problem, but that it is not obvious that you are faking. For example, some strategies that would be too obvious, and would alert the examiner that you are faking, would be to answer every question incorrectly or to not answer some of the items. Once the examiner enters the room, you won't be able to ask any questions about these instructions, so, do you have any questions about what you are trying to accomplish during this experiment?"

Appendix B

Post-Test Questionnaire

1) Recall, in your own words, what the instructed objective was for this experiment.
2) How much effort did you put in to accomplish this objective?

0 1 2 3 4 5

(No effort) (Great effort)

3) How motivated were you to accomplish this objective?

0 1 2 3 4 5

(Not motivated at all) (Very motivated)

4) How confident are you that you accomplished this objective?

0 1 2 3 4 5

(Not confident at all) (Very confident)

5) What strategies did you use to accomplish the objective? (check all that apply)

_______ answered most/all items incorrectly

_______ answered in a pattern (e.g. alternated between "yes" and "no")

_______ answered randomly

_______ looked purposely away from the task-relevant materials (e.g., looked at scenes, but not at faces)

_______ blurred vision so could not see stimulus during study or test phase

_______ attempted to get a certain percentage correct (what percentage? ________)

_______ did not respond to some/all test items

_______ took longer than was necessary to respond to test items

_______ other (please describe): ____