Eye Spy a Liar:

The effect of deception on fixation-based measures of memory

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Abstract

The over-arching aim of this thesis was to evaluate a new experimental approach to detect recognition memory in liars, when recognition of familiar photographs was intentionally concealed. Eye tracking was selected as a novel methodological approach to memory detection because previous eye movement research documented that recognition of familiar faces and scenes produced fewer fixations to fewer regions of longer durations. The effect of deception on fixation-based measures of memory was examined in four experimental chapters. **Experiment 1** explored whether fixations exposed concealed person recognition of three different familiar face types: newly learned via one exposure, famous celebrities, and personally known. Multiple fixation measures exposed recognition when liars denied recognition of famous celebrities and people who were personally known. Memory for newly learned faces was revealed during honest recognition solely in fewer fixations, with a trend in the number of fixations to suggest memory in lie trials. **Experiment 2** emphasised monitoring of memory and eye movements during a similar concealed recognition task. Participants told the truth and lied about faces that were newly learned-to-criterion and personally familiar faces followed by a confidence rating (0-100%) based on each honest and deceptive recognition judgement. Effects of memory were observed in multiple fixation quantity measures and in fixation durations. The pattern of results for newly learned faces was the opposite of results found in Experiment 1. Unexpectedly, no effects of memory were found during honest recognition of newly learned faces, but fewer fixations and run counts were observed during lie

trials. The data suggest that the clear reduction in viewing during lie trials could be a consequence of participant's efforts to control their gaze behaviour to evade detection combined with recollective efforts to remember then conceal newly learned faces. **Experiment 3** monitored fixations during concealed recognition of objects and scenes. When participants told the truth about personally familiar scenes and buildings memory effects were observed in fewer fixations, run counts and interest areas visited. During lie trials, effects of memory were only robust for the number of fixations. Similar to Experiment 2, lies about items newly learned-to-criterion produced no effect of memory in truth trials but revealed fewer fixations, run counts and areas of interest visited during lies. In both Experiments 2 and 3, a reduction in the variability of verbal confidence ratings was associated with recognition of personally familiar faces. **Experiment 4** monitored fixations whilst participants viewed pairs of faces associated with specific scenes. The location and duration of first fixations revealed a preference for viewing faces that matched the scene displayed. Longer fixation durations in the last fixation also indicated deceptive efforts when intentionally making misidentifications.

Overall, the results of the present thesis supported the potential of fixations as markers of memory when people lied about recognition of faces, scenes, and objects, as well as face-scene relationships. The results suggest that memory effects during recognition of personally known faces is robust in the number of fixation measure, but is observed in less fixations measures during lies about recognition of personally familiar objects and scenes. Furthermore, memory effects during recognition of newly learned items is more vulnerable to cognitive load and other executive processes, such as trying to control eye movements, and thus caution is advised when interpreting the effect of memory on fixations during concealed recognition of newly learned items. The research recommends that future experiments carefully explore the ability of liars to effect countermeasures on gaze behaviour to evade memory detection. The research further suggests that fixations durations might be a better measure to distinguish lies from truths about recognition and that the combined effect of memory and cognitive effort during lies produce more consistent and distinguishable differences in fixation durations between truth tellers and liars.

Contents

Declaration

Whilst registered as a candidate for the above degree, I have not been registered for any other research award. The results and conclusions embodied in this thesis are the work of the named candidate and have not been submitted for any other academic award.

Liar Illusion by Paul Agule (Source: www.anopticalillusion.com)

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List of Figures

Abbreviations

CIT	Concealed Information Test
EMMA	Eye Movement-based Memory Assessment
EMME	Eye Movement-based Memory Effect
ERP	Event Related Potential
fMRI	functional Magnetic Resonance Imaging
*m*CIT	modified Concealed Information Test
RM ANOVA	Repeated Measures Analysis of Variance
SCR	Skin Conductance Response

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Dissemination

Conference Papers

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Millen, A., Hope, L., Hillstrom, A & Vrij, A. (2011). *Tracking the truth: Cognitive load, eye movement-based memory effects (EMME) during concealed face recognition.* Paper presented at The American Psychology-Law Society (AP-LS). Florida, Miami, March 3-5.

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CHAPTER 1.

General Introduction.

Eye movements and Memory Detection.

1.1. Overview

The on-going threat from terrorism and organised crime demands new and better methods to extract concealed information from the memories of deceivers. The overall aim of the present research was to develop a novel eye movement methodology to explore the cognitive processes that occur during concealed recognition of photographic evidence. Despite the prevalence of photographic evidence in forensic investigations (Ministry of Justice, 2011), most memory detection research has focussed on verbal or manual responses to questions or two-word phrases presented on computer screens such as *blue coat* or *green tie*, and so have been more relevant to identifying persons lying while being interviewed than to persons lying while inspecting photographic evidence (e.g., Farwell & Donchin, 1991; Rosenfeld, Soskins, Bosh, & Ryan, 2004). The overarching research question concerns whether eye movements might facilitate memory detection when recognition of photographic evidence is being intentionally concealed by liars.

In a series of laboratory experiments, the current research employed eye tracking technology to investigate the effect of perceptual and other cognitive processes (response conflict, eye movement strategies) on fixation quantity and durations during concealed recognition. Predominantly the experiments explore fixations during concealed person recognition (Experiments 1 and 2). Establishing the identity of persons connected to a crime, whether suspected associates or potential victims, is a critical task for intelligence-gathering officers. Despite the key role that person identification plays in intercepting and resolving crimes, relatively few studies (as compared to interviewing protocols) have employed memory detection approaches to detect concealed recognition of photographs of known persons. Of the few studies that have investigated concealed recognition of known persons, only one (Schwedes & Wentura, 2012) has adopted an eye movement methodology to detect memory during concealed person recognition.

Suspects and witnesses may also conceal critical knowledge relating to a crime scene or an object critical to an investigation (i.e., a weapon). For this reason, the thesis also examines concealed recognition of non-face photographic stimuli: namely concealed object or scene recognition (Experiment 3). Only one peer reviewed study has combined eye movement monitoring with a memory detection paradigm to look for signs of recognition memory when lying about photographs of objects central or peripheral to a mock crime (Peth, Kim, & Gamer, 2013). No research has explored eye movement behaviour to detect concealed recognition of whole scenes. In a final experiment (Experiment 4), the extent to which eye movements revealed memories for critical faces associated with specific scenes was also examined. The monitoring of eye movements to explore relational memory effects during lies about face-scene pairs is a unique contribution to research in memory detection. Furthermore, Experiment 4 is the first known experiment to explore an alternative deceptive decision making strategy (false incrimination of known innocent) during relative processing of more than one person at a time (concealed information tests typically require absolute decisions to single items). This final experiment makes the first step to exploring alternative decision making strategies potentially exploited by deceptive witnesses viewing line-ups.

To explore the cognitive processes in concealed recognition, and the potential use of eye movements in memory detection, the thesis combined two leading paradigms in memory research: The Concealed Information Test (CIT; Lykken, 1959, 1960) and Eye Movement Memory Assessment (EMMA; Althoff, 1998). By developing novel combinations of these paradigms, the present work developed variations of the CIT to create three original tests of concealed recognition (Experiments 1 -3). In the final experiment, an alternative Differentiation of Deception Paradigm was employed (i.e., Furedy, Davis, & Gurevich, 1988; see Chapter 5).

1.1.1. Cognitive Approaches to Deception

Most modern lie detection techniques focus on developing cognitive load approaches (CLAs) to the study of deception (Lancaster, Vrij, Hope, & Waller, 2013; Leal, Vrij, Mann, & Fisher, 2011; Vrij, Granhag, Mann, & Leal, 2011; Vrij, Fisher, Mann, & Leal, 2008; Vrij, Mann, & Fisher, 2006; Walczyk, Igou, Dixon, & Tcholakian, 2013; Walczyk, Roper, Seemann, & Humphrey, 2003). Cognitive aspects of deception (Zuckerman, DePaulo, & Rosenthal, 1981) emphasise the need to strategically monitor memory and control behaviour to appear honest when lying, which underscores the cognitive demands of truth-lie conflicts. A liar must suppress a dominant truth response before executing a pre-formulated lie, and this response competition allegedly exerts increases in cognitive load that makes lying harder than truth telling (Spence et al., 2001; Vrij, Fisher, et al., 2008; Zuckerman, DePaulo, & Rosenthal, 1981). The fundamental assumption that lying is, under some conditions, harder than telling the truth is defined as the Cognitive Load Theory of Deception (Vrij, Fisher, et al., 2008). This conceptual notion defines most contemporary and well-accepted approaches to lie detection. A popular approach in lie detection is to impose additional cognitive load on interviewees to make lies easier to detect (Lancaster, Vrij, Hope, & Waller, 2013; Vrij et al., 2011; Vrij, Fisher, et al., 2008; Vrij, Mann, et al., 2008). Such socio-cognitive approaches are often applied in the field of field of investigative interviewing but are quite disparate from theoretical approaches to memory detection research (although see Visu-Petra et al., 2013 for an exception).

In contrast to CLAS, memory detection research tends to focus on detecting the presence of crime critical information stored in long term memory via the recording of various dependent measures that are thought to be largely involuntary such as the skin conductance response (for a comprehensive review see Verschuere, Ben-Shakhar, & Meijer, 2011). To do this, memory detection researchers use a particular test, known as The Concealed Information Test (CIT). The Concealed Information Test (CIT), originally referred to as The Guilty Knowledge Test (Lykken, 1959; 1960), is an experimental and diagnostic tool used to detect the presence or absence of crime-critical information in long term memory when a person is intentionally concealing that knowledge. During a CIT three stimulus protocol, examinees are presented with three types of information to which they are asked if they recognise the item or not; these items are defined as probes, irrelevants and targets. Probes are familiar, crime-relevant, items that are presented infrequently among several unfamiliar, irrelevant items. The CIT is based on the assumption that presentation of critical information, presented by the probe item, is salient only to the liar and thus elicits an enhanced response that distinguishes them from an honest naïve person who has no knowledge of the critical probe item. An honest person should, in theory, display similar responses to probes and irrelevants, whereas a liar will should display enhanced responses to the probe items. CIT measures thus look for signs of recognition of familiar items, from which deception is inferred when liars deny or conceal recognition. For liars the presentation of the rare but meaningful probe carries a signal value and thus elicits an observable response in a particular dependent measure (Lykken, 1959, 1960). The additional target item (familiar but not crime relevant) is a relatively new additional to the original guilty knowledge test (Farwell & Donchin, 1991; Rosenfeld et al., 2004) to encourage attention towards the stimulus screen so that the participant does not systematically respond unfamiliar for every trial without engaging properly to the test. The target item also serves to establish cooperation in the interviewee. Also, because the target is a rare task relevant (but crime irrelevant) stimulus it evokes a benchmark with which other responses can be compared. The probability based formula (rare probe: many irrelevants) of the three stimulus protocol have earned it the status as the most reliable and valid tool for the study of memory detection (Ben-Shakhar, Bar-Hillel and Kremnitzet, 2002; Ben-Shakhar and Elaad, 2003; Lykken, 1998).

The most popular theoretical account of the CIT is Orienting Response Theory (OR; Sokolov, 1963). The human orienting response is based on theories of attention orientation. If a person experiences a novel or unexpected stimulus, a change to a previously seen stimulus, or the presentation of something that is personally meaningful to them, attention will be preferentially oriented towards that significant element (Sokolov, 1990). In the CIT liars' attention orients towards the rare but meaningful crime relevant test item that may be recorded via physiological measures from the autonomic nervous system (e.g, skin conductance response; Ben-Shakhar & Elaad, 2003; Gamer, 2011), or psychophysiological familiarity signals in event related potentials (Marchand, Inglis-Assaff, & Lefebvre, 2013; Meijer, Smulders, Merckelbach, & Wolf, 2007; Meijer, Smulders, & Wolf, 2009). In addition to measures such as SCRs and ERPs that tend to focus on orienting responses to recognised crime critical items, other researchers focuses on the measuring of response conflict component of lying. ERP (Johnson, Barnhardt, & Zhu, 2003, 2004) and fMRI researchers (Bhatt et al., 2009; Ganis, Rosenfeld, Meixner, Kievit, & Schendan, 2011; Schumacher, Seymour, & Schwarb, 2010) have also focussed, on monitoring executive processes and response conflict experienced during lying. The relative contribution of the orienting response and executive processes required for lying has been addressed by some memory detection researchers in single studies (Ambach, Stark, Peper, & Vaitl, 2008; Furedy, 2009; Sokolov, 1990; Verschuere, Crombez, Smolders, & De Clercq, 2009) although field practitioners are less concerned with the relative contribution of the different subcomponents given that they provide incremental discriminative ability to detect liars (Ambach, Bursch, Stark, & Vaitl, 2010; Gamer, Verschuere, Crombez, & Vossel, 2008).

A more comprehensive memory-based account of concealed knowledge tests that attempts to account for orienting of attention to familiar items as well as efforts to conceal that knowledge, is described by The Parallel Task Set (PTS) model (Seymour, 2001). The PTS model emphasises competing demands for sub components crucial to the concealed information task: memory processes, response selection, response preparation, and motor execution (Schumacher, Seymour, & Schwarb, 2010; Seymour & Schumacher, 2009; Seymour, 2001). Recognition can be explained in terms of two task sets that occur independently and in parallel for each question relating critical probe items: familiarity and recollection. The familiarity task set occurs quickly and relies predominantly on automatic priming mechanisms whereas the recollection task set occurs more slowly, is under conscious control and draws on cognitive resources. Truthful responses are triggered by automatic familiarity based memories, whereas deceptive responses are mediated by the recollective task set overriding the automatic processing of familiarity. Responses initiated by familiarity may well be underway when they are interrupted by recollective task sets, resulting in response competition and thus conflict. Of course, honest familiarity based judgements also subsequently employ recollective processes for the classification of faces into different categories such as friends or foes (e.g., Schwedes & Wentura, 2012). The importance of response competition between source memories and response intentions during lying are central to conflict-monitoring and cognitive control (Botvinick, Braver, Barch, Carter, & Cohen, 2001). Considering the importance of both tasks sets to the concealment of recognition it is important to develop a tool that can identify and account for both (Blandon-Glitlin, Fenn, Masip, Yoo, & Blando, 2014). In each experiment presented in the current thesis, the effect of deception on a range of fixation-based measures is explored to evaluate the effect of cognitive load and memory effects on visual attention during lies about recognition.

Proposing an modified eye movement-based CIT

A key aim of the thesis is to explore a new method for memory detection that fulfils the key objectives of modern day CLAs: to better elucidate the cognitive mechanisms that underpin deception, to inform how to better detect instances of deceit in field settings, and to develop a tool that will be relatively practical, relatively non-intrusive and effective to implement in the field.

In 1959, when Lykken first discovered that phasic skin conductance could be used to detect concealed knowledge based on the orienting response (OR; Sokolov, 1963), the most common method of measuring OR with humans had been through the recording of eye movements (Zajonc & Burnstein, 1959). This method was favoured because, in experiments of perception and attention, not only is it important to determine if the participant is in fact looking at what they are hypothesised to but it is also informative to know exactly where, when and how they are attending the visual stimulus. The ability to accurately monitor visual attention via eye movements might be particularly informative when trying to identify potential countermeasures or strategies used by liars to evade detection. Unfortunately eye movement apparatus such as the opthamolograph or Brandt's eye-camera were costly and presented technical weaknesses and thus fell out of favour (Allen, 1955; Brandt, 1945). In recent years, however, there have been considerable advances in eye tracking technology such that a range of eye movement parameters can be collected simultaneously and with relative ease and speed (e.g., SR Research Eyelink II). Each eye movement parameter provides insights into different aspects of visual processing and cognition. It is important to note that the practical and technical problems that eye movement monitoring faced in the 1950's are largely resolved, however similar issues are still problematic in the present day for the data collection and analysis of ERP and fMRI recordings.

ERP and fMRI procedures have, and continue to make, important theoretical contributions to the understanding of cognitive processes central to concealed recognition, but the apparent lack of utilisation by practitioners suggests limitations as practical tools for real world application. Limitations of both methodologies include their invasive nature, the technical expertise and time required for precise administration. All these limitations are costly, especially considering that research reveals them to be vulnerable to simple countermeasures such as toe wiggling (Ganis et al., 2011, Rosenfeld, Soskins, Bosh, & Ryan, 2004). If eye movement monitoring succeeds in revealing key processes central to deception, such as the identification of critical memories as well as the effort required to conceal these memories then eye tracking might be a relatively simpler and less invasive way to measure concealed memories as compared to other ERP-based or neuroimaging approaches to memory detection.

Trends in eye movement research reveal that eye movement monitoring is evolving as a popular cognitive process tracing methodology in human decision making research (Glaholt & Reingold, 2011). The eye-mind assumption (Just & Carpenter, 1980; Just & Carpenter, 1976) that eye movements provide direct insights into brain processes was influential to the rising popularity of eye movement research in experiments of attention, perception and memory in the 1980's. Eye tracking as a process tracing methodology allows the tracking of psychological events that occur prior to a response, advancing research on human decision making from a purely behaviourist approach to a more cognitive one that focuses on attentional resources and decision processes as opposed to decision outcomes alone (Russo, 2011).

In the past decade or so, eye movement monitoring has played a major role in investigations of memory (for review see Hannula, Althoff, Warren, Riggs, Cohen & Ryan, 2010). Eye movement research allows the tracking of visual (i.e., hue and luminance) and cognitive factors based on previous experience during recognition (Antes, 1974; Buswell, 1935; Henderson, Weeks, & Hollingworth, 1999; Loftus & Mackworth, 1978; Mackworth & Morandi, 1967; Parker, 1978), whilst being able to examine the link between concealed recognition and attentional processes more directly (Ganis & Patnaik, 2009; Just & Carpenter, 1976).

Furthermore, on a practical level, the development of video-based mobile trackers potentially allows the covert recording of these eye movements should the examiner desire to minimise awareness in the examinee. Conversely, more evident eye tracking equipment may be used if the goal of the experiment is to heighten awareness. Regardless, unlike other cognitive-based procedures to study memory processes (i.e., ERP and fMRI), eye movement data may be gathered relatively non-invasively, quickly and inexpensively; making it a relatively practical and flexible tool for the study of cognitive processes while liars are attempting to conceal secret memories. Eye movement monitoring also allows the examination of the key subcomponents required for the concealment of memory; memory (Althoff & Cohen, 1999; Hannula, Althoff, et al., 2010), response selection efforts (Ryan, Hannula, & Cohen, 2007; Schwedes & Wentura, 2012) and deception on fixations (Cook, Hacker, Webb, Osher, Kristjansson, Woltz, & Kircher, 2012; Zenzi M Griffin & Oppenheimer, 2006).

1.1.2. Eye Movement-based Memory Assessment

While the past ten years of CIT research has developed sophisticated methods (i.e., ERP, fMRI) to elucidate the cognitive neuroscience of deception, the field of eye movement behaviour has made similar advances in the neuroscience of memory (for a review see Hannula et al., 2010). The memory at the centre of the current thesis is that of recognition, specifically the ability to recognise people, places and objects that have been previously viewed and subsequently stored in declarative long term memory. The ability of eye movements to identify recognition memory, as explored in the present thesis, was guided by two key articles that were pivotal to the development of the experiments presented (Althoff & Cohen, 1999; Ryan et al., 2007):

The first paper by Althoff and Cohen (1999) documents memory reprocessing effects in eye movement behaviour during recognition of famous faces compared to non-famous faces. The main finding of their research was that different fixation patterns were observed when participants viewed familiar (famous) and unfamiliar faces (non-famous), and that this effect of memory on eye movements could be quantified in a range of fixations measures prior to recognition, as indices of memory. The reprocessing effect was observed in multiple eye movement parameters such as fewer fixations and the number of areas viewed on the face when familiar faces were viewed, compared to unfamiliar faces. Althoff & Cohen's (1999) seminal article was the first to explicitly document the finding that previous exposure changes the way we visually inspect photographs of familiar faces. The authors propose that this occurs because familiar faces re-engage visual pattern analysers encoded during previous viewings and thus influence face processing mechanisms in the brain.

In their experiments, Althoff and Cohen (1999) presented participants with a series of portrait photographs of familiar (famous) and unfamiliar (non-famous) faces. Faces were each presented for five seconds, during which participants made a familiarity based button press response. Their findings documented fewer fixations and fewer regions sampled for famous faces, reported in the number of fixations, the regional distribution of the number of fixations on the face (right eye, left eye, nose, mouth, outer) and the spatial distribution of these fixations (proportion of fixations directed to the inner regions of the face). The order of the fixations on the face was also more random (less constrained) when viewing famous faces than for non-famous faces. Simply put, a re-processing effect occurred when viewing familiar faces that changed the nature of perceptual processing and way in which familiar faces were subsequently viewed (Althoff & Cohen, 1999). The quantification of familiarity via physical eye movement behaviour has since provided a range of opportunities for the study of multiple memory systems in the brain (Hannula, Althoff, et al., 2010).

In further experiments, Althoff and Cohen (1999) documented that the effect of memory on eye movements extended from recognition of identity to judgments of emotions. From the emotions task the researchers suggested that the recognition based effects were obligatory, because they occurred irrespective of the nature of the task. By measuring the fixations before a response selection was made, the researchers also observed that memory effects occurred early in viewing behaviour before an actual judgement was made (first two seconds), a finding that they took to suggest that memory effects on eye movements were obligatory in nature. The proposed obligatory effect of memory on eye movements is also reinforced by clinical research that has found the same pattern of eye movements in patients with amnesia (Robert Russell Althoff, 1998) and congenital prosopagnosia (face blindness) (Bate, Haslam, Tree, & Hodgson, 2008). If the effect of recognition memory on eye movements is obligatory in nature it may prove to a useful method for memory detection, as an involuntary markers of recognition are favourable in memory detection due to the belief that they are more resistant to countermeasures (Verschuere, Ben-Shakhar, et al., 2011).

In another experiment, the researchers also discovered that memory effects were not limited to viewing of and judgements to pre-experimentally familiar faces (i.e., famous celebrities) but that they also emerged with repeated exposure to pre-experimentally unfamiliar faces. Also importantly, the eye movement effect was not specific to face stimuli. The researchers observed memory effects in the eye movements of participants that viewed images of famous and unknown buildings. That the EMME is generalisable to non-face stimuli such as familiar and unfamiliar buildings (Althoff, 1998) and scenes (Ryan, Althoff, Whitlow, & Cohen, 2000), makes it a potentially comprehensive tool for all types of photographic, forensic evidence.

In sum, the effect of memory on eye movements distinguished not only between repeated and novel faces, it also emerged during controlled exposures to pre-experimentally faces, and was found for faces (pre-experimentally unfamiliar and famous faces) and non-face photographic stimuli (buildings). Althoff and colleagues (Althoff et al., 1999; Althoff & Cohen, 1999; Althoff, 1998) extensive and original research paved the way for understanding how previous experience changed the nature of visual processing and the resultant manifestation of memory effects in eye movement behaviour. Researchers have since extended Althoff & Cohen's (1999) seminal work to more specifically identify exactly when the effect of memory on eye movements emerged (Ryan et al., 2007; Schwedes & Wentura, 2012).

Ryan et al., (2007) further explored the emergence of memory on fixation durations by monitoring eye movements using fixation-by-fixation analyses and time course analyses (500 ms time bins). The researchers presented participants with three-face displays of familiar and unfamiliar faces. Familiar faces had been learned during a study phase (5 seconds exposure) prior to the experimental trials. There were two types of display: known and unknown. In the known displays one known face was presented with two unknown faces. In the unknown display all faces were unknown. In the known display the participant was instructed to select the known face, whereas in the unknown display they were asked to select a face at random. The main finding was that fixation durations were longer for known faces selected in the known display than unknown faces selected in the unknown display. Fixation-by-fixation analyses identified the effect of memory (longer fixations) during recognition judgements emerged as early as the first fixation, and time course analyses revealed the effect of memory from 1000-1500 ms and was remained for the rest of the viewing period (10 seconds). The researchers also found effects of memory effects whether participants freely viewed the face (incidental encoding) or made a recognition based judgement (intentional identity retrieval) or told to avoid looking at the face, which the authors documented support for Althoff and Cohens's (1999) claim that the effects of memory are obligatory. Furthermore, from these findings the researchers inferred that changes in fixation duration in the unknown display were mainly a result of cognitive efforts required for the planning and execution of their intended response (response intention). Later work further dissociated the effect of planned response selections on fixations durations separate from memory (Schwedes & Wentura, 2012).

The potential for fixation durations to elucidate the temporal dynamics of different cognitive processes (recognition and response intentions) during recognition of faces was a new finding in the eye-movement literature. The potential of this particular eye-movement parameter to explore cognitive efforts associated with recognition and response intentions during concealed recognition is yet to be thoroughly explored. Given the clear link between memory and eye movements it is surprising that only one study modified a CIT to investigate fixation durations as a marker of cognitive processes during lies about recognition (Schwedes & Wentura, 2012; see Chapter 2 for a full discussion of this paper). No other known peer reviewed articles have been published on the topic. More importantly, no work has directly explored the effect of deception-based cognitive load on recognition memory and response intention effects.

Aim of Thesis

The present research developed novel modifications of the Concealed Information Test (*m*CIT) to investigate whether eye movement memory effects could reveal concealed recognition of faces, scenes and objects. In each experiment the impact of cognitive load on multiple eye movements during concealed recognition was assessed. A key focus throughout the thesis was to manipulate the familiarity of faces to test the robustness of eye movement memory effects when familiarity varied. The abstracts for each experimental chapter are presented.

1.2. Abstracts for Experimental Chapters

1.2.1. Chapter 2: The effect of deception on fixation-based measures of memory during concealed person recognition.

Experiment 1 monitored participants' eye movement behaviour whilst they lied and told the truth about recognition of different familiar faces that varied in familiarity (newly learned, famous celebrities, personally known). Experiment 1 primarily examined whether fixations could distinguish known from unknown faces during truths and lies, and also explored the sensitivity of the eye movements to distinguish memory for faces that varied in degree of familiarity. Multiple fixation behaviours were recorded to examine the effect of cognitive load on different fixation measures during lies to familiar probe items, directly compared to the truth trials (unfamiliar irrelevants and familiar targets) for each familiar face type. Results reveal multiple markers of memory in fixation-based measures and that lying had negligible difference on pattern of fixations for memory detection. The number of fixations made to familiar faces was most reliable and strongest marker of memory across different face types (newly learned, famous celebrities and personally known). Proportion of fixations to inner regions was the least reliable measure of memory. Largest and most consistent effects of memory were observed during recognition of personally familiar faces.

1.2.2. Chapter 3. Emphasising memory confidence and eye movement monitoring: Effects on the detection of concealed person recognition.

Experiment 2 introduced memory confidence judgements as a novel way to distinguish truth tellers and liars by assessing variability in verbal confidence reports based on recognition judgements, and whether eye movement behaviour differed during deliberation of confidence reports. To encourage task focus and motivation to deceive the experiment made four main adjustments to the previous experiment: (1) To investigate the role of meta-memory in recognition judgements, participants were asked to report a confidence rating (0-100%) after each truthful and deceptive recognition judgement. (2) The experimenter explicitly emphasised that they would be monitoring the location, duration and distribution of fixations during both recognition and confidence judgements. (3) To encourage task-focussed motivation, participants were asked to make a verbal response at the same time as a button-press for both recognition (e.g., *familiar)* and confidence judgements (e.g., *ninety)*. (4) Participants were also informed that they would receive £5 cash at the end of the experiment if they evaded lie detection by the examiner. Instructions emphasised that, in both recognition and confidence judgements, the task was to appear honest during both truths and lies and that eye movement behaviour would be monitored during both judgements. The changes to the procedure were intended to stimulate meta-cognitive monitoring and control processes in the interviewee that likely operate at a high level during real-world questioning of suspects. Predictions that honest confidence reports based on unknown faces would display more variability than lies about familiar faces was partially supported by the data (personally familiar faces only). Predictions based on fixation behaviour were that eye movement patterns would be similar to Experiment 1 but that cognitive demands would be greater as a consequence of increased efforts for cognitive monitoring and control. The recognition based data revealed large effect size differences in multiple fixation behaviours between unfamiliar faces and personally known faces during both truths and lies. Contrary to Experiment 1, large effect size differences were observed between unfamiliar and newly learned faces, although only during lie trials. The lack of differences in fixation data during honest recognition of newly learned faces, compared to large effect size differences when lying, are discussed with reference to the attempted strategies to control of eye movements during lies.

1.2.3. Chapter 4. The effect of deception on fixation-based measures of memory during concealed recognition of objects and scenes.

Extending Experiment 2, which examined whether memory effects were observed during concealed recognition of faces, Experiment 3 explored the effect of cognitive load on liars' fixation patterns during concealed recognition of objects and scenes. Instructions that emphasised the monitoring of memory confidence and eye movements by the examiner was consistent with Experiment 2. Predictions were also the same as Experiment 1. Participants would display fewer fixations of longer durations during recognition of familiar objects and scenes, and that memory effects would be strongest and most reliable to during recognition of personally familiar objects and scenes. Results revealed that lies about personally familiar objects and scenes produced fewer and longer fixations in liars' eye movements. Contrary to predictions, but consistent with Experiment 2, larger differences in fixations were found between probes and irrelevants during concealed recognition of newly learned objects and scenes. The results suggest combined effects of memory and deceptive strategies for fixation patterns during lies about newly familiar items. Fixations durations were longer during concealed recognition of both newly familiar and personally familiar probes, compared to unknown irrelevants. Longer fixation durations for probes were significant in the third fixation (but trends emerged in the second fixation for personally familiar items only), and were tightly linked to deceptive response selections (500 ms before a lying response).

1.2.4. Chapter 5. Faces in context: Do fixations reveal memory for faces related to scenes?

Experiment 4 explored whether liars' eye fixations revealed (1) memory for previously learned associations between faces and scenes and (2) cognitive efforts to mislead the experimenter when liars purposely selected the wrong association. Participants were shown two-face displays presented on a single background scene; one face had been previously paired with the background scene during a study phase, the other face had been presented during the learning phase but was matched to another scene. Thus, test screens displayed two faces and a scene that were similarly familiar but only one face matched the scene displayed. At test, the participant either told the truth (identified face that matched the background scene) or lied (identified the non-matching face). Results revealed that the majority of first fixations were made to the matching face during both truth and lie trials, suggesting preferential orienting of attention to the face previously matched to the scene. Also, durations of first fixations were longer to the non-selected, matching face in lie trials than to the non-selected, non-matching face in truth trials. In the last fixation, the majority of lie trials revealed preferential orienting of attention to the face that did not match the scene, consistent with action planning. Durations were longer for the last fixation on the selected but non-matching face on lie trials compared to the last fixation on the selected matching face in truth trials, supporting predictions that planning of response selections is more difficult for liars. This novel experimental design contributes to memory detection research that traditionally uses protocols that investigate responses to known and unknown stimuli to reveal memory. The protocol presented here may be useful for police officers attempting to directly link a particular suspect to a specific crime scene.

CHAPTER 2.

The effect of deception on fixation-based memory effects during concealed person recognition

2.1. Introduction

During criminal investigations, deceptive interviewees might conceal recognition of persons they know and these will likely vary in degree of familiarity (i.e., highly familiar co-conspirators or lesser known criminal associates). To address this problem, Experiment 1 systematically manipulated familiarity of concealed faces and instructed participants to lie about different groups of faces (newly learned, famous celebrities, personally known) during a modified Concealed Information Test (*m*CIT). Experiment 1 novelly combined eye movement monitoring with a *m*CIT to investigate whether eye movement patterns might facilitate memory detection of known faces that varied in saliency. Previous CIT research has revealed test sensitivity to vary as a function of probe encoding strength (Rosenfeld, Shue, & Singer, 2007; Rosenfeld, Biroschak, & Furedy, 2006; Seymour & Fraynt, 2009). Recognition effects in eye movements are also known to scale with amount of previous exposure (Althoff, 1998; Althoff et al., 1999; Althoff & Cohen, 1999: Ryan et al, 2007). The present experiment, however, is the first of its kind to have combined eye movement monitoring with a *m*CIT whilst systematically manipulating probe familiarity within a single experiment.

The Concealed Information Test was designed to detect guilty knowledge withheld by a liar (Lykken, 1959, 1960). Interviewees probed under the CIT are presented with a series of single items to which they respond if they recognise the item or not. During a CIT three stimulus protocol, three types of items are presented to participants: *probes*, *irrelevants* and *targets* (*3SP*; Farwell & Donchin, 1991;

Rosenfeld, 2011). Critically, liars conceal recognition of probe items (such as a familiar face) whilst responding honestly to unknown irrelevants and familiar targets. The idea is that the probe item will be salient for the liar, thus an orienting response will be observed in the guilty persons as measured by a suitable dependent variable (behavioural, psychophysiological, or neural) that would not be evident in an honest person's responses to probe items. Target items in the 3SP are similar to the probe, such that they are familiar, rare and task relevant. The crucial difference is that they are not crime relevant and thus do not require concealed recognition. The function of the honest response to targets in the 3SP is to encourage and monitor task compliance, whilst providing a familiar benchmark by which to compare responses to probes items. Whereas orienting responses to targets and probes items tend to be similar, direct comparison of differences between targets and probes can further quantify cognitive efforts specific to a lie.

Few studies have adapted the CIT to study concealed person recognition (Bhatt et al., 2009; Ganis & Patnaik, 2009; Lefebvre, Marchand, Smith, & Connolly, 2009; Meijer, Smulders, Merckelbach, & Wolf, 2007; Meijer et al., 2009; Schumacher et al., 2010; Seymour & Kerlin, 2008). In these studies concealed recognition of a critical probe item resulted in slower response times (RT-CIT; Seymour and Kerlin, 2008), stronger event-related P300s (CIT-P300; Meijer et al., 2007, 2009) increased cerebral blood flow (fMRI-CIT; Bhatt et al., 2009; Schumacher, Seymour, & Schwarb, 2010) and an attentional blink in which detection of a familiar probe stimulus reduced detection accuracy rates of subsequent familiar target stimuli (Ganis & Patnaik, 2009). Changes in dependent measures during concealed recognition of familiar probe items are sometimes called guilty knowledge effects (GKEs; Seymour, Seifert, Shafto, & Mosmann, 2000), because they are used to infer guilt when an examinee explicitly denies secret knowledge of the probe item.

Central to Experiment 1, previous research supports that GKEs are modulated by probe saliency (Carmel et al, 2003, Gamer, Kossiol, & Vossel, 2010; Rosenfeld et al., 2007; Rosenfeld et al., 2006; Seymour & Fraynt, 2009). For example, self-referring probes such as the interviewees social security number have produced larger probe *versus* irrelevant difference amplitudes during an ERP-CIT compared to probes that were incidentally acquired details of a mock crime (Rosenfeld et al., 2007). Although larger probe-irrelevant difference amplitudes made probe detection easier for personally significant details, P300 amplitudes for probe items were greater than irrelevants for both self-referring and incidentally acquired details.

Despite the obvious importance of probe saliency for the discriminative ability of the CIT to reveal knowledge of known persons, no studies of concealed person recognition have systematically manipulated probe saliency in a single study. One study, however, explored the discriminative ability of the event-related P300-CIT to identify actively concealed recognition using differently familiar faces as probes (Meijer et al., 2007). When participants were presented with highly familiar photographs (i.e., siblings and best friends) and instructed to actively conceal recognition, results showed that the detection of concealed face recognition was highly successful. When photographs depicted faces of university professors and participants were given no specific instructions to conceal recognition (mere recognition), detection was unsuccessful. In a later study (Meijer et al., 2009) the researchers re-examined the P300 using personally significant photographs of friends and siblings during mere recognition (respond to the presence of a dot on the right or left cheek) and found that a P300 was elicited even when the task was not to explicitly conceal recognition. Although task instructions about truthful versus false responses were confounded with probe salience in the first experiment (Meijer et al., 2007), the results highlight that photographs of personally known and highly familiar faces elicit stronger P300 markers of recognition that may affect CIT results.

The idea that face recognition is not an all-or-none process, as suggested in the previous CIT studies (Meijer et al., 2007, 2009), is extensively supported by decades of research face processing research (Bruce & Young, 1986; Natu & Toole, 2011; Schweinberger & Burton, 2011). Essentially, the processing of an unfamiliar face requires more cognitive effort to optimise information extraction in the initial viewing for encoding, whereas a familiar face is already represented in memory and, as a consequence, requires less effort for recognition on subsequent viewings. In the face processing literature, for example, it is generally accepted that unknown and relatively unfamiliar faces are processed in a qualitatively different way to known faces. Indirect tests of recognition memory report speed, confidence, and accuracy as indicative of richly encoded memories (Balas, Cox, & Conwell, 2007; Ellis, Shepherd, & Davies, 1979; Stacey, Walker, & Underwood, 2005), whereas the opposite is more characteristic of weaker memories which are often poorly identified and more fragile (Hancock, Bruce, & Burton, 2000).

It is also important to acknowledge that unfamiliar faces become familiar in different ways and are therefore represented differently in the visual system. A face may be familiar because we have seen a photograph of a particular person in a photograph album (visual familiarity), exposed to images and information about them in magazines and on the television (e.g., famous celebrities) or someone we encounter regularly on a day to day basis (personal familiarity). Support that different familiar face types are represented differently is found in the neuroimaging literature that extensively documents that different classes of familiar faces (i.e., newly learned visual familiarity or well established personal familiarity) are reprocessed to different degrees and activate distinct neural pathways in the brain (for a review see Natu & Toole, 2011). Increasingly familiar faces require less processing, such that with each new exposure, stronger and multiple memories are created that are represented more richly in neural networks for later access and retrieval (Schacter, Norman & Koutstaal, 1998).

According to Bruce and Young's (1986) cognitive-based model of face perception, newly learned faces likely only activate face recognition units (FRUs) and familiarity, whereas personally familiar faces would access FRUs and personal identification nodes (PINs) with fast and accurate recollection of all aspects relating the person's identity. This logic is consistent with dual process theories of memory that occur at different time points prior to a recognition based judgement (Yonelinas, 2002). Recognition of familiar famous faces such as celebrities, however, is quite different. In most cases famous faces will be associated with numerous pictorial, semantic and episodic representations but these are predominantly gained through the media and not through real-life personal interactions, thus lack the social experiences associated with people who are personally known. Faces with which we have real world experience are recalled more automatically and with less effort due to the amount of exposure to that person but also to emotional and semantic associations as well as representations of that person's personality and other mental states (Gobbini, Leibenluft, Santiago & Haxby, 2004; Gobbini & Haxby, 2007). Considering the wealth of knowledge concerning important differences in the processing and recognition of faces that differ in type and degree of familiarity, it is surprising that researchers interested in faces often use different types of familiar faces interchangeably in their experiments. To provide a more comprehensive investigation of the effect of memory for familiar faces on eye movements, Experiment 1 included the use of newly familiar faces (learned within the experimental environment), famous celebrity faces and personally familiar faces to specifically examine the effect of memory on visual processing for different familiar face types during concealed recognition.

2.1.1. Eye movements and honest identification of faces

Two key studies on memory and eye movements, presented below, further support that the processing of familiar faces is qualitatively different to unfamiliar faces, and that re-processing effects for familiar faces are observed most strongly in fewer and longer fixations to famous compared to visually familiar faces learned at task (Althoff & Cohen, 1999; Ryan et al., 2007). Neither study however explored how patterns of fixations differ to personally known faces.

Althoff & Cohen's (1999) paper on memory and eye movements documented how previous experience with a person's face changed the nature of visual processing, resulting in distinct changes in the quantity and distribution of fixations during face recognition. Participants who were serially presented with a sequence of single photographs of famous and non-famous faces revealed changes in characteristics of fixations that indicated a general decrease in eye movement sampling behaviour to known famous faces compared to those that were unknown. Decreased quantity and distribution of fixations were observed in fewer fixations, less regions of the face viewed, less return fixations to previously viewed regions of the face and less fixations directed to the inner regions of the face. The authors coined this The Eye Movement-based Memory Effect (EMME; Althoff & Cohen, 1999).

Most relevant to the issue of graded familiarity in the present experiment is that the effect of memory on eye movements increases when a new face is repeatedly viewed: the more familiar the face, the less fixation behaviour (Althoff et al., 1999; Althoff, 1998). Three groups of participants were presented with the blocks of previously unfamiliar study images on a computer screen either once, three times or five times (5 seconds each). At test, participants made recognition-based judgements by pressing one of two buttons. Effects of memory on eye movements were robust after three repeated exposures of the previously unfamiliar face. The number of fixations at recognition further decreased after five previous exposures. The finding that memory effects resulted in decreased fixations for newly learned faces that were only visually familiar support the robustness of the memory effect and its potential to detect recognition of faces that vary in familiarity, whether via years of exposure to faces (such as famous celebrity faces in the media) or relatively recent exposure to previously unknown faces.

Ryan and colleagues (2007) explored fixation duration as a marker of memory also for two types of familiar faces; visually familiar, famous faces. Participants were presented with three-face displays of photographs of peoples' faces. Participants viewed two display types: a known display and an unknown display. The known display comprised one known target face and two unknown faces and the unknown display showed three unknown faces only. In the known display the participant selected the familiar target face whereas in the unknown display they were instructed to arbitrarily select any one of the unfamiliar faces.

Ryan and colleague's (2007) main finding was that the fixation durations on the known target faces that were selected in the known condition were longer than on the unknown faces that were selected in the unknown condition. The author's named this the Recognition Effect. An important point for the present experiment was that fixation durations were longer on familiar faces whether the familiarity of the face was via experimental familiarisation or from years of indirect exposure to famous faces. Effects of memory on eye movement behaviour were more robust for famous faces (known prior to the experiment) than faces familiarised only within the experimental context. Effects of recognition emerged early in viewing for both face types but earliest for the familiar famous faces (as early as first fixation). The data suggest that fixation duration, like the ERP-300, may provide an early, uncompromised index of recognition. More familiar faces may take only one or two centrally directed fixation for recognition whereas a newly learned face may require a lot more sampling by the eyes to determine from memory if it is familiar or not (Althoff, 1998; Heisz & Shore, 2008; Hsiao & Cottrell, 2008). The differences in fixation patterns, therefore, not only index familiar and unfamiliar recognition but also recognition strength.

From their data the authors also inferred that the fixation length in the unknown display was a result of the response intention to select the unknown face. The assumption that fixation duration in the known display was a consequence of both early recognition and response intentions has important implications for the analysis of fixations during concealed recognition, since the response intentions of liars presumably require more effort than those making honest recognition judgements (Vrij, Fisher, et al., 2008; Zuckerman, DePaulo, & Rosenthal, 1981). Whereas the fixation duration to a known selected target (truth) would be moderated by the effects of recognition and efforts required for an honest response, the fixation duration for a liar would represent recognition of the familiar target face, but efforts to suppress responses to that face instead of selected it. In tests that require a dichotomous (familiar/unfamiliar) button press to single face displays this would require pressing a different button to indicate the familiar target face was unfamiliar, most likely whilst still viewing the single face on the screen (e.g. Althoff & Cohen, 1999). In multiple face displays, this would likely involve orienting of visually attention to the alternative face intended for selection before making the appropriate response (e.g., one of three buttons depending on face location in Ryan et al., 2007).

Ryan et al (2007) observed particular qualities in the memory effect that led them also to conclude that memory effects may be an obligatory effect of previous experience on perceptual processing and eye movement behaviour. One of these qualities was that memory increased fixation durations whether the participant was instructed to make a familiarity judgement, to view the face freely or to avoid looking at the familiar face. Ryan et al.'s (2007) series of recognition tests support the notion that certain elements of eye movements may be difficult to control (Rayner, 1998; Russo, 2011) and that this appears to be particularly true when making fast recognition judgements to well known, highly familiar faces (Ryan, Hannula & Cohen, 2007). Taken together, both Althoff and Cohen (1999) and Ryan et al.'s (2007) studies support that processing of unknown faces is cognitively effortful. Participants appear to engage in more effortful and deterministic sampling behaviours to maximise information extraction from completely novel faces and newly learned faces. Re-processing of progressively familiar faces during recognition results in increasingly fewer fixations of longer durations than processing of unknown faces.

One final point on the obligatory nature of the eye movement memory effect for familiar faces: The pattern of eye movements (fewer fixations, longer durations) for familiar faces also distinguished recognition memory when reports of conscious memory failed (amnesia; Althoff et al., 1999; prosopagnosia; Bate, Haslam, Tree, & Hodgson, 2008). More relevant to the forensic nature of this work, a mock line-up experiment also found recognition effects in the eye movements of participants who made unintentional suspect misidentifications (Hannula, Baym, Warren, & Cohen, 2012).

The question pertinent to the present experiment, however, is whether eye movements can establish veracity when errors are intentional acts to deceive and not incidental. Deception in the present context is defined as *"a successful or unsuccessful attempt, without forewarning, to create in another a belief which the communicator considers to be untrue"* (Vrij, 2008, p.15). The distinction between lying as an intentional act is an important one, and this is not the same as accidental misidentification. Particularly emphasised in the deception literature, lying involves addition cognitive operations that make lying harder than truth telling (Zuckerman & Driver, 1985; Zuckerman, DePaulo, & Rosenthal, 1981). This Cognitive Load Theory of deception (Vrij, Fisher, et al., 2008) hypothesises that cognitive demands will likely differ during lies and truths about recognition that may potentially impact recognition-based eye movement patterns as an index of memory during deceit. Eye movement evidence that documents the effect of cognitive load and lying on fixation characteristics is described below.

2.1.2. Eye movements and lies about face recognition

The investigation of intentional concealment as compared to unintentional errors is an important one considering that intentional deceit involves additional cognitive operations that impose extra cognitive load on an individual (Vrij, Fisher, et al., 2008), a phenomenon commonly known as response conflict (Botvinick et al., 2001; Spence et al., 2001; Zuckerman, DePaulo, & Rosenthal, 1981). Despite the importance of understanding how memory and response processes interact, theories of exclude recognition performance often focus on familiarity and recollection processes alone (Yonelinas, 2002). Fast familiarity based judgements are a component of all recognition judgements, but more often than not recognition generates slower recollective processes to determine to whom that face belongs. Empirical support for the role of response conflict in intentionally concealed recognition can be found most simply in behavioural reaction time data (e.g., Walczyk, Roper, Seeman & Humphrey, 2003; Seymour and Fraynt, 2009, Seymour, Kerlin, & Kurtz, 2000, Seymour, Seifert & Shafto, 2000, Seymour and Kerlin, 2008) and are further validated in fMRI brain imaging studies that record activation from brain regions that are associated with response conflict, such as the anterior cingulate cortex (McDermott, Jones, Petersen, Lageman, & Roediger, 2000; Seymour & Schumacher, 2009).

Tasks that are cognitively effortful, resulting in increased reaction time, also result in increased fixation behaviour. This is because the longer we look at something the more eye movements we generate. The longer the pause the more information processing that occurs, signalling an increase in depth of processing and cognitive effort (Castelhano & Rayner, 2008; Rayner, 1998; Russo, 2011). This is true not only in the eye movements of individuals who are thinking hard under honest circumstances (Griffin & Bock, 2000; Griffin, 2001; Meyer, Sleiderink, & Levelt, 1998; Meyer & van der Meulen, 2000) but additionally in the fixations of liars during deception. Changes in fixation behaviour have been observed in deception studies when lying during reading based tasks (Baker, Goldstein, & Stern, 1993; Baker, Stern, & Goldstein, 1992; Cook, Hacker, Webb, Osher, Kristjansson, Woltz, Kircher, et al., 2012) and when deliberately giving incorrect names to items in line-drawings (Griffin & Oppenheimer, 2006). Griffin and Oppenheimer (2006) revealed that during a task where participants wrongly reported the relationship between an animal and an action in a line drawing, participants looked at items (pictures of animals) longer when intentionally giving inaccurate responses to them. For example, participants that reported the drawing showed a horse kicking a dog, when in fact it was kicking a cow, displayed longer fixations longer than honest participants. Despite not being an explicit study of deception, the data indicate that intentionally giving misinformation affects fixation behaviour during what is essentially a lie. Despite the apparent potential for eye movement behaviour as a method to facilitate memory detection, only one very recently published study has employed eye movements to determine whether eye movements might serve as a reliable indicator of memory when lying about photographs of familiar people (Schwedes & Wentura, 2012).

Schwedes and Wentura (2012) developed a modified Concealed Information Test (CIT) to extend the work of the original study by Ryan and colleagues (2007). Consistent with a CIT protocol, participants lied about recognition of familiar probes whilst correctly classifying the familiar targets and unfamiliar irrelevants. The photographic face stimuli in the Schwedes and Wentura study (2012) were presented in circular arrays of six-face displays, not sequential single items as in typical CITs. Face stimuli used were all pre-experimentally unfamiliar. During a study phase, prior to experimental trials, familiarisation was conducted for two separate groups of previously unfamiliar faces. Participants were requested to learn one set of faces and remember these as their 'friends', and another set that they were to memorise as 'foes'. Schwedes and Wentura (2012) presented their participants with three types of display; a concealed display, a revealed display and a neutral display. In the concealed display, the familiar target was a photograph of a face that had been introduced as a friend during a study phase as part of the experimental session. The participant was instructed to conceal knowing the photo of their friend and instead deceptively select one of the other five unfamiliar faces as the familiar face. In the revealed display the participant was informed to correctly select the photograph of the face previously introduced as their foe and not to protect their identity. In the neutral display all photographs were of unfamiliar faces but participants were instructed to select one arbitrarily regardless.

The results of the study supported an effect of memory (longer fixations) in the total average fixation duration for concealed targets. Fixations on concealed faces (known but not selected) were longer than fixations on the unfamiliar faces that were not selected in the neutral display. They also found that fixations displayed efforts for response intentions such that the average fixation duration on a familiar target that was known and selected (revealed display) was longer than a familiar target that was known but not selected (concealed display). Finally, within display comparisons of fixation durations on targets compared to distractors revealed longer fixations on targets than distractors in revealed and concealed displays respectively but not in neutral displays.

Fixation-by-fixation analyses revealed effects of recognition in the first fixation but, unlike Ryan and colleagues, this was not significant until the second fixation. There was no effect of response selection efforts, however, in the first three fixations. The authors propose that finding of a recognition effect in the second fixation is perhaps due to the increased complexity of the display screen (six faces compared to three). The lack of evidence of a response intention effect in any of the first three fixations was considered partly due to the additional difficulty of the friend or foe task. In the friend or foe task participants have to first determine if there is a familiar face and then decide which category it belongs to and then plan their decision based on an honest or deceptive response. It is plausible that the extra decision making processes might delay the classification of the face and the planning of the response according to truth and lie instructions. Schwedes and Wentura's (2012) results indicate that eye fixation behaviour is a reliable index of both early recognition and the response intentions of liars. They also importantly highlight that the additional cognitive demands of the concealment of a subset of faces and the complexity of the display alter the temporal dynamics and thus the emergence of the effect of memory on eye movement behaviour. The present research further explored the effect of concealment of subsets of faces (newly learned, famous celebrities, personally known) using single face displays, consistent with display presentations of the classic CIT.

Experiment 1 differs from Schwedes and Wentura's (2012) study in several important respects; Schwedes and Wentura asked participants to lie about recognition of newly learned faces by asking them to select an unknown face in a six-face display. Their main aim was also to dissociate the effect of response efforts from memory. However, they did not explore the effect of deceptive load on existing memory effects. They also only explored one fixation measure, fixation duration. The present research explores the effect of memory during recognition of three different faces types, and directly examined the effect of deception on memory effects during visual inspection of each familiar face type in turn. The present experiment also explored the effect of deception on a range of different fixations measures, and predicts opposite effects of deception on fixation quantity and fixation durations.

To combine and further explore research findings by Althoff and colleagues (1998; 1999) and Ryan et al. (2007) a range of eye movements parameters were analysed: to measure the amount and distribution of fixations (number of total fixations, the number of times gaze returns to specific areas of interest, the number of interest areas visited, and the proportion of fixations made to the inner regions of the face). Fixation duration was selected to further explore the temporal nature of memory effects that previous researchers (Ryan et al., 2007; Schwedes & Wentura, 2012) proposed were a product of both recognition and response intentions. It is important to note that deception has shown to increase fixations quantity (Cook, Hacker, Webb, Osher, Kristjansson, Woltz, Kircher, et al., 2012) but also to increase fixation durations (Griffin & Oppenheimer, 2006). Since the effect of deception on fixation quantity is the opposite to the effect of memory on number of fixations, then it lying might diminish memory effects. The opposite would be true for fixation durations, wherein an increase in fixation durations during lies could potentially magnify memory effects.

It is apparent that a number of factors interact in both the CIT and eye movement-based memory paradigms. The most notable here are degree of face familiarity and whether the participant is lying or telling the truth about recognition. A number of eye movement parameters are discussed in the literature and each provide different insights to different aspects of cognitions during recognition and deceit. To combine and further explore the work of Althoff and colleagues (1998; 1999) and Ryan et al. (2007) a range of eye movement parameters are recorded in Experiment 1: number of fixations as a general measure of processing effort (Cook et al., 2012), the number of interest areas of the face viewed to explore the degree of spatial distribution of fixations patterns, the number of return fixations made to the same face region to as a means to explore attempts to resolve featural ambiguity to unfamiliar faces (Barton, Radcliffe, Cherkasova, Edelman, & Intriligator, 2006), and the proportion of fixation made to informative inner regions of the face (Stacey et al., 2005). Additionally average durations of individual fixations were analysed to explore effects of recognition (Hannula, Ryan, Tranel, & Cohen, 2007) and cognitive effort required for lying (Zenzi M Griffin & Oppenheimer, 2006; Schwedes & Wentura, 2012). The predictions follow below:

Primary *fixation-based predictions* for Experiment 1 were that memory for familiar faces would result in a reduction in eye movement behaviour when reprocessing photographs of known faces compared to those that were unknown. This effect of memory on eye movements (fewer fixations of longer durations) for familiar faces. Based on Althoff & Cohen (1999), Experiment 1 predicted a decrease in the quantity and distribution of fixations as observed in fewer fixations overall (Num. Fixations), fewer regions of interest on the face visited (IAs Visited), fewer return fixations to the face (Run Count), and a smaller proportion of fixations made to the inner regions of the face (Proportion Inner).

Based on Ryan et al. (2007) the current experiment predicted that fixation durations would be longer when processing photographs of familiar faces compared to unfamiliar. Consistent with Ryan et al (2007), Experiment 1 also predicted that the effect of memory for familiar faces would be observed via longer fixation durations in the first fixations (First three fixations analysed) and the effect of response intentions just prior to the response selection (1500 ms pre and post response analysed).

Secondary *familiarity-based predictions* were that eye movement-based memory effects (less fixations, longer durations when viewing familiar faces) would be most distinct for the photographs of well-known faces that have the strongest real-world saliency (e.g., personally known faces) (Ryan et al., 2007; van Belle, Ramon, Lefèvre, & Rossion, 2010).

Predictions based on the *cognitive load theory* that lying is harder than telling the truth, are that liars might display more fixations and longer durations of fixations during concealed recognition than during revealed recognition. The predicted increase in fixation quantity (Cook, Hacker, Webb, Osher, Kristjansson, Woltz, Kircher, et al., 2012) during concealed recognition, could potentially decrease the difference in eye movement behaviour between the probe (conceal recognition of familiar face) and irrelevant faces (reveal unknown faces as unfamiliar), thus diminishing the eye movement-based memory effect. Whereas, longer fixations durations during lying (Griffin & Oppenheimer, 2006) would tend to magnify effects of memory during recognition. Consistent with (Meijer et al., 2007), the research predicts that personally known faces will be most robust to changes in cognitive load as a consequence of instructions to tell the truth or lie.

To assess whether *choosing to lie or being instructed to lie* change the fixation patterns of liars, a final block was included where participants chose whether to lie or not. A final supplementary prediction was that heightened strategic monitoring processes when participants chose to lie might further increase fixation quantity and duration as previous research showed than participants were much slower at completing deceptive tasks when lies were self-generated compared to directed (Johnson et al., 2004).

2.2. Method

2.2.1. Design

The research employed a modified Concealed Information Test during which participants lied and told the truth about recognising different types of familiar faces. Participants were randomly presented with a series of singly presented colour photographs of faces: unfamiliar faces and three different types of familiar faces to which they made 'familiar' or 'unfamiliar' button press responses. A nested within-subjects design independently manipulated Task Instruction (Lie, Truth) and Familiar Face Type (*unfamiliar, newly learned, famous celebrities, and personally known*). There were three lying condition blocks in which participants were asked to lie in turn about the three different types of familiar faces: Familiar-learned (*Lie-learned*), Familiar-famous (*Lie-famous*) or Familiar-personal (*Lie-personal*).

Participants did not lie about unfamiliar faces. In each of these lying blocks, participants lied about only one type of familiar face, whilst telling the truth about all the others. For example in the *Lie-Personal* block, every time the participant saw a photograph of a personally familiar face they had to lie and make an unfamiliar response by pressing the appointed button on the game port. When presented with *newly learned* and *famous celebrity* photographs within this block, however, the participant honestly indicated that they were familiar. Presentations of unfamiliar faces always required an honest unfamiliar response. There were equal numbers (4 x 10) of each face type in each block of trials. The Lie-learned, Lie-famous and Lie-personal blocks were fully counter-balanced. In the final block the participants were permitted to 'choose' whether to lie or tell the truth and, if they opted to lie, selected which type of familiar face to lie about. This condition was performed as a manipulation check to test assertions that directed lies (explicit deception instruction) are cognitively different to self-generated lies (spontaneously chosen ad executed). All participants were informed not to disclose their choice to the experimenter who was closely monitoring them during the experiment.

2.2.2. Participants

59 undergraduate students (13 males, 46 females) participated in the experiment. Participant ages ranged from 18 to 44 years (M = 19.6, SD = 3.6). All participants had normal or corrected-to-normal vision and were awarded course credit for their participation. Participants were recruited from psychology undergraduate tutor groups. Participants were specifically recruited from pre-existing tutor groups so that photographs of tutor group members could be used as

personally familiar stimuli in the experiment. Recruiting from tutor groups established a baseline of real-world familiarity. (Tutor groups were established at the start of term by random allocation to class lists. At the time of the first experimental trials, participants had been in these tutor groups for at least 5 months, which meets the criteria for reasonably close familiarity (Wegner, Erber, & Raymond, 1991).

2.2.3. Apparatus and Materials

Eye tracker.

Participant's eye movements were tracked while they viewed photos using the Eyelink II head mounted eye tracker (SR Research, Canada). The mean image size was approximately 4.03° of visual angle (SD=1.32). A programme written using Experiment Builder controlled the presentation of images on a flat CRT monitor. Manual button press responses were collected by a Microsoft Sidewinder Plug-and-Play game pad.

Photographic stimuli.

A total of 200 digital colour photographs of faces were presented to each participant over five blocks of test trials (40 photos x 5 blocks). All photographs showed the full face of a person against a blue background. The face had a neutral expression and gaze was towards the camera. Forty test photographs were presented in each block of trials that comprised 10 Unfamiliar faces (UF), 10 *newly learned faces* (F-L), 10 famous celebrity faces (F-F) and 10 personally known faces (F-P).

Unfamiliar faces were resourced with kind permission from the databases of other academic institutions (Burton, White, & McNeill, 2010; PICS; http://pics.stir.ac.uk; Weyrauch, Heisele, Huang, & Blanz, 2004) and individuals from schools and universities (Taunton College, University of Stirling) who volunteered to have their photographs taken to create a new unfamiliar face database for the purposes of the present experiment.

Personally known faces were photographs of the student participants. Photographs of personally familiar faces were of the class-mate participants and were taken against a blue background screen using a SONY Cybershot digital still camera (model, DSC-W55), a tripod stand, and spot lamps for studio lighting. A photo-shoot was organised to generate the stimuli for personally familiar faces where the opportunity was also taken to further establish personal familiarity within each group. During a team-building activity each participant shared five pieces of personal information with their fellow group members; full name, age, place of birth, a personality characteristic and favourite pass time. After this process, each team member noted down a secret word they associated with that person to act as a cue to remembering each member's personally relevant information. Participants then recalled, as a group, each person's details. Likert scales were used to record familiarity ratings (1 = not familiar at all; 7 = very familiar) for each team member at the beginning and end of the session and again when they returned for the experimental test. A RM ANOVA performed on the familiarity ratings before and after the team building task revealed significant differences in familiarity ratings, $F(1.67, 69.92) = 68.20$, $p < 0.001$, $\eta_p^2 = 0.62$.

Ratings taken before the team building task revealed a pre-existing level of familiarity before the session (*M* = 3.42, *SD* =0.92) that further increased after the familiarisation process (*M* = 4.30, *SD* = 1.12; $t(43) = 5.91$, $p < 0.001$) and again by the day of the *m*CIT (*M* = 5.16, *SD* = 0.68; $t(43) = 4.88$, $p < 0.001$).

Famous faces were contemporary celebrities faces sourced on the internet. During the team-building task, participants had each identified a celebrity that similarly matched their own face in terms of hair, eye and skin colour. In this way, group members were familiar with the celebrity faces chosen for the concealed recognition test. The experimenter sourced the appropriate number of images for each group. One celebrity phot for each student (10 in each group) for each block (5 condition blocks), equally 50 in total for each block of trials for each group.

Newly learned faces became familiar by exposing participants to photographs of unfamiliar faces within the experimental session, directly before performing the actual *m*CIT. Participants were asked to look at the unfamiliar face images on the display monitor until they had learned them to memory. Participants were then asked to rate each newly learned face for attractiveness, distinctiveness and familiarity of 7-point Likert scales (1 = not at all, 7 = very) before being asked to state what feature of the face they thought was most distinctive and to estimate the perceived age in years. This procedure is often used to familiarise participants with faces in recognition-based experiments as such psychological judgments represent those made in real life when we meet new people (e.g., Osborne & Stevenage, 2013).

The appearance of all photographs were standardised using Adobe Photoshop Elements (Version 2.0) for the removal of red-eye, accessories and jewellery and extracted from their original background to a standardised blue (HEX: 91BE87) background measuring (666 x 500 px). Photographs were presented using Experiment Builder (Version 1.6.121, SR Research) on a desktop computer linked to a 19-inch CRT Monitor (model, G90FB; resolution, 1280 x 1024 pixels; refresh rate 89Hz). Images were presented randomly to the left (292, 292) or the right side (704, 292) of the screen to minimise anticipatory guessing behaviour of picture location.

Deception Strategies Questionnaires

A simple questionnaire designed to gauge whether participants attempted to adopt any behavioural strategies during the task posed the following questions: One closed question, *Did you adopt any strategies during the task?* Participants circled a yes or no answer. Four open ended questions, *What strategies did you adopt when lying? What strategies did you adopt when telling the truth? What behaviours do you think are indicative of lying? What behaviours do you think are indicative of telling the truth?*

The final closed question asked, *when do you think you displayed more of the following behaviours; when lying, telling the truth or no difference (please circle)?* Twelve statements were listed to which the participant had to circle when they thought they displayed more of each behaviour (during lies, truths, or no difference). An example or two of these statements are: *Looked at the face*, and *Looked less at the eyes.* No specific hypotheses were generated in relation to possible eye movement strategies.

2.2.4. Procedure

Participants were seated in a controlled quiet and dimly lit room at a distance of 0.80m from the display screen.

Participants were first shown the ten photographs of personally familiar classmates on the display screen in turn. Participants were asked to look at each of these faces and rate each of them for attractiveness, distinctiveness and familiarity using seven-point Likert scales (1 = not familiar at all; 7 = most familiar). There was no time limit for the ratings task. When finished, participants pressed the space bar to indicate they were ready for their eye gaze position to be calibrated with the eye tracker.

After the rating of the personally known faces, the eye tracker's measurement of gaze was calibrated to the participant's eye movements prior to the study phase using a 3 x 3 dot array. Where necessary, the calibration was repeated between condition blocks. The Eyelink II headband was comfortably secured to the participant's head. Retinal and corneal reflections induced by an infrared source were recorded at a frequency of 250Hz (Pupil-CR mode) to obtain participants' points of fixation on the screen.

To calibrate, a black dot with a white centre was presented in middle of the screen. Upon request, the participant fixated the white centre of the black dot. Once the participant steadily fixated on the dot, the experimenter accepted the fixation by pressing a button on the host computer, positioned behind and to the right of the participant. Once the initial fixation was accepted the same dot was displayed randomly, one location at a time, using a 3x3 array. The experimenter validated that eye gaze was being tracked with high spatial resolution (error of resolution: 0.5°-1.0°) before moving on to the next procedural phase.

Following calibration, and prior to the test phase, participants were exposed to ten unfamiliar faces and asked to 'learn' these for the purpose of the task. The participants were instructed to study the 10 unfamiliar faces in turn, for as long as was required to satisfy that each face had been 'learned'. Once the participant reported that they had learned the face presented, the experimenter then asked them to rate each face on the psychological dimensions of attractiveness, distinctiveness and familiarity. Ratings were made based on 7-point Likert scales; '1' indicated the face as 'not at all' attractive, distinctive or familiar and '7' indicated that the face was very attractive, distinctive or familiar. The participant then pressed a button to begin the experimental trials. Using psychological dimension ratings in this way is one procedure used to aide face learning by encouraging attention to and processing of the face (Osborne & Stevenage, 2013). Participants were exposed to a new set of ten previously unfamiliar faces before each block of trials.

During each block of the CIT, participants were presented with a sequence of 40 full face colour photographs. Prior to the display of each face a fixation dot was shown in the centre of the screen to correct any drift in eye movements following the initial calibration. Within each condition block *unfamiliar* (10), *newly learned* (10), *famous celebrities* (10) *and personally known* (10) faces were displayed to the participant randomly. Participants responded by making a dichotomous 'familiar' or 'unfamiliar' button press response. The button assigned to familiarity was counterbalanced for handedness so that approximately half of the participants pressed it with their dominant hand (30). After the button press was made, the face remained on the display screen for three seconds, followed by a blank screen for two seconds (Figure 2.1). The rationale for leaving the display on-screen post-response was driven by previous deception research that investigated blinking as a cue to deception. A compensatory eye blink responses to reveal deception after a lie that presumed to be inhibited prior to the lie due to cognitive load (Leal & Vrij, 2008). Hannula et al., (2012) also found fixation durations during unintentional misidentification to reveal recognition 500ms post response compared to truths that occurred prior to response selections. There was no upper time limit for the button press.

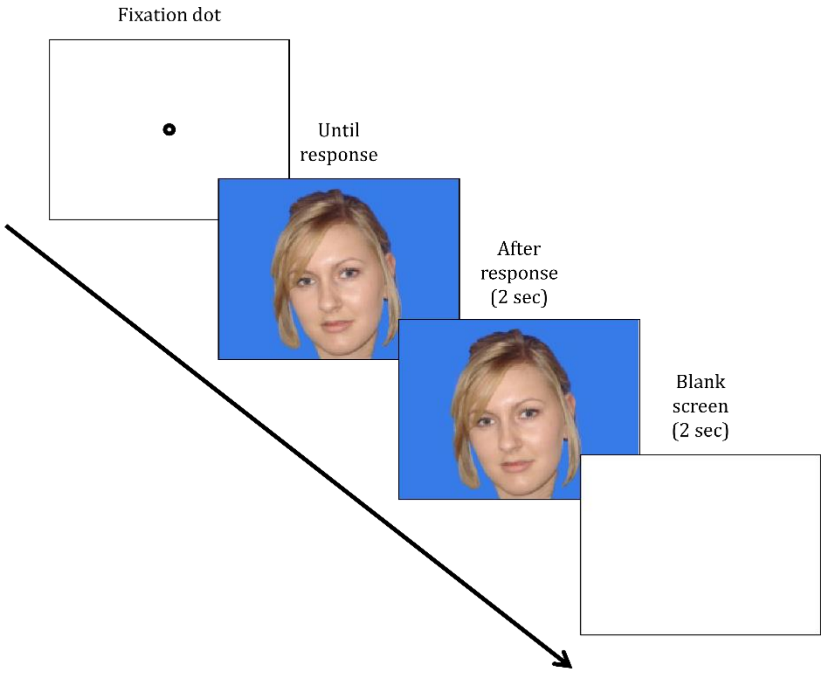


Figure 2 1. Sequence order of display screen presentation in test trials. Participants made a familiar/unfamiliar (button press) response to each face. The face remained on the screen for 2 secs post response followed by the presentation of a blank screen for 2 secs. Each trial was preceded by the fixation dot to ensure accuracy of eye movement monitoring and to correct for any drift in eye movements on a trial-by-trial basis.

Instructions were different in each of the five blocks of trials. In the first block, participants were required to respond honestly to all trials. This was a practice block and responses were not analysed. Then followed three lying blocks in which the participants had to lie, in turn, about the three different types of familiar faces: newly learned faces (*Familiar-Learned)*, famous celebrity faces (*Familiar-Famous)*, and personally known faces *(Familiar-Personal)*. The *Lie-Learned* condition required that participants lie about the faces that they learned during the study phases, whilst telling the truth about all other faces types; the *Lie-Famous* condition, that they lie about famous faces, whilst telling the truth about all other face types; and the *Lie-Personal* condition to lie about personally known faces whilst telling the truth about all other face types. To emphasise, in the lying conditions, participants made both honest *and* dishonest responses but lied about only *one* specific group of familiar face in each condition block (*Familiar-Learned, Familiar-Famous or Familiar-Personal)*. In that way the design was based on the classic CIT where participants lied about specific familiar faces (probes) and told the truth about other familiar faces (targets). Participants always told the truth about unfamiliar irrelevant faces. When all five test blocks were completed, participants rated the famous faces for attractiveness, distinctiveness and familiarity. This procedure allowed the experimenter to verify that all famous faces had in fact been correctly recognised.

2.2.5. Data preparation: Defining Interest Areas (IAs)

The selection and naming of these areas is consistent with other face research (Bate et al., 2008; Walker-Smith, Gale, & Findlay, 1977). After data collection, all photographs of faces were marked with *a-priori* selected areas of interest; the right eye (left visual space), the left eye (right visual space), the nose and the mouth. For some data analyses these areas were combined to form the 'inner' region of the face. The rest of the face, including the hair, ears, cheeks and chin, were labelled the 'outer' face area. Interest Areas (IAs) were marked up using the ellipse, rectangle and freehand tools in Data Viewer (Version 1.6.121, SR Research, Ontario, Canada).

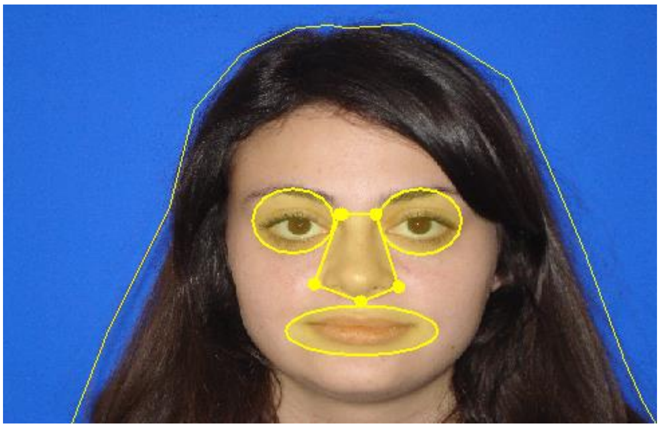


Figure 2 2. Example of Interest Areas (IAs) defined for analyses.

Measures

Consistent with Althoff and colleagues (1998; 1999), the amount and distribution of eye movement behaviour for familiar and unfamiliar faces was measured in the total number of fixations made to the face before the recognition judgement was made (Num. Fixations), the number of regions of the face sampled (IAs Visited), the number of independent clusters of fixations on an interest area, defined precisely as the number of times that a series of two or more fixations were made on an interest area without any fixations intervening on other interest areas (Run Count) and the proportion of fixations directed to the inner regions of the face (Proportion Fixations Inner). These five measures assessed general viewing behaviour (Num. Fixations), the distribution of fixation behaviour (IAs Visited), apparent attempts to resolved featural ambiguity or uncertainty in recognition (e.g., Barton, Radcliffe, Cherkasova, Edelman, & Intriligator, 2006), and more specifically the proportions of fixations made to the informative inner regions of the face (Proportion Fixations Inner). Finally, we measured the average fixation duration of individual fixations (Ryan et al., 2007; Schwedes & Wentura, 2012).

2.2.6. Analysis Strategy

First all targets (truths about familiar faces) were compared to irrelevants (truths about unknown faces) to assess memory effects in fixations during honest recognition. Second, probes (lies about familiar faces were compared to the same irrelevants (truths about unknown faces) to assess the presence of memory effects when participants lied about recognition. Third, targets (truths about familiar faces) and probes (lies about familiar faces) were compared to assess whether lying caused any significant differences between truths and lies for familiar faces alone. Each analyses was performed using separate Repeated Measures analyses of Variance for each fixation measure; number of fixations, run counts, IAs visited, proportion fixations inner, (fixation quantity and distributions as analysed in Althoff & Cohen, 1999), fixation-by-fixation analyses for the first three fixations, and time course analyses (500 ms time bins) 1500 ms before and after response selections (see Hannula et al., 2012; Ryan et al., 2007; Schwedes & Wentura, 2012).

2.3. Results

Where Mauchley's Test of Sphericity were violated, RM ANOVAs were calculated using Greenhouse Geisser adjustments to degrees of freedom (*df*). The corrected *p* value and Greenhouse Geisser epsilon (ε) are reported for *F* tests. Post hoc tests were performed using paired sample t-tests. Adjusted *p* values (α) are denoted in each relevant figure caption for the number of post hoc tests conducted. The use of Bonferroni comparisons for correcting multiple tests on multiple fixations measures is consistent with other eye movement research using similar analyses as the current thesis (Hannula et al., 2012, 2007; Hannula & Ranganath, 2009).

2.3.1. Exclusion criteria

Fifteen of the original 59 participants were removed from the data set for the following reasons: corrupted data files (3), not completing the task (3), or failure to recognise one or more of the famous faces (9). Trials were also removed from the analyses if the participant presented extreme outliers in the reaction time data responded incorrectly to the face. In the honest trials, incorrect responses were recorded if a familiar response was made to an unfamiliar face or an unfamiliar response to any of the familiar faces. In the lie trials, further incorrect response were recorded if the participant failed to conceal their knowledge and reported familiar faces as familiar instead of the desired unfamiliar response. Error rates were low across all trials: Familiar-Personal (truths, 3%, lies, 10%) Familiar-Famous (truths, 3%, lies, 1%), Familiar-Learned (truths 8%, lies 13%) and unknown faces (truths 92%). These exclusion criteria resulted in removal of 6.7% of the data the Lie-Learned condition, 4.49% and 6.65 % in the Lie-Famous and Lie-Personal conditions respectively. This left 4966 trials out of the original 5280. Similar to previous research (Greenwald, Nosek, Banaji, 2003; Verschuere, Spruyt, Meijer & Orgaar, 2011) outliers in the reaction time data were removed if they were faster or slower than specific set thresholds (acceptable range for present data, <300 ms or >5000 ms). This removed a further 54 trials (1.09%) leaving a total of 4912 trials out of the original 5280.

2.3.2. Fixation Quantity

Truth trials (Irrelevants and Targets)

Repeated Measures ANOVAs were performed on *truth* data with four independent levels of task instruction; tell the truth about unfamiliar faces (irrelevant), tell the truth about recognition of newly learned faces (target), tell the truth about recognition of famous celebrity faces (target), reveal recognition of personally known faces (target). Post hoc tests were performed using paired sample t-tests to compare means and Bonferroni correction for three multiple comparisons ($\alpha = 0.017$).

There was an effect of task instruction in all four eye movement parameters; Num. Fixations, $F(2.50, 94.92) = 33.35$, $p < 0.001$, $\eta_p^2 = 0.47$, Run Count, $F(3, 114) = 31.25$, $p < 0.001$, $\eta_p^2 = 0.45$, IAs Visited, $F(3, 114) = 22.44$, $p < 0.001$, $\eta_p^2 = 0.37$, Prop. Fixations Inner, $F(3,114) = 3.24$, $p = 0.025$, $\eta_p^2 = 0.08$, showing substantial medium-large effect sizes across measures (see Figure 2.3). When participants truthfully identified newly familiar, famous celebrity and personally known faces all four eye movement parameters (Num. Fixations, IAs Visited, Runs, Proportion fixations made to inner face regions) significantly differed from the quantity of these four measures when correctly rejecting recognition of unknown faces.

Newly learned faces. When participants revealed recognition of newly learned faces, a significant decrease in fixation behaviour also distinguished known from unknown faces in the one measure Num. Fixations, $t(43) = 2.72$, $p = 0.009$, $d = 0.28$.

After Bonferroni corrections trends were observed for IAs Visited, $t(43) = 2.12$, $p = 0.040$, $d = 0.25$ and Run Count, $t(43) = 2.22$, $p = 0.032$, $d = 0.22$. No significant effect of memory emerged for the measure Prop. Fixations Inner, $t(43) = 1.92$, $p = 0.062$, $d = 0.21$.

Famous celebrity faces. When participants revealed recognition of famous celebrity faces, a significant reduction in fixation behaviour also identified memory for known compared to unknown faces; Num. Fixations, $t(43) = 7.220$, $p < 0.001$, $d = 0.82$, Run Count, $t(43) = 0.24$, $p < 0.001$, $d = 0.71$, IAs Visited, $t(43) = 5.75$, $p <0.001$, $d = 0.57$, Prop. Fixations Inner, $t(43) = 3.69$, p < 0.001, $d = 0.33$.

Personally known faces. When participants revealed recognition of personally known faces they made significantly less fixations on the personally known compared to the unknown face in three parameters; Num. Fixations, $t(43) = 9.54$, $p < 0.001$, $d = 1.12$, Run Count, $t(43) = 8.56$, $p < 0.001$, $d = 0.96$, and IAs Visited, $t(43) = 7.86$, $p < 0.001$, $d = 0.88$. A trend in the data was observed for the measure, Prop. Fixations Inner, $t(43) = 2.28$, $p = 0.027$, $d = 0.25$.

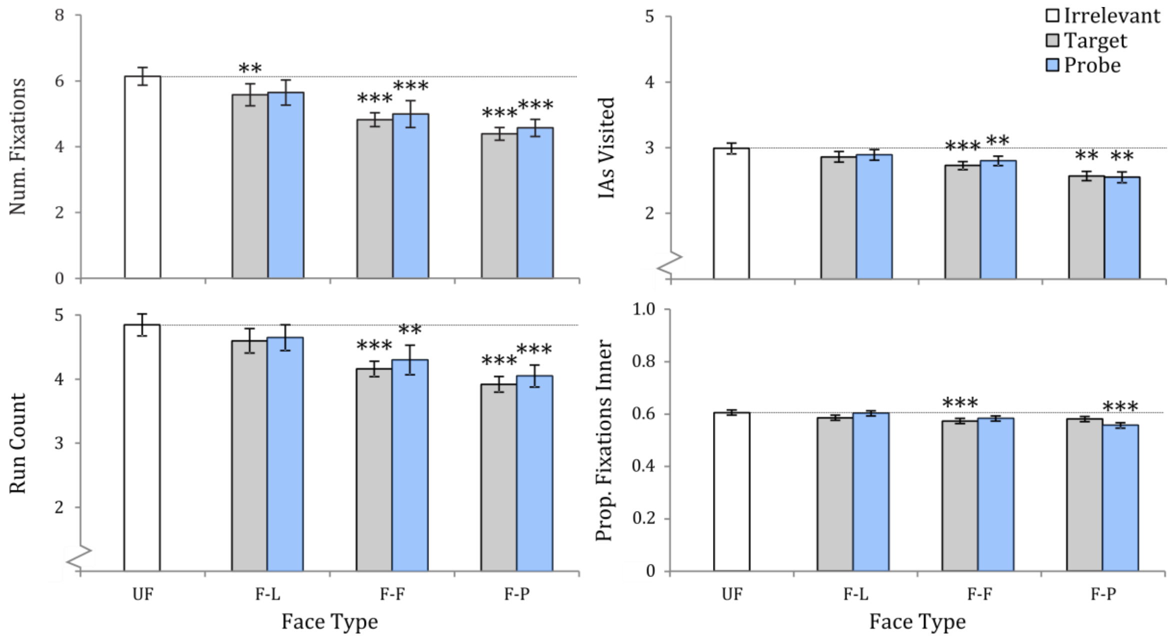


Figure 2 3. RM ANOVAs for fixation measures, Num. Fixations, Run Count, IAs Visited, Prop. Fixations Inner (*d.f.* = 43 in each case, no effect of condition order), with Bonferroni adjustments for multiple paired sample t-tests (α=0.017). The y-axis shows data for unfamiliar faces (UF), newly learned faces (F-L), famous celebrity faces (F-F), and personally familiar (F-P) faces. In each graph, the unfamiliar (UF) irrelevants (white bars) are the comparison point for all truth (grey) and lie data (blue). p<0.001***, p<0.01**. Error bars represent M±SEM.

Lie trials (Irrelevants and Probes)

RM-ANOVA's were performed on the *lie* data also with four independent levels of within subjects task instruction, tell the truth about unknown faces, conceal recognition of personally known faces, lie about recognition of celebrity famous faces, lie about recognition of newly learned faces. (Truth-Unknown (Irrelevant), Lie-Learned (Probe), Lie-Famous (Probe) and Lie -Personal (Probe)). Analyses reveal significant differences in fixation behaviour in all four parameters measured; Num. Fixations, $F(2.3, 88.18) = 13.16$, $p < 0.001$, $\eta_p^2 = 0.26$, $\eta_p^2 = 0.11$, Run Count, $F(2.34, 12.67) = 12.67$, $p < 0.001$, $\eta_p^2 = 0.25$, IAs Visited, $F(3, 114) = 19.23$, $p < 0.001$, $\eta_p^2 = 0.34$, Prop. Fixations Inner, $F(2.49, 94.43) = 4.51$, $p = 0.010$, $\eta_p^2 = 0.11$, with medium to large effects. Post hoc tests were performed using paired sample t-tests to compare means and Bonferroni correction for three multiple comparisons (α = 0.017). (see also Figure 2.3 above).

Newly learned faces. When participants concealed recognition of newly learned faces, a trend in the data distinguished between concealed recognition trials and honest judgements to unfamiliar faces for Num. Fixations only, $t(43) = 2.220$, $p = 0.032$, $d = 0.23$. No significant effects of memory emerged for the remaining three measures, Run Count, $t(43) = 1.737$, $p = 0.090$, $d = 0.16$, IAs Visited, $t(43) = 1.871$, $p = 0.068$, $d = 0.21$.Prop. Fixations Inner, $t(43) = 0.212$, $p = 0.833$, $d = 0.03$.

Famous celebrity faces. When participants concealed recognition of famous celebrity faces, fixation behaviour was also significantly less compared to fixations made during honest response to unfamiliar faces; Num. Interest Areas $t(43) = 3.75$, $p = 0.001$, $d = 0.50$, Run Count, $t(43) = 3.35$, $p = 0.002$, $d = 0.42$, IAs Visited, 3.28, $p = 0.002$, $d = 0.40$, No significant effect of memory was found for Prop. Fixations Inner $t(43) = 1.99$, $p = 0.054$, $d = 0.20$.

Personally known faces. When participants lied and reported that they did not recognise a personally familiar face compared to honestly reporting that they did not recognise the unfamiliar face, a reduction in fixation behaviour consistently revealed recognition for the personally known face for all four parameters; Num. Fixation, $t(43) = 8.58$, $p < 0.001$, $d = 0.89$, Run Count, $t(43) = 6.89$, $p < 0.001$, $d = 0.72$, IA Visited, $t(43) = 7.45$, $p < 0.001$, $d = 0.87$, Prop. Fixations Inner, $t(43) = 3.60$, $p = 0.001$, $d = 0.45$.

Targets and Probes. To explore if fixation behaviour for familiar faces significant differed between truth and lie tries of familiar faces (excluding unfamiliar irrelevants), multiple 2 (WS: Deception Instruction: Truth, Lie) x 3 (WS: Familiar Face type: Familiar-Learned, Familiar-Famous, Familiar-Personal) RM-ANOVAs revealed no significant interactions between Deception Instruction and Familiar face type for any of the four eye movement measures: Num. Fixations, $F(2,86)$ = 0.09, p = 0.910, η_p^2 = 0.00, IAs Visited, $F(2, 86)$ = 0.60, p = 0.551, η_p^2 = 0.43, Run Count, $F(2, 76)$ = 0.17, p = 0.840, η_p^2 = 0.00. Proportion Fixations Inner, $F(2, 76)$ = 2.21, p = 0.120, η_p^2 = 0.05, Average Fixation Duration, $F(2, 76)$ = 1.36, p = 0.260, η_p^2 = 0.03.

Comparing Directed to Self-Generated Lies.

In the first three lying blocks participants were instructed to lie about a specific group of familiar face (Directed Lie) whilst telling the truth about others. In the final condition block participants were given a choice whether to lie or tell the truth and, if lying, to choose which group of faces to lie about (Self-Generated Lie). Out of 44 participants, 25 chose to lie (57%). Five chose to lie about the Familiar-Learned faces, eight about the Familiar-Famous faces, and twelve about the Familiar-Personal faces.

RM ANOVAs (WS: Deception: Directed; Self-Generated) x (BS: Face Type: Familiar-Learned, Familiar-Famous, Familiar-Personal) performed on the data Proportion Fixations Inner, IAs Visited, Run Count, AFD revealed that there was no main effect of Directed or Self-Generated Lies. Overall there were no interactions between deception and face type for the eye movement variables Num. Fixations, Prop. Fixation Inner, Run Count, AFD, with one exception (IAs Visited). Paired sample t-tests, however, reveal that these do not occur at the comparisons of interest; Choice-Learned v. Instructed-Learned, $t(4) = 2.05$, $p = 0.110$, Choice-Famous v Instructed-Famous, $t(7) = 1.25$, $p = 0.252$, Choice-Personal v Instructed-Personal, $t(11) = 1.30$, $p = 0.221$.

2.3.3. Fixation Durations

Irrelevants and Targets: RM-ANOVA's conducted on *truth* data with four independent levels of Task Instruction (Irrelevant, Target-Learned, Target-Famous and Target-Personal) revealed significant differences between Task Instruction conditions, $F(3, 114) = 4.39$, $p = 0.006$, $\eta_p^2 = 0.10$. Post hoc tests revealed no significant different in fixation durations between irrelevants and newly learned targets faces, $t(43) = 1.24$, $p = 0.220$, $d = 0.13$ or irrelevants and famous targets, $t(43) = 0.24$, $p = 0.815$, $d = 0.03$. There was also a clear difference in fixation duration between irrelevants and personally familiar targets, $t(43) = 3.11$, $p = 0.003$, $d = 0.22$.

Irrelevants and probes: The pattern was consistent in lie trials, $F(2.24, 85.15) = 5.52$, $p = 0.004$, $\eta_p^2 = 0.13$. No significant differences were found between irrelevants and newly learned faces, $t(43) = 0.71$, $p = 0.480$, $d = 0.11$, or irrelevants and famous probes, $t(43) = 1.07$, $p = 0.293$, $d = 0.14$. However, fixation durations were significantly longer to personally familiar probes than irrelevants, $t(43) = 2.92$, $p = 0.006$, $d = 0.46$.

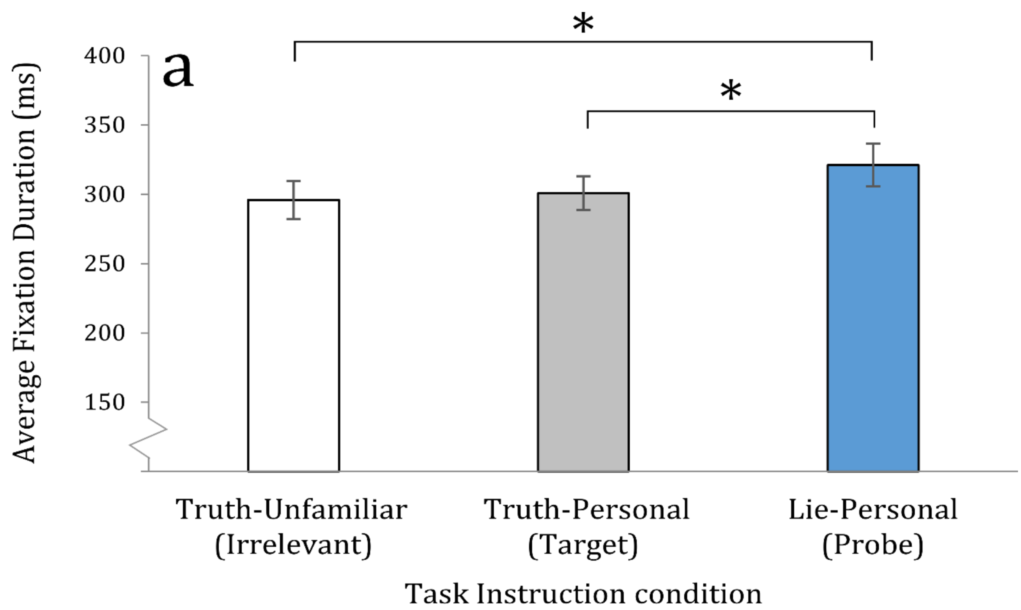
Because overall RM ANOVAs indicated that significant differences between irrelevants versus targets and irrelevants versus probes were evident only for personally known faces, additional analyses of the first three fixations and 1500 ms pre and post response were restricted to personally familiar faces.

First three fixations

To explore the emergence of a memory effect early in viewing behaviour, a RM-ANOVA was performed on fixation duration for responses to *irrelevants*, *targets* and *probes* in the first three fixations. The factors Task Instruction (Truth-Irrelevant, Truth-Target, Lie-Probe) and Fixation (First, Second, Third) were entered into the analysis. Main effects were found for Task Instruction, $F(1.85, 62.82) = 4.70$, $p = 0.014$, $\eta_p^2 < 0.12$, and Fixation, $F(1.68, 57.04) = 27.28$, $p < 0.001$, $\eta_p^2 < 0.45$, but no interactions between these factors emerged, $F(2.19, 74.70) = 0.80$, $p = 0.463$, $\eta_p^2 < 0.02$) (Figure 2.4a and b).

Post hoc tests performed on the main effect of Task Instruction revealed that fixation duration was not significantly longer for targets than irrelevants, $t(34) = 5.84$, $p = 0.560$. However, fixation durations were longer for probes than irrelevants, $t(34) = 2.58$, $p = 0.015$, $d = 0.29$, and targets and probes, $t(34) = 2.64$, $p = 0.012$, $d = 0.25$ (Figure 2.4a).

The main effect of fixation (first, second, third): fixation duration significantly increases from the first to the second fixation, $t(34)=7.61$, $p < 0.001$, $d = 1.14$ and the first to the third fixation, $t(34)=5.07$, $p < 0.001$, $d = 1.00$. There was no significant difference in fixation duration between second and third fixations, $t(34)=0.67$, $p = 0.506$, $d = 0.09$ (Figure 2.4b).



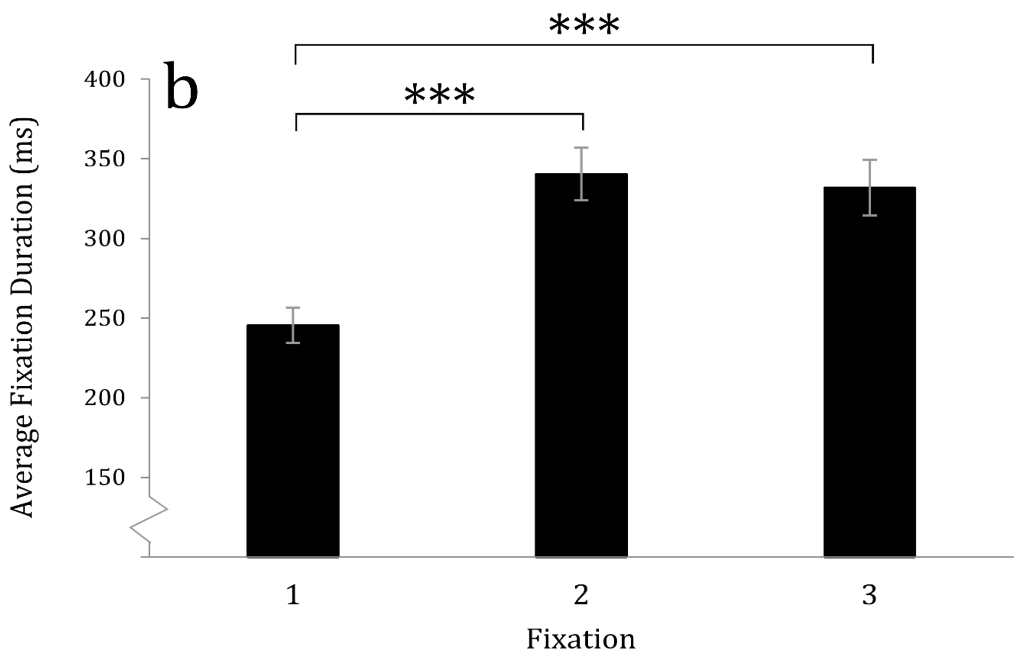


Figure 2 4. RM ANOVAs for fixation duration data are presented according to (a) task instruction condition (Truth-Unfamiliar, Truth-Personal, Lie-Personal) for the first three fixations combined to show a main effect of task instruction, (b) the main effect of fixation for the first three fixations with all three task instruction conditions combined (*df* = 43 in each case), with Bonferroni corrections for three multiple comparisons (α = 0.017), p*<0.001***, p<0.017*. Error bars represent M±SEM.*

Response locked analyses (1500 ms pre and post response)

To assess the time bins in which differences in fixation duration emerged, a 3 (Task Instruction: Truth-Irrelevant, Truth-Target, Lie-Probe) x 6 (Time bin (ms): -1500, -1000, -500, +500, +1000, +1500) was performed on the data for irrelevants, targets and probes. Significant main effects were found for Task Instruction, $F(1.64, 70.58) = 9.94$, $p < 0.001$, $\eta_p{}^2 = 0.19$, Time Bin, $F(4.00, 172.10) = 40.79$, $p < 0.001$, $\eta_p^2 = 0.49$, and a significant interaction between Familiarity and Time Bin, $F(10, 43) = 4.82$, $p < 0.001$, $\eta_p^2 < 0.10$ (Figure 2.5).

The main effect of task instruction revealed that fixation durations were significantly longer during recognition of familiar faces during both truths, $t(43) = 2.82$, $p = 0.007$, $d = 0.22$ and lies, $t(43) = 3.87$, $p < 0.001$, $d = 0.41$ compared to honest responses to unknown faces. Lies about recognition of probes also produced longer fixations than truths about familiar targets, $t(43) = 2.24$, $p = 0.031$, $d = 0.21$.

A main effect of time bin was observed for each of the three conditions: AFD data plotted from -1500 before the response until 1500 after consistently show a sharp significant increase in mean fixation duration from -1000 to -500msecs for each of the conditions, Truth-Irrelevant, $t(43) = 3.92$, $p < 0.001$, $d = 0.57$, Truth-Target, $t(43) = 5.54$, $p < 0.001$, $d = 0.82$, Lie-Probe, $t(43) = 7.36$, $p < 0.001$, $d = 1.11$.

Next, post hoc tests were performed to compare fixation durations between irrelevants *versus* targets, irrelevants *versus* probes, and targets *versus* probes within each time bin.

Irrelevants and Targets: Comparing data from six time bins, post hoc tests revealed a trend in fixation duration in the 500 ms time bin before the button-press familiarity judgement, $t(43) = 2.62$, $p = 0.012$, $d = 0.36$. The effect of increased longer fixation durations for targets compared to irrelevants remained significant until 500 ms after the response was made, $t(43) = 4.45$, $p < 0.001$, $d = 0.48$.

Irrelevants and Probes: Lies to familiar probes revealed significantly longer fixation durations compared to irrelevants also 500 ms prior to the familiarity judgement, $t(43) = 4.90$, $p = 0.001$, $d = 0.85$. Interestingly longer fixation durations were still observed 1500 ms post lie response; +500, $t(43) = 3.42$, $p = 0.001$; +1000, $t(43) = 2.43$, $p = 0.019$; + 1500, $t(43) = 2.92$, $p = 0.006$.

Targets and Probes: Fixation durations when lying about probes were longer than truths about targets also 500 ms before response selection, $t(43) = 3.96$, $p < 0.001$, $d = 0.39$. The data suggest that additional effort experienced directly before making a deceptive response increased load beyond the cognitive efforts required for recognition and response selections for personally familiar faces. No differences in fixation duration were found between targets and probes post response.

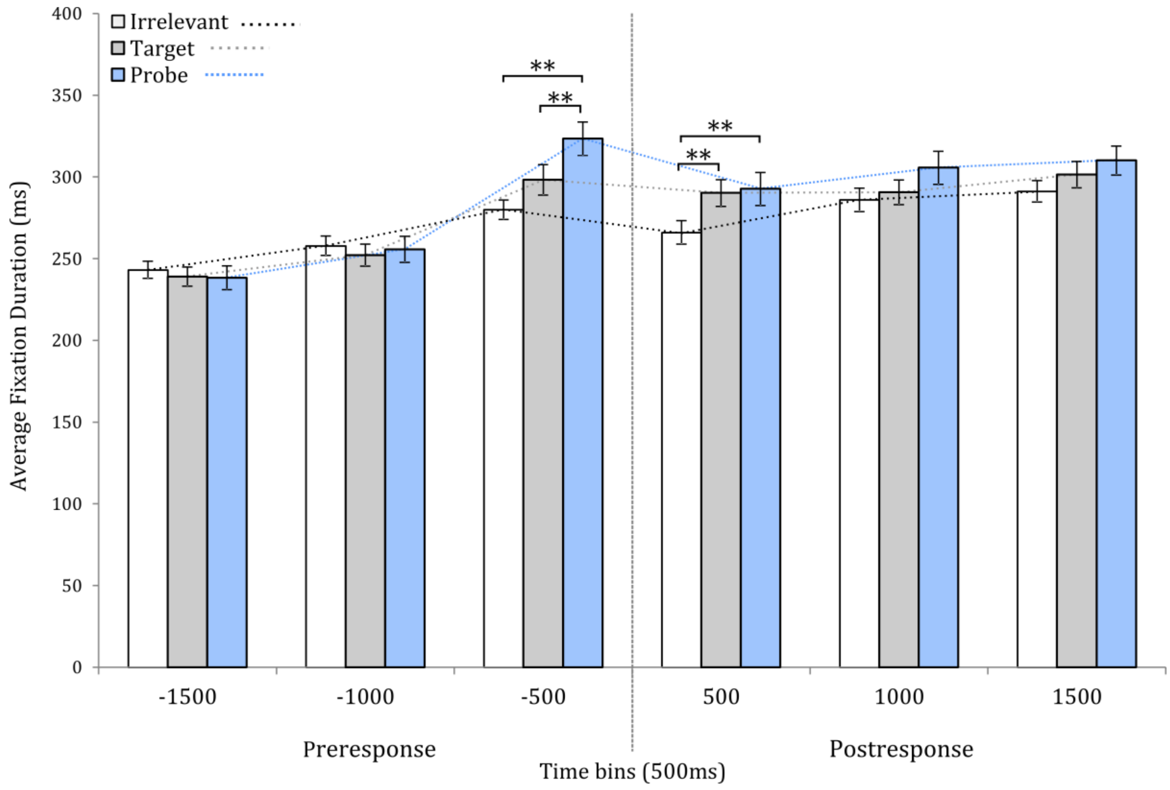


Figure 2 5. Fixation duration time course analysis, response locked 1500 ms pre and post button response. Data are presented in 500 ms time bins (error bars represent M±SEM). Bonferroni corrections for 33 pairwise comparisons ($\alpha = 0.002$), **p<0.002, ***p<0.001.

2.3.4. Questionnaire Data: Deceptive Strategies

Less than a third of all participants (32%, all female) reported attempting to use some sort of eye movement strategy when lying about recognising faces of people they knew. These strategies fell into three basic categories; trying to look less at the face when lying compared to truth telling (50% gaze aversion), attempting to look more at the face on the screen when lying (43%, deliberate gaze), trying to engage in the same viewing behaviour when both lying and telling the truth (consistent gaze, 7%).

2.4. Discussion

Experiment 1 aimed to determine whether participants' eye movement behaviour displayed memory effects (less fixations, longer durations) that identified recognition between familiar and unfamiliar faces that varied in degree of familiarity. Overall, effects of memory were observed in multiple fixations behaviours when participants viewed and correctly identified faces that varied in familiarity.

The fixation data for honest recognition of familiar faces are consistent with Althoff & Cohen's (1999) previous findings that effects of memory are observed in number of fixations, number of face regions viewed, and proportion of fixations to the inner face regions. Additionally, memory were found in the measure run count for all familiar face types. Furthermore, the findings in the present experiment reveal a memory effect for familiar face viewing in the number of fixations (and a trend in the data for run counts and number of interest areas visited) after only one brief exposure. This finding for singly presented faces is new compared to previous findings that memory effects for newly familiar faces were only evident after at least three exposures (Althoff, 1998; Althoff et al., 1999; Heisz & Ryan, 2011; Heisz & Shore, 2008). The prediction that viewing of familiar faces would also produce longer fixation durations compared to unfamiliar faces (Hannula et al., 2007) was partially supported by the present data. Longer fixation durations were found for personally known faces, but not for famous or newly learned faces. A possible reason why an effect of memory was not observed in fixation durations for lesser known faces (famous and newly learned) in the present experiment might be a consequence of the different display compositions presented in the different experiments (see Flowe & Cottrell, 2011; Flowe & Ebbesen, 2007). Multiple three-face displays were used in Ryan et al.'s (2007) experiments whereas single face displays in the present experiment. Future research should directly explore the effect of sequential versus simultaneous face displays on memory effects for faces that vary in degree of familiarity.

Although memory effects were observed in multiple fixation behaviours for honest identification of faces that vary in familiarity. However, cognitive efforts required for lying predicted further increases in fixation number, distribution, as well the mean durations of individual fixations. It is important to highlight that the effect of lying on fixation quantity (number of fixations, run counts, interest areas visited and proportion of fixations inner) is the opposite to the effect of memory (fewer fixations), and thus fixation-based markers of memory might be diminished during lies. In contrast, the effect of lying on fixation durations is a further increase in the length of fixation, and thus should not diminish an effect of memory but serve to make lie detection easier. To date, only Schwedes & Wentura (2012) have explored fixations during concealed recognition of faces and, even so, their investigations solely focussed on one measure (fixation duration) using one type of familiar face (newly learned). The data discussed below examine the effect of lying on both fixation quantity and duration for three different face types: personally known, famous celebrities and newly learned faces.

Overall, the present research found memory effects in multiple fixation measures which, in most cases, were robust in the face of lying. Consistent with the results for honest identifications of familiar targets, effects of memory were also reliable during concealed recognition of personally known probes compared to unknown irrelevants. Large effects of memory were observed in the number of fixations and number of face regions viewed, and an effect size approaching large was for run counts. This finding is almost identical to results for the same three fixation measures during honest identifications, except that the number of face regions visited took second place as the second largest indicator of memory.

Notably, the proportion of fixations made to inner face regions during concealed recognition of personally familiar probes were fewer than observed during honest identification of targets. This decrease in proportion of fixations increased resulted in a larger difference between irrelevants and probes, thus suggesting a larger, albeit misleading, effect of memory. This decrease was contrary to predictions that lying would be harder and thus increase fixation quantity. Although this decrease was not significant when comparing truth (targets) and lie (probes) trials directly, it did increase the effect size of the irrelevant-probe difference making it appear that there was a larger effect of memory on fixation behaviour during lies. This exception in fixation behaviour was contrary to the patterns in the other measures of fixation quantity (number of fixations, run counts or number of face regions visited). In those measures, numerical increases (presumably as a result of increased load as predicted) were observed when lying about probes and, although negligible, had a tendency to reduce effect sizes between irrelevants and probes, compared to effect sizes observed between irrelevants and targets.

It is difficult to determine if any particular factor caused the numerical decrease in proportions of fixations to the inner regions of the face between revealed and concealed recognition trials. Or indeed if it was simply a spurious result. We might speculate that lying about recognition of personally known faces is particularly conflicting and that this might have automatically triggered a gaze aversion response that resulted in less proportions of fixation being directed to the inner regions of the face. Given that the inner portions of the face are particularly important to the processing of a face and that well known faces can be recognised based on one or two fixations to the inner face regions (Hsiao & Cottrell, 2008; van Belle et al., 2010), it might be that participants were better able to execute deceptive responses by visually disengaging from these regions. The current study, however, is not able to answer this question although it is an interesting question for future research. The present findings on proportion of fixations, however, do suggest that it may not be the most reliable measure for memory detection during deceit.

The second notable finding was that the mean fixation duration was numerically longer during concealed recognition of probes, compared to honest identification of familiar targets. Although the difference in fixation duration did not significantly increase when viewing targets compared to probes, the numerical increase did serve to augment the effect size of the fixation duration difference between irrelevants and probes as compared to irrelevants and targets. This particular property of fixation duration makes it appealing for a measure of memory detection since lying does not diminish the effect of memory as it did with fixation quantity. However it is advisable to note that fixation duration differences were not found between irrelevants and targets or irrelevants and probes for lesser known faces when analysed for the full trial period, as reported below.

Also consistent with predictions and results for honest identification of famous targets, memory effects were observed during concealed recognition of famous faces in three fixation measures: number of fixations, run counts, number of face regions visited. The effect sizes of the differences calculated between the means for irrelevant and probes were smaller during concealed recognition than for irrelevants and targets during honest identifications. From truth to lies trials the effect sizes dropped as follows: Number of fixations, from large to medium, Run Counts, from approaching large to approaching medium, Number of face regions viewed, from medium to approaching medium. Furthermore, the difference between irrelevants and probes for the proportion of fixations to inner face regions emerged only as a trend in probe trials as significance values did not reach significance after corrections (although the calculated effect size still reached criteria for a small effect as defined by Cohen's *d*). This results confirm that this latter measure is less suitable as a marker of memory and even less so when memory is being intentionally concealed during lies. Again, no differences in average fixation duration were found between irrelevants and probes for famous faces. When comparing effects and significance across eye movement measures from truth to lie trials, effects sizes were smaller and *p* values slightly less significant. Most importantly, despite small numerical decreases in effect sizes from truth to lie trials, three of the five eye movement measures validly indicated memory for famous faces in lie trials.

Notably, in trials where participants lied about newly learned faces only a trend emerged in the data for number of total of fixations, although the calculated effect size was similarly small to honest responses to targets. No other evidence of memory effects were found in any of the other measure for learned faces. Although small, the discovery that memory exerts an effect on the number of fixation to a newly learned face (after only one exposure) in both truth and lie trials suggests that this variable is the most reliable for memory detection across different types of familiar faces. It is also the most simple to analyse, a practical asset for potential field uses of fixation behaviour for memory detection.

The finding that few differences were found in the eye movement variables for newly learned faces is most likely due to the procedure employed for learning. The procedure for learning was specifically chosen to explore memory effects for faces that were only familiar via brief exposure. Schwedes & Wentura (2012) previously found that longer fixation durations exposed recognition of newly familiar faces during attempts to conceal memory, however they employed a more extensive study phase that required correctly classifying faces according to groups over at least three presentations. Schwedes and Wentura's (2012) experiment also used six face displays. Other research using multiple face displays (Hannula et al., 2012; Ryan et al., 2007) have revealed memory effects in longer fixation durations after only one brief five-second exposure to a previously unfamiliar face. In the present experiment, it is encouraging that an effect of memory was observed in at least one fixation measure also after only one brief exposure but future research should address the limitations of different display types in generating useful fixation behaviour for memory detection.

A final but important point relating the lack of memory effects for newly familiar faces; it is possible that a lack of certainty for recognition of newly learned faces during lie trials was compounded by the difficulty of concealing recognition that resulted in guessing behaviour. Because the response required only a dichotomous button press response, it is possible that in some of these trials that the participants were guessing correctly as a matter of chance (errors were removed). Guessing behaviour could most certainly explain the lack of memory effects for newly learned faces. Thus, additional load in lie trials might have increased task difficulty resulting in more guesses that might explain the lack of a significant memory effects in lie trials for newly learned faces. It should also be noted that the statistics reported here are extremely conservative due to the number of analyses conducted and would unlikely be applied in real-world data analysis where data analysis selections would be more refined.

In sum, fixations observed over the full trial period during both truth and lie trials suggest that number of fixations most consistently reveals memory for known faces. The number of fixations made to familiar faces produces largest effect sizes for personally familiar faces (as observed in truth and lie trials) but also reveals an effect of memory (although small) when the face is only familiar from one brief study exposure. The proportions of fixations to inner face regions appeared to be the most inconsistent measure of memory showing inconsistent patterns of results dependent on degree of familiarity and veracity. Lying trials tended to produce less significant results and slightly smaller effect sizes suggesting a degree of cognitive interference during concealed recognition. In most cases, however, memory effects were still evident albeit slightly smaller. Finally, average fixations duration indicated a small effect of memory when comparing irrelevants to familiar targets, but a medium effect when comparing irrelevants to probes. The data support predictions that lying further increases fixation durations that serves to augment effect size differences between irrelevants and probes. It is important to note the opposite effect that lying has on fixation quantity and its implications for specific fixation measures employed for memory detection.

In the final two sets on analyses, the data was explored to further investigate the emergence of memory effects and deceptive efforts in the first three fixations and the last 1500 ms respectively. This analysis was limited to irrelevants and personally familiar faces only. To attempt to identify the effect of memory distinct from deceptive intentions, fixation durations were first compared for irrelevants and targets. Since both unfamiliar irrelevants and familiar targets both require a dichotomous button selection, the main difference between irrelevants and probes is recognition for the familiar target. To attempt to identify the additional effort required for deception in fixation durations, targets and probes were directly compared. Since targets and probes are both familiar, and in both trials, a response selection was made, the main difference between the two should be addition of effort required for response suppression of the truth, and execution of the lie.

Predictions that an effect of memory between irrelevants and targets would be revealed in the first three fixations was not supported by the data. The length of mean fixation duration was not significantly different when comparing for honest identifications of familiar target faces to honest responses to unknown irrelevant faces. No distinct effect of memory was observed for targets (compared to irrelevants) in the first, second or third fixation. This result was particularly surprising considering that differences in fixation durations between irrelevants and targets were observed when analysing the data for the full trial period. The results suggest that the effect observed between irrelevants and targets in the data for the full trial period was largely driven by effort required for the planning and execution of response selections.

Collapsing the data over the first three fixations revealed significantly longer fixation durations for irrelevants compared to probes, and targets compared to probes. These findings suggest that efforts for response intentions significantly impact fixation durations from trial onset and not just prior to a response. These results are inconsistent with previous research that found effects of memory in the first fixations (Althoff & Cohen, 1999; Ryan et al., 2007). The present experiment, however, was far more complex in design. Participants had to classify face types according to four different categories unfamiliar, newly learned, famous celebrities, and personally known as well as remembering whether the to tell the truth or lie about recognition, according to instruction. The studies by Althoff and Cohen (1999) and Ryan and colleagues (2007), however, only required identification of one familiar face type amongst a series of unfamiliar faces and did not require any deceptive responses to conceal recognition. The present result, however, is also not consistent with Schwedes & Wentura (2012) who found an effect of recognition in the second and third fixations when comparing fixation durations made to known (but not selected faces) during concealed recognition and unknown faces (also not selected) in an unknown condition. It is unclear why a recognition response was not revealed in any of the first three fixations for the present experiment when Schwedes and Wentura's (2012) found a recognition effect in the first three fixations for less personally significant faces. This finding is inconsistent with our predictions considering that personally familiar faces should theoretically produce larger recognition effects. A possible reason for the different results, as noted earlier, is the number of faces in the displays in the two experiments and thus the nature of decision making processes differed in the two experiments (absolute decisions in the present experiment and relative decision making in the latter). The effect of task difficulty is also commented on in Schwedes and Wentura's discussion on why they identified an effect of recognition in the second and third fixations and not the first, as in Althoff and Cohen (1999) and Ryan et al (2007).

A final analysis performed on the 1500 ms before and after participants' response selections investigated the effect of cognitive load when lying about recognition to probes, compared to correct identifications of familiar targets. Initial analyses revealed that fixation durations generally increased 500 ms directly prior to making explicit response selections (familiar or unfamiliar) in all conditions (honest responses to unknown irrelevants, identification of familiar targets, and concealed recognition of familiar probes). In the 500 ms prior to a response selection, fixations durations during concealed recognition of probes was significantly longer than honest responses to familiar targets. The difference in fixations duration during concealment of probes support predictions that lying is more difficult that telling the truth and this effect of load is observed here in just prior to (500ms) to making a deceptive response selection (refs). The effect of load during lie trials was still evident 500 ms post response and fixation durations for probes were still higher than targets in the +100 ms and +1500 time bins after a response was made. A trend in the data 500 ms before response selections also indicated that fixations durations to targets tended to be longer than to irrelevants, but the result was not significant after corrections for multiple comparisons.

In sum, Experiment 1 supports that a number of different fixation behaviours present markers of memory during both truthful and deceptive recognition responses. Results were most clear and reliable for personally familiar faces where memory effects were observed in the direction predicted for all fixation measures. One particular eye movement measure, number of fixations, most consistently displayed effects of memory (less fixations) for all face types with large effect sizes for personally known faces, but small effects for newly learned faces. Caution is advised, therefore, in the use of fixation count to infer concealed memory in liars when faces are newly familiar (after only one brief exposure). Although, it is likely that in most cases that an individual who intentionally lies about knowing a person involved in a crime is most likely to be more familiar with them than one brief exposure. Furthermore, the proportion of fixations made to inner face regions appeared to be a less stable measure of memory. The findings in the present experiment suggest that, although the processing of inner face regions is particularly important for the processing of faces (Stacey et al., 2005), it does not appear to be a particularly reliable measure for the purpose of memory detection. The analysis of fixation duration analysed across different time bins (1500 ms pre and post response divided into 500 ms time bins) suggested that increases in cognitive demands required for deceptive responses occur 500 ms before the selection was made. No early effect of memory was observed in the first fixation, or in the first, second and third fixations combined. An explanation as to why no early effect of memory is unclear. It is, however, apparent that the emergence of memory effects depend on the interaction of a number of variables that contribute to the overall task load and thus characteristics of fixation behaviour during the task; learning procedure, face familiarity and task instruction (tell the truth or lie), Future research should address these factors to determine designs best to reveal fixation that could be potentially used for memory detection in applied settings.

CHAPTER 3.

Emphasising memory confidence and eye movement monitoring: Effects on the detection of concealed person recognition.

3.1. Introduction

The aim of Experiment 2 was to replicate and extend Experiment 1. An entirely novel strand of Experiment 2 was to evaluate memory-based confidence judgements whilst participants told the truth and lied about recognition of faces that varied in familiarity (unfamiliar, newly learned, and personally known). The current experiment explicitly emphasised the monitoring of memory confidence and eye movements during truths and lies about recognition. With this manipulation it was intended that liars would manipulate their confidence to appear convincing (e.g., Tetterton, 2005) and also would be more likely to attempt control of eye movements during lies (Mann et al., 2013).

No research to date has explored using patterns of confidence to distinguish lies from truths. Confidence in eyewitness identifications of persons involved in a crime remain the most common way to assess witness credibility, most likely because confident witnesses are very convincing to jurors (Wells & Olson, 2003). The legal system is painfully aware that reports of high confidence often lead to false incriminations and wrongful convictions (Wells et al., 1998) as well as an impaired ability to detect deception (Tetterton, 2005). Neither lay people (jurors) nor professionals (judges, customs inspectors) are particularly skilled at distinguishing when others are lying (Bond & DePaulo, 2006; Vrij, Mann, Kristen, & Fisher, 2007), particularly with respect to the confidence-accuracy relationship (DePaulo, Charlton, Cooper, Lindsay, & Muhlenbruck, 1997). Liars often appear to exploit the belief that high confidence reports are convincing by providing well-rehearsed, consistent and confident memory reports when questioned. The present research attempts to turn this confidence-lie relationship around (high confidence equals credible witness) and assess patterns of confidence in liars to determine whether stereotypical patterns of confidence ratings during lies might actual distinguish them from truths to reveal deception.

To examine patterns of confidence during lies and truths, the present experiment recorded multiple confidence indices (Sauer, Brewer, & Weber, 2008) to a series of singly presented faces that varied in familiarity (unfamiliar, newly learned, personally known). Based on Craik & Lockhart's (1972) *levels of processing framework* (stronger memory traces equal higher confidence) we predicted that confidence ratings would be highest for recollection of personally known faces, and lower for newly learned faces and unfamiliar faces, respectively. Patterns of confidence ratings for honest judgements to faces would, therefore, display variation depending on how well each face was remembered within and across groups of faces. It is predicted that liars' patterns of confidence ratings would not display the same variation as truth tellers and that an over-inflation of confidence ratings during lies might well reveal liars attempts to manipulate lie-detectors (Prediction 1a). The second prediction was that participants' eye movements during honest trials would also display variations representative of genuine confidence decisions that would not be evident in the eye movement patterns of liars (participants are presented with an on-screen scale during the request for a confidence rating). Eye movements as a process tracing methodology propose that eye movements during decision making reflect deliberations and evaluations of decision outcomes (Chua, Hannula, & Ranganath, 2012; Glaholt & Reingold, 2011; Russo, 2011). The specific prediction was that fixation behaviour during lies about confidence would display less eye movement variability and thus distinguish lies from truths (Prediction 1b).

Eye movements and Recognition

The present experiment revisited the assessment of eye movements as a marker of recognition with an important emphasis on the monitoring of memory and fixation behaviour. In Experiment 1, no task instructions or financial incentives were used to manipulate participant motivation. The post-experiment *Deception Strategy Questionnaire* revealed that few participants attempted to monitor and control their eye movements based on a specific strategy. When participants were asked what behaviours they thought were indicative of lying, the majority (64%) of participants reported that they thought liars would avert their gaze. This finding is consistent with previous research that lay people and professionals generally believe and expect that liars look away (Strömwall, Granhag, & Hartwig, 2004; Taylor & Hick, 2007; Vrij, 2008; Vrij, Akehurst, & Knight, 2006; Vrij, 2004). Surprisingly less than a third of the participants (32%) in Experiment 1 reported trying to employ any eye movement strategy to control their eye movements, suggesting that participants were treating the task as somewhat abstract. Half of these participants reported trying to look less at the photograph of the face when lying, which was unexpected considering that the majority reported gaze aversion as an indicator of deceit. This inconsistency in reported beliefs about gaze when lying and reports of attempted strategies by liars highlight conflicts in resolving how to control eye movement behaviour when the task is not interpersonal but based mainly on the processing of information (DePaulo et al., 2003; Doherty-Sneddon & Phelps, 2005).

The patterns of eye movement data from Experiment 1 were generally consistent across truth and lie trials and showed no obvious attempts to control eye movements, this is perhaps not surprising considering that few participants reported attempts to monitor and control their eye movements. From the information reported by participants in Experiment 1 it is difficult to determine whether they were not particularly task-focused to evade deception detection or simply did not know how to attempt control of eye movement patterns. Attempted eye movement strategies based on how an honest person might inspect a photograph of a known or unknown person are not intuitive, and may be inconsistent with beliefs about gaze in general. Experiment 2 emphasised eye movement monitoring and control processes to explore whether participants in the present experiment would actively attempt to manipulate their eye movement patterns when incentivised to do so. In laboratory-based deception studies, task instructions and incentives designed to motivate participants sometimes increase cognitive effort resulting in changes in behaviour that make lie detection easier (Ben-Shakhar & Elaad, 2003; Davidson, 1968).

The ability to successfully monitor and control behaviour during a lie is a key component to its success (Zuckerman & Driver, 1985; Zuckerman, DePaulo, & Rosenthal, 1981). The mere act of deception is demanding because liars have to suppress the truth in order to successfully execute the lie (Spence et al., 2001; Vrij, Fisher, et al., 2006). Lying is made further difficult by attempts to monitor and control behaviours consistent with beliefs about how liars behave and strategies employed to counteract these (DePaulo et al., 2003). Experiment 1 suggested that mere cognitive load during concealed recognition of *newly learned* faces interfered with eye movements patterns and thus reduced the difference in fixation behaviour between irrelevants and probes on which memory detection is typically based. The eye movement data for personally known faces however appeared less vulnerable to effects of load when lying. By motivating people to consciously think about their behaviour, the present research increased the cognitive load of lying and investigated whether that increased cognitive load impacted evidence for concealed recognition.

In the present experiment participants were instructed that, in both recognition and confidence judgements, the task was to appear honest during truths and lies and that verbal, button press and eye movement responses would be monitored. Participants were advised that the experimenter-examiner would assess their guilt based on patterns of eye movements (where they looked, for how long, and distribution of fixations) and, if they successfully evaded lie detection, they would receive a £5 reward. Only one eye-movement-based mock crime study has explored the effect of eye movement monitoring and motivation on fixation behaviour (Cook, Hacker, Webb, Osher, Kristjansson, Woltz, Kircher, et al., 2012).

It is difficult to predict how, and indeed, if, examinees might try to control their oculomotor behaviour under the very specific set of circumstances posed in the present experiment. Eye movement research suggests that demand on working memory slows down task performance and thus leads to an increase in fixation behaviour (Cook, Hacker, Webb, Osher, Kristjansson, Woltz, Kircher, et al., 2012; Zenzi M Griffin & Oppenheimer, 2006; Zenzi M Griffin, 2004; J M Henderson, 1992; Meyer & van der Meulen, 2000; Rayner, 1998). Research on cognitive load and interpersonal gaze supports that people often automatically avert their gaze (visually disengage) when they experience cognitive load in a bid to free up working memory process (Doherty-Sneddon, Bruce, Bonner, Longbotham, & Doyle, 2002; Doherty-Sneddon & Phelps, 2005). However, if metacognitive strategies for problem solving (such as evading lie detection) are based on knowledge about social gaze (e.g., liars look away; Stromwall et al, 2004; Taylor and Hick, 2007; Vrij, 2004, 2008; Vrij et al, 2006, 2010), then participants might try to regulate their eye movements based on these beliefs (i.e., stay focussed on screen, maintain consistent responding). It is possible, however, that efforts to control eye movement behaviour might incur further cognitive demands that result in more visual disengagement. Such ironic effects of attempted mental control over action, in that behaviours sometimes represent the opposite of what they intended to do, are neatly outlined by Wegner's ironic processing theory (Wegner, 1994; Wegner, Ansfield, & Pilloff, 1998). In the field of eye movement monitoring there is a lack of information concerning the extent to which people have volitional control over their eye movements and under what conditions. Hence, the question in the present experiment was whether participants attempted to control their eye movements during lies and whether their selected strategy impacted on patterns of recognition in eye movement behaviour.

Both Althoff and Cohen (1999) and Ryan and colleagues (2007) propose that memory effects for familiar faces are an obligatory consequence of previous exposure. Rayner also proposed that the ability to consciously control or manipulate individual fixations during processing of visual information is physically difficult, if not impossible (Henderson, 1992; Rayner, 1998). However, it is well established that eye movements are not only based upon cognitive factors such as previous experience (Antes, 1974; Buswell, 1935; Henderson et al., 1999; Loftus & Mackworth, 1978; Mackworth & Morandi, 1967; Parker, 1978), they are also subject to shifts in attention driven by explicit task instructions (e.g., Yarbus, 1967).

In one experiment, Althoff and Cohen (1999) explicitly instructed participants to adopt specific eye movement strategies when viewing both familiar (famous) and unfamiliar faces. The intentional strategies included a reading-like strategy (move eyes across the face from left to right, starting at the top and finishing at the bottom) and a features strategy (fixate features in a particular order; i.e., top of head, left ear, left eye, right eye, right ear, nose, mouth, chin). Eye movement patterns were compared during intentional strategies compared to free viewing of the faces. Intentional strategies significantly increased viewing behaviour similar to optimal extraction eye movement patterns observed during processing of unfamiliar faces (i.e., number of fixations, number of regions). The proportion of fixations directed to the inner regions of the face, however, still distinguished famous from unfamiliar. The finding suggest that some eye movement variables are more resistant to manipulations than others. The research however did not explore intentional gaze strategies during concealed recognition of known faces.

One eye-movement-based deception study elaborated task instructions to guide participants' behaviour (Cook et al., 2012). Guilty participants took part in a mock crime whereas innocents were given a general description of the crime but did not enact it. Participants made true/false mouse click responses to single statements presented on a computer screen related to their involvement in the crime. The task brief explicitly instructed that all participants should respond to test statements *as quickly and accurately as possible* because delays in responding or errors could be taken as indicators of deception. Guilty and innocent participants' reading behaviours were recorded while they responded to statements about a mock crime via a computerized questionnaire.

As a general measure of processing difficulty the researchers measured the overall number of fixations made to the statement before making their response. In addition, they analysed the time spent fixating on the text during the first reading of it (ms per character) and then the re-reading of it after looking away from the text. These analyses allowed consideration of cognitive effort overall during the first reading of the statement and subsequently any delayed difficulty associated with the task during re-reading. Consistent with predictions based upon the cognitive workload hypothesis, guilty participants made more fixations per character than did innocent participants. Guilty participants also displayed longer first pass reading times on average than did innocent participants. No main effect of guilt was found in the analysis of second pass, re-reading times.

Surprising results, however, were found in the interaction between guilt and statement type in the reading and re-reading data. Contrary to the hypotheses, guilty participants' first pass reading times for crime related probe items where shorter than when they responded to neutral fillers. As expected, innocents' first pass durations did not vary as a function of statement type. In addition, second pass rereading times were shorter for guilty participants when re-reading critical probe items as compared to neutral (irrelevant) items. The data suggest evidence of strategic monitoring and control of reading and re-reading behaviours in the eye movements of guilty participants. Consistent with the task instruction regarding speed and honesty, guilty participants appeared to intentionally read faster and minimise re-reading to appear honest. The data suggest increased cognitive effort partly as a consequence of response inhibition in the main effect of guilt. Furthermore, the interactions reveal quite novel data patterns suggesting an ability to monitor and control eye movement behaviour based on the instruction to respond quickly and as accurately as possible so as not to appear guilty. Finally, the researchers also varied financial incentive ($30 vs. $1) as a means to manipulate motivation. Results suggested that motivation interacted with guilt and number of fixations, such that there was less difference between guilty and innocent participants' fixation behaviour in the low motivation condition than the high motivation condition. The authors also note that the financial incentive manipulation had a greater effect on innocent participants than guilty participants suggesting that guilty participants were already motivated to manipulate fixation behaviour to a degree more than less motivated innocent participants.

The present research differed from the Cook et al. (2012) study in several important respects. First and foremost, Experiment 2 generally emphasised monitoring of memory and fixation behaviour during truths and lies and that these would be used to assess deception (compared to specifically instructing participants that innocence was associated with speed and accuracy). The effect of cognitive load on multiple fixation behaviours was examined during presentation of photographs of people that varied in familiarity (compared to statements that varied in complexity). The assessment of memory during revealed (truths) and concealed (lies) information was analysed as using the following measures and stimuli comparisons:

As in Experiment 1, predictions were that the quantity of fixations would be fewer and distribution of viewing less dispersed during reprocessing of a familiar face compared to first-time processing of an unfamiliar face. The familiar-unfamiliar (Target-Irrelevant) difference would display a *memory effect* as manifested in fewer fixations to fewer regions of the face during processing (Althoff & Cohen, 1999; Heisz & Shore, 2008) (Prediction 2a). Second, this Target-Irrelevant difference would be largest for personally known compared to newly learned faces making the memory effect more reliable for highly familiar faces (Meijer et al., 2007; Ryan et al., 2007) (Prediction 2b).

Prediction based on cognitive load during concealed recognition are also subdivided into two parts: Increased cognitive load during concealed recognition will increase fixation behaviour and potentially weaken/interfere with the memory effect, as a result of a smaller Probe-Irrelevant difference (compared to the Target-Irrelevant difference) (Prediction 3a). Consistent with the predictions that the memory effect will be strongest for well-known faces, it was predicted that concealed recognition of personally known faces would be less susceptible to cognitive interference compared to newly learned faces (Prediction 3b).

Predictions based on fixation durations were also the same as Experiment 1 (Ryan et al., 2007; Schwedes & Wentura, 2012). Participants' fixation durations would be longer when viewing familiar faces compared to unfamiliar faces (Target-Irrelevant difference) (Prediction 4a). The Target-Irrelevant difference would be larger between personally known and unknown faces, compared to newly-learned and unknown faces (Prediction 4b). Fixation duration-based effects will be observed in two different analyses (Ryan et al., 2007; Schwedes & Wentura, 2012). Recognition effects will be observed in the First Three Fixations of each trial, whereas effect of response intentions will be observed in the Last 1500 ms before the response is made (Prediction 4c). An increase in cognitive load during concealed recognition of the familiar face would increase fixation duration and thus the Probe-Irrelevant difference for fixation duration would be greater than for Target-Irrelevant comparisons, potentially making the Probe-Irrelevant distinction in deceptive trials easier than the Target-Irrelevant distinction in honest trials (Prediction 3d).

No single prediction was made in relation to the effect of intentional strategies on eye movements. Predictions based on the beliefs that liars look away might result in liars deliberately trying to look more at the faces when they conceal recognition of (Mann et al., 2012, 2013; Vrij, Mann, Leal, & Fisher, 2010). Whereas predictions based on the beliefs that liars experience cognitive difficulty and thus take longer to respond (Walczyk et al., 2003), might result in liars intentionally averting their gaze so as not to give anything away in their on-screen gaze behaviour. Either way, ironic effects of mental strategies on actions may result in behaviour counter to that intended (Wegner et al., 1998).

In sum, the predictions are that liars will display less variability in their verbal confidence judgements (1a) and associated eye movements (1b), which will expose their deceit when they lie, stating that they do not recognise a known face. Recognition of familiar faces will produce a decrease in the quantity and distribution of fixation behaviour that will be consistent with revealed recognition of familiar faces, but that will betray explicit denial of recognition (2a). Eye movement-based memory effects will be most pronounced for personally known faces (2b).

Fixation data will be similar for both truths and lies but increased cognitive load during lies might increase fixation behaviour and potentially diminish the ability of eye movements to distinguish actual unknown faces from those the liar declared they do not know (3a). Eye movement-based memory effects for personally familiar faces will be most resilient to cognitive interference during lies (3b). An increase in mean fixation durations will also indicate recognition of familiar faces during truths and expose lies (4a). Fixation durations will be longest for personally known faces (4b). Increased fixation durations will be observed during recognition in the first three fixations and response inhibition in the last 1500 ms respectively, before the recognition judgement is made (4c). Cognitive load experienced during lies might increase fixation duration and serve to augment the recognition effect for memory detection during lies (Griffin & Oppenheimer, 2006).

3.2. Method

3.2.1. Participants

33 undergraduate students (26 females, 7 males) participated in the experiment. Participant ages ranged from 19 to 21 years (M = 20.3, SD = 1.9). All participants had normal or corrected-to-normal vision and were awarded £5 remuneration for their participation. Participants were specifically recruited from the same pre-existing tutor groups as Experiment 1 (established at the start of term by random allocation to class lists) to ensure a baseline of real world familiarity. At the time of Experiment 2, participants had been personally acquainted with fellow tutees for approximately five months.

3.2.2. Design

The research used a modified Concealed Information Test during which participants lied and told the truth about recognising different types of familiar faces (newly learned, personally known). In a sequential presentation, participants were randomly presented with a series of singly presented colour photographs of faces: unfamiliar faces and three different types of familiar faces to which they made 'familiar' or 'unfamiliar' button press responses. A nested within-subjects design independently manipulated Task Instruction (2 levels: Lie, Truth) and Familiar Face Type (4 levels: *Unfamiliar, Familiar-Learned, Familiar-Famous, and Familiar-*

Personal). Instructions varied by three different blocks of trials. In the first block, participants were required to respond honestly to all trials. The honest block served as a practice session and was not analysed for the purpose of this experiment. Two lying condition blocks followed: In the lying blocks participants were asked to lie in turn about the two different types of *familiar* faces: Familiar-learned (*Lie-learned*), or Familiar-personal (*Lie-personal*). In these lying blocks, participants lied about only one type of familiar face, whilst telling the truth about all the others. For example in the *Lie-Personal* block, every time the participant saw a photograph of a personally familiar face they had to lie and make an unfamiliar response by pressing the appointed button on the game port. When presented with *Familiar-Learned* photographs within this block, however, the participant honestly indicated that they were familiar. Presentations of unfamiliar faces always required an honest unfamiliar response. To reduce the length of the present experiment, participants did not complete a block where they were asked to lie about celebrity famous faces. Familiar-Famous faces were included in the presentation trials so that the number of test trials in each block (N=40) was consistent in Experiments 1 and 2. There were equal numbers (4 x 10) of each face type in each block of trials. Lie-learned and Lie-personal blocks were counter-balanced.

3.2.3. Apparatus and Materials

Apparatus

As in Experiment 1, participant's eye movements were tracked using the Eyelink II head mounted eye tracker (SR Research, Canada). The mean image size was 5.53° of visual angle (*SD* = 6.83; mean image size taken from a sample of 24 representative images from all face types). Manual button press responses were collected by a Microsoft Sidewinder Plug-and-Play game pad and relayed back to the host computer. The button assigned to familiarity was counterbalanced for hand dominance. Sixteen out of 27 participants used their dominant hand for familiarity, 11 used their non-dominant hand (25 were right handed and 2 left-handed).

Photographs

A total of 120 digital colour photographs of faces were presented to each participant over three blocks of test trials (40 photos x 3 blocks). All photographs were portraits showing the full face of a person with a neutral expression and eye gaze towards the camera. Forty test photographs were presented in each block of trials that comprised 10 *Unfamiliar* faces (UF), 10 *Familiar- Learned* (F-L), 10 *Familiar- Famous* (F-F) and 10 *Familiar- Personal* (F-P).

As in Experiment 1, the appearance of all photographs were standardised using Adobe Photoshop Elements (Version 2.0) and Adobe Photoshop CS4 on a blue background (HEX: 377BE8) measuring (640 x 480 px). Photographs were presented using Experiment Builder (Version 1.6.121, SR Research) on a desktop computer linked to a 19-inch CRT Monitor (model, G90FB; resolution, 1280 x 1024 pixels; refresh rate 89Hz). Images were presented randomly to the left (292, 292) or the right side (704, 292) of the screen to minimise anticipatory guessing behaviour of picture location.

Unfamiliar faces (UF) were sourced from the unfamiliar face database created for Experiment One (see Section 2.2.3). *Familiar- Learned* (F-L) faces were familiarised using a learn-to-criterion procedure (Schyns, Bonnar, & Gosselin, 2002) directly before performing the actual *m*CIT (see procedure). *Familiar- Famous* (F-F) faces were contemporary celebrities faces sourced on the internet, *Familiar-Personal* faces were photographs of the student participants from Experiment 1.

3.2.4. Procedure

Participants were seated in a controlled, quiet and dimly lit room at a distance of 0.80m from the display screen. Light levels were carefully controlled for all participants. The Eyelink II headband was comfortably secured to the participant's head. Retinal and corneal reflections induced by an infrared source were recorded at a frequency of 250Hz (Pupil-CR mode) and 500Hz (Pupil only) to obtain participants' points of fixation on the screen (error of resolution: 0.5°-1.0°).

Rate personally known faces: Prior to the CIT, participants were presented with photographs of personally familiar classmates on a paper hand out. Participants were asked to look at each face in turn and to indicate, yes or no, if they recognised the person in the photograph. The participant also rated each photograph for familiarity (1 = not at all familiar; 7 = most familiar), to note from where the person was originally known, and, if possible, to note down their name. To encourage re-processing of the image they were also asked to record the gender, eye colour and hair colour as they appeared in the photograph. Rating taken prior to the experiment confirmed personally known group members as familiar (*M* = 4.90, *SD* = 0.82) and that mean familiarity did not significantly different to ratings taken at the time of experiment one, $t(26) = 1.56$, $p = 0.131$.

Study Phase: Prior to the CIT, participants were shown ten photographs of unfamiliar faces and asked to learn them to memory for the purpose of the task. Unfamiliar faces were presented on ten individual colour photographs cards (dimensions). These were laid out on the table in front of the participant who was asked to study them until they had learned them to memory. A name was then placed below each photograph and participants were then instructed to learn which name belonged to each face. Once the participant indicated that they had learned the face-name pairings the face and name cards were shuffled and handed back to the participant. The participant had to match each face to each name correctly. The criterion for learning was that participants pair all faces and names correctly 100% twice consecutively. This learn-to-criterion procedure was based on previous face research (Schyns et al., 2002). The learn-to-criterion procedure was introduced in the present experiment to ensure learning and to meet the conditions of previous experiments that documented robust effects of memory after three exposures to previously unfamiliar faces (Althoff et al., 1999; Althoff, 1998). There was no time limit for the successful completion of the study phase. Upon completion, participants' eye movements were calibrated for accurate eye movement monitoring by the eye tracker.

Calibration: Eye position was calibrated prior to each test block using a 3 x 3 dot array and, where necessary, in between condition blocks. To calibrate, a black dot with a white centre was presented in middle of the screen. Upon request, the participant fixated the white centre of the black dot. Once the participant steadily fixated on the dot, the experimenter accepted the fixation by pressing a button on the host computer. Once the initial fixation was accepted the same dot was displayed randomly, one location at a time, using a 3x3 array. The host computer was operated by the experimenter and was positioned behind the participant and the display computer.

Following calibration, and directly prior to the test phase, participants were informed that eye movements were carefully monitored by the experimenter-observer with the explicit purpose of detecting their deception. They were advised that the experimenter would be recording a number of eye movement behaviours such as, where they looked on the screen, for how long, how often they looked away and looked back, and that this was being done from a separate host computer behind them. They were not advised at any point at what eye movement behaviours might indicate deception or to adopt any specific eye movement strategies. The emphasis on the monitoring of eye movements aimed to increase awareness of the monitoring process to explore whether this triggered any specific strategies to avoid detection.

Test Phase: During the mCIT, participants were presented with a sequence of 40 full face colour photographs. Prior to the display of each face a fixation dot was shown in the centre of the screen to correct any drift in eye movements following the initial calibration. Within each condition block *Unfamiliar* (10)*, Familiar-Learned* (10)*, Familiar-Famous* (10) *and Familiar-Personal* (10) faces were displayed to the participant randomly. Participants responded by making a dichotomous 'familiar' or 'unfamiliar' button press response whilst at the same time verbalising their response. After the button press was made, a confidence scale was presented. Participant were instructed to look at the scale (0-100%) and decide how confident they were about their previous familiarity judgement. Participants indicated their confidence judgement by pressing a trigger button on the game pad (any) whilst verbalising there rating (numerators of ten, i.e., "ninety"). There was no upper time limit for recognition or confidence judgements. The sequence was repeated for each of the 40 trials over the three condition blocks.

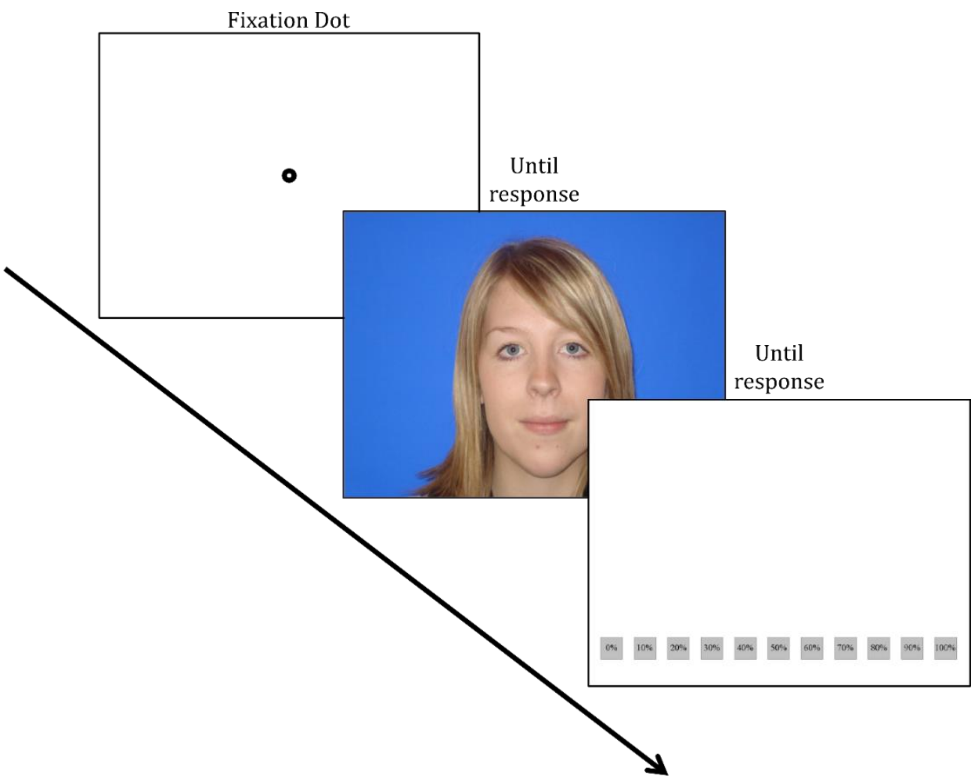


Figure 3. 1. The display sequence for each trial commenced with the presentation of a fixation dot followed by a photograph of an unfamiliar or familiar face until the participant made a

familiar/unfamiliar response. After each face recognition trial a confidence scale was presented during which the participant had to provide a confidence rating ranging from 0-100% in numerators of 10 (e.g., fifty).

Instructions varied by three different blocks of trials. In the first block, participants were required to respond honestly to all trials. Then followed two lying blocks during which participants lied, in turn, about the two different types of familiar faces. The two lying conditions were named *Lie-Learned and Lie-Personal*. The *Lie-Learned* condition required that participants lie about the faces that they learned during the study phases, whilst telling the truth about all other faces types; during the *Lie-personal* to lie about personally known faces whilst telling the truth about all other face types. To emphasise, in the lying conditions, participants made both honest *and* dishonest responses but lied about only *one* specific group of familiar face in each condition block (*Familiar-Learned or Familiar-Personal)*. After the completion of all trials, participants were administered with a Deception Strategies Questionnaire to record whether participants tried to evade detection by employing specific eye movement strategies.

3.2.5. Data preparation: Defining a-Priori Interest Areas (IAs)

Faces: Consistent with previous research (i.e., Walker-Smith, Gale & Findlay, 1977; Bate, Haslam, Tree & Hodgson, 2008) and Experiment 1, five areas of interest were defined: right eye (left side of visual space), left eye (right side of visual space), nose, mouth, and outer. The eyes, nose and mouth were grouped for analysis of the proportion of fixations made to the inner region of the face.

*Confidence Screens***:** To analyse the sampling distribution of eye movements during confidence judgements, boxes were drawn around each confidence decision box to created 11 interest areas: 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100%. This allowed calculation of the number of interest areas (IAs) fixated on viewed during deliberation of each confidence rating.

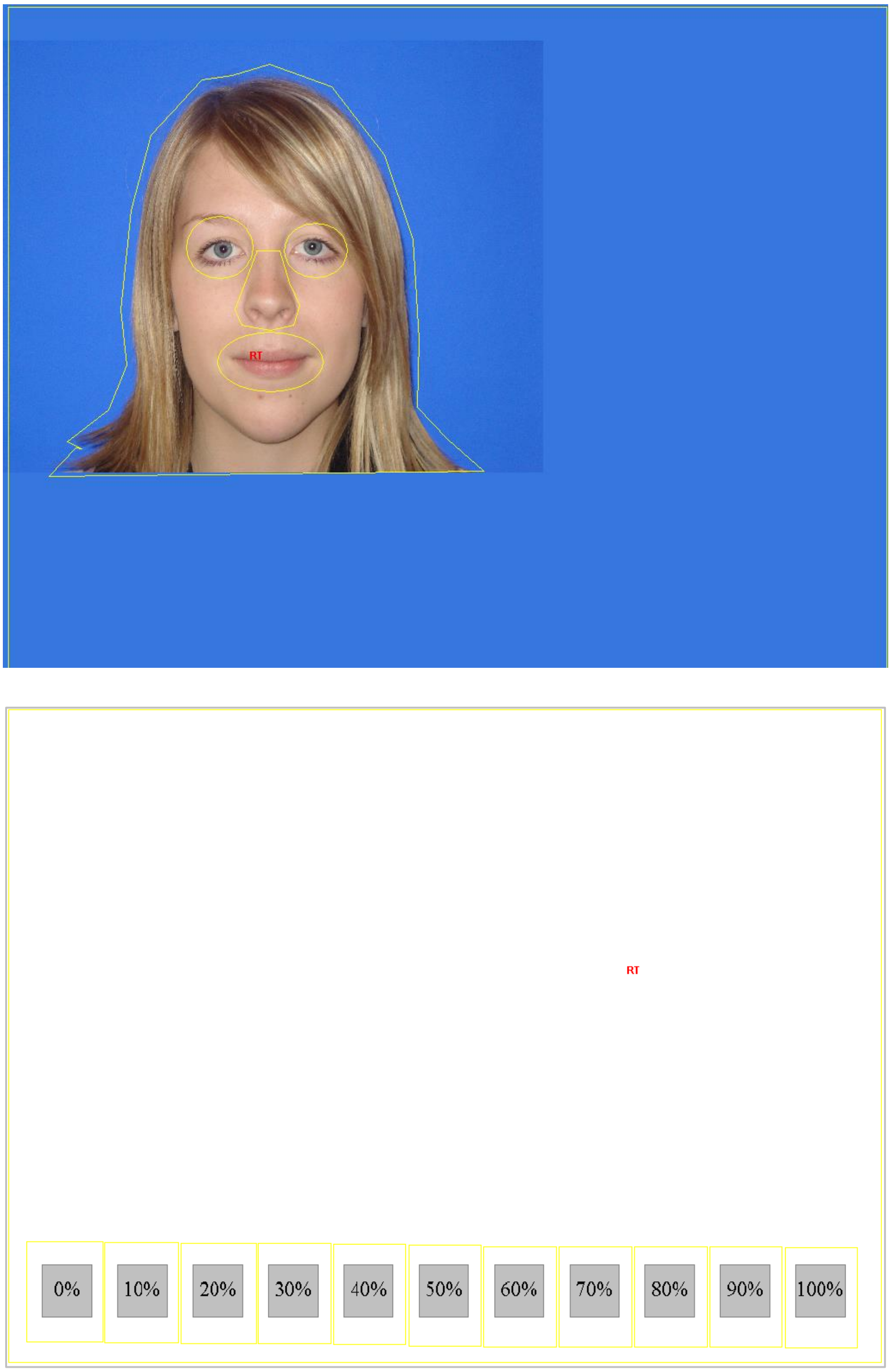


Figure 3. 2. The display sequence for each trial commenced with the presentation of a fixation dot followed by a photograph of an unfamiliar or familiar face until the participant made a familiar/unfamiliar response. After each face recognition trial a confidence scale was presented during which the participant had to provide a confidence rating ranging from 0-100% in numerators of 10 (e.g., fifty).

3.2.6. Analysis Strategy

Confidence judgements: Verbal confidence ratings ranged from 0-100% in multiples of ten, such that each participant selected one out of eleven possible confidence judgements for each trial (0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100%).

Eye movement variability behaviour was defined according to how many IAs of the confidence scale were fixated before the verbal rating. The possible number of IAs visited ranged from one to eleven (see Figure 3.2). As with the chosen confidence being less variable when a person is lying, we would expect the number of IAs looked at during this time also to be less variable, thus the variance of IAs visited was analysed. Variability in mean verbal confidence and eye movements were analysed by entering SDs as the unit of analysis in RM ANOVAs (see also Johnson et al., 2003; Leongómez et al., 2014). Multiple RM ANOVA were performed on the verbal and eye movement data. (1) Truth data with 1 within subjects task instruction manipulation (3 levels: Truth-Unfamiliar, Truth-Learned, Truth-Personal). (2) Lie data with 1 within subjects task instruction manipulation (3 levels: Truth-Unfamiliar, Lie-Learned, Lie-Personal). (3) Truth and Lie data were analysed with 2 within subjects factors, Task Instruction (2 levels: Truth, Lie) and Face Type (2 levels: newly learned, personally known). The condition order of trial block presentation was entered as a between subjects factor into each analysis, no main effects were found.

Fixation quantity and distribution were analysed with multiple RM ANOVAs on four different fixation measures: the number of total fixations made to the face (Num. Fixations), the number of runs made on the face (Run Count), the number of interest areas on the face visited (IAs Visited), and the proportion of fixations made to the inner regions of the face (Prop. Inner). Separate RM ANOVAS were performed first on the truth data (Irrelevants and Targets) with 1 x within subjects factor, Task Instruction (3 levels: Truth-Unfamiliar, Truth-Learned, Truth-Personal), then on the lie data (Irrelevants and Probes) also with 1 x with subjects factor (3 levels: Truth-Unfamiliar, Lie-Learned, Lie-Personal). Further RM-ANOVAs were performed on the same four fixation measures with 2 within subjects factors, Task Instruction Condition (2 levels: conceal recognition, reveal recognition) and Familiar Face Type (2 levels: Familiar-Learned and Familiar-Personal) (Targets and Probes).

Fixation Durations: Fixation durations were analysed for the (1) First Three Fixations and (2) Last 1500 ms of the decision making process to differentiate cognitive load factors linked to *recognition* and *response intention*s respectively. For each set of analyses, post hoc paired sample t-tests tests were performed on the same comparisons as those for fixation quantity and distribution; Target-Irrelevant, Probe-Irrelevant, and Probe-Target.

3.3. Results

As in Experiment 1, where Mauchley's Test of Sphericity were violated, RM ANOVAs were calculated using Greenhouse Geisser adjustments to degrees of freedom (*df*). The corrected p value and Greenhouse Geisser epsilon (ε) are reported for F tests. Post hoc tests were performed using paired sample t-tests. Adjusted p values (α) are denoted in each relevant figure caption for the number of post hoc tests conducted. The use of Bonferroni comparisons for correcting multiple tests on multiple fixations measures is consistent with other eye movement research using similar analyses as the current thesis (Hannula et al., 2012, 2007; Hannula & Ranganath, 2009).

3.3.1. Exclusion Criteria

Data was analysed for 27 participants. Six (4 females, 2 males) of the original 33 participants were removed from the data set for the following reasons; technical difficulties that resulted in loss of data (4) and failure to complete the task according to instructions (2). As in Experiment 1, individual trials were also removed from the analyses if the participant responded incorrectly to the face or presented outliers in the reaction time data (less than 300 ms or more than 5000 ms).

Error rates were low across all trials: Familiar-Learned (truths, 4.07%, lies, 1.48%) Familiar-Personal (truths 1.85%, lies 4.07%) and unknown faces (truths 7.04%). This left 3040 trials out of the original 3240. Similar to previous research (Greenwald, Nosek, Banaji, 2003; Verschuere, Spruyt, Meijer & Orgaar, 2011) outliers in the reaction time data were removed if they were faster or slower than specific set thresholds (acceptable range for present data, <300 ms or >5000 ms). This removed a further 30 trials (0.93%) leaving a total of 3010 trials out of the original 3240.

3.3.2. Confidence Ratings

Truths: (Irrelevants and Targets). Task instruction manipulation had no effect on mean variability in verbal confidence ratings across honest trials, $F(2,50) = 1.74$ $p = 0.186$, $\eta p2 = 0.01$ (see Figure 3.3).

Lies: (Irrelevants and Probes). Task instruction manipulation had a significant effect on mean variability of confidence ratings, $F(2,50) = 5.14$, $p = 0.009$, $\eta p2 = 0.17$. Lies about personally known probe faces produced less variability ($M = 4.79$, $SEM = 1.12$) than truths about unknown, irrelevant faces ($M = 8.16$, $SEM = 1.62$), $t(26) = 2.99$, $p = 0.006$, $d = 0.46$; the effect size was medium. A non-significant trend between newly learned probes and irrelevants, $t(26) = 1.98$, $p = 0.058$, $d = 0.24$ also revealed less variability in confidence during lies about newly learned faces ($M = 6.21$, $SEM = 1.48$); the effect size was small (see Figure 3.3).

Truths and Lies (Targets and Probes). There was no main effect of task instruction, $F(1,25) = 4.19$, $p = 0.051$, $\eta p2 = 0.14$, face type, $F(1,25) = 0.09$, $p = 0.766$, $\eta p2 < 0.01$, or any interaction between the two, $F(1, 25) = 0.25$, $p = 0.595$, $\eta p2 = 0.01$ (see Figure 3.3).

In sum, it appear that liars displayed less variability in their verbal confidence ratings when lying about recognising personally known faces compared to honest judgements of unknown faces. A non-significant trend also suggests that liars display less variability, albeit a small effect, in patterns of confidence ratings for newly learned compared to unknown faces. Variability in truth data did not differed significantly to the degree that liars' confidence ratings did.

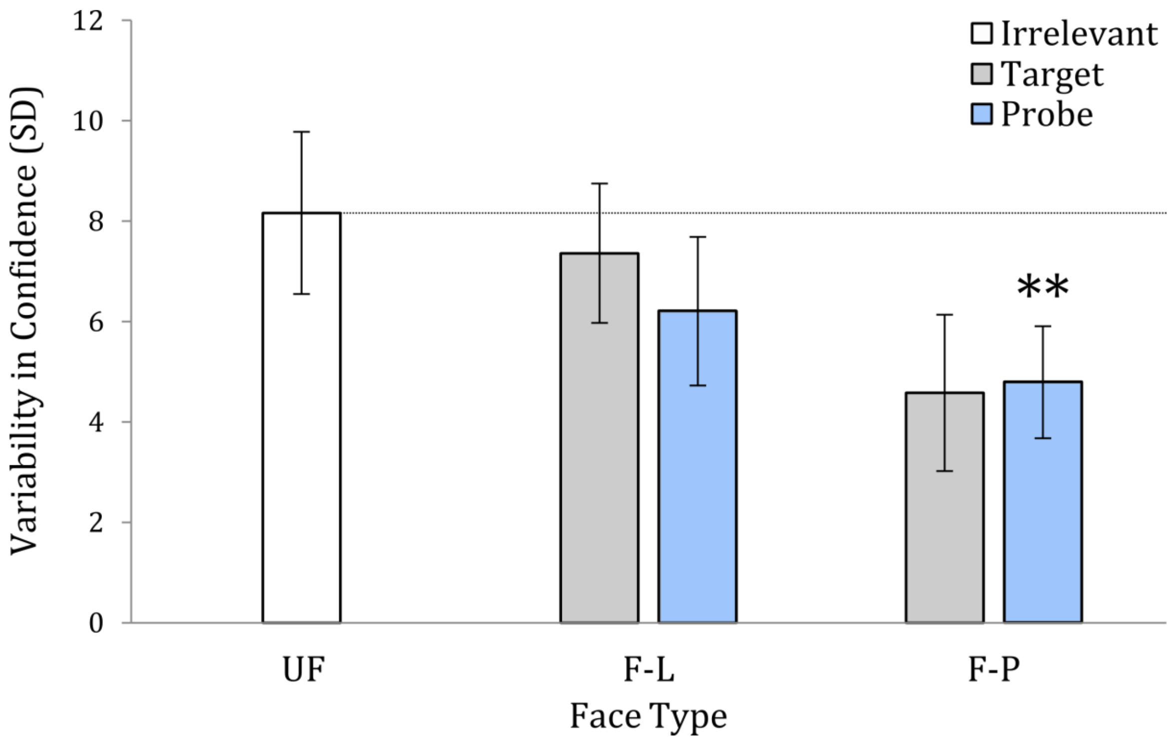


Figure 3. 3. RM ANOVAs for variability in verbal confidence ratings (SD), (*d.f.* = 26 in each case with Bonferroni adjustments for multiple paired sample t-tests (α=0.017). The y-axis shows data for unfamiliar faces (UF), newly learned faces (F-L) and personally familiar (F-P) faces. In each graph, the unfamiliar (UF) irrelevants (white bars) are the comparison point for all truth (grey) and lie data (blue). P<0.01**.

3.3.3. Eye Movements (Inspection of confidence scale)

Truths: (Irrelevants and Targets). Task instruction condition had a significant effect on viewing of the confidence scale across truth trials, $F(2,50) = 7.60$, $p = 0.001$,

$\eta p2$ = 0.23. Recognition of personally known faces produced less variability in number of IAs visited (*M* = 0.62, *SEM* = 0.04) than classification of unknown faces (*M* = 0.79, *SEM* = 0.05), *t*(3.73, *p* = 0.009, *d* = 0.84), with a large effect size. Recognition of newly learned faces did not produce less variability (*M* = 0.74, *SEM* = 0.05) in eye movements compared to unknown faces, *t*(26) = 1.13, *p* = 0.267 (Figure 3.4).

Lies: (Irrelevants and Probes). A trend in the data suggest task instruction manipulation had a medium sized effect on eye movement variability, *F*(2, 50) = 2.73, *p* = 0.075, $\eta p2$ = 0.10. Exploratory t-tests indicated that mean variability was lower for lies about personally known faces (*M* = 0.65, *SEM* = 0.05) than for correct rejection of unknown faces (*M* = 0.79, *SEM* = 0.05), *t*(26) = 2.23, *p* = 0.035, *d* = 0.57, with a medium effect size. Mean variability was also lower during lies about newly learned faces (*M* = 0.70, *SEM* = 0.04) than unknown faces, *t*(26) = 2.54, *p* = 0.017, *d* = 0.41, also with an effect size approaching medium (Figure 2.4).

Truths and Lies (Targets and Probes). There were no main effects of task instruction, *F*(1, 25) = 0.16, *p* = 0.691, $\eta p2$ = 0.01, or face type, *F*(1, 25) = 4.10, *p* = 0.05, $\eta p2$ = 0.14, nor an interaction between the two, *F*(1, 25) = 1.91, *p* = 0.179, $\eta p2$ = 0.07 (Figure 3.4).

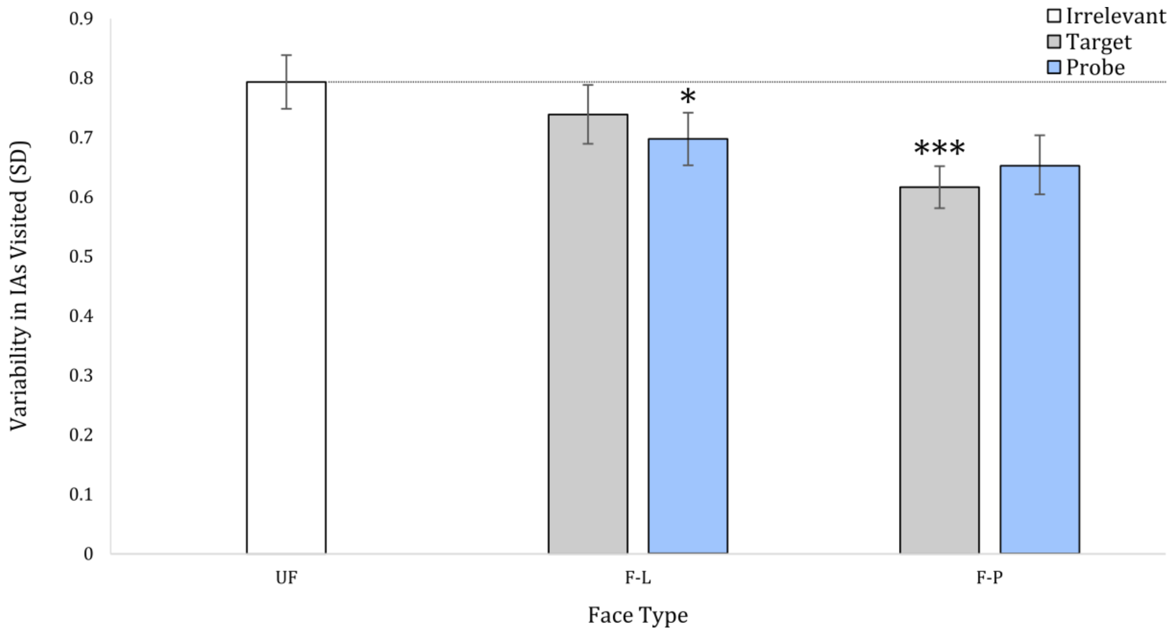


Figure 3. 4. RM ANOVAs for variability in eye movements during inspection of the confidence scale (*d.f.* = 26 in each case with Bonferroni adjustments for multiple paired sample t-tests (α=0.017)). The y-axis shows data for unfamiliar faces (UF), newly learned faces (F-L), and personally familiar (F-P) faces. In each graph, the unfamiliar (UF) irrelevants (white bars) are the comparison point for all truth (grey) and lie data (blue). $p < 0.01$**, $p < 0.05$*.

3.3.4. Fixation Quantity (face recognition task)

Truths: (Irrelevants and Targets).

There were significant, large effects of task instruction manipulation on all four measures: Num. Fixations, $F(1.54, 38.37) = 17.03$, $p < 0.001$, $\eta p2 = 0.41$, Run Count, $F(2,50) = 29.99$, $p < 0.001$, $\eta p2 = 0.55$, IAs Visited, $F(2,50) = 23.18$, $p < 0.001$, $\eta p2 = 0.48$, Prop. Fixations Inner, $F(2,50) = 8.12$, $p = 0.001$, $\eta p2 = 0.25$ (see Figure 3.5).

Newly Learned. There was no significant difference on any of the four measures during recognition of newly learned faces compared to irrelevants; Num. Fixations, $t(26) = 1.66$, $p = 0.108$, $d = 0.21$, Run Count, $t(26) = 0.88$, $p = 0.387$, $d =$

0.11, IAs Visited, $t(26)=0.27$, $p = 0.79$, $d = 0.03$, Prop. Fixations Inner, $t(26)=1.30$, $p = 0.206$, $d = 0.26$.

Personally known. There was a reduction in fixation quantity on all four measures during recognition of personally known probes compared to irrelevants; Num. Fixations, $t(26) = 4.74$, $p < 0.001$, $d = 0.88$, Run Count, $t(26) = 5.62$, $p < 0.001$, $d = 1.05$, IAs Visited, $t(26)=5.23$, $p < 0.001$, $d = 1.01$, Prop. Fixations Inner, $t(26)=3.39$, $p = 0.002$, $d = 0.62$. Effect sizes were large overall, with the exception of a medium sized effect for Prop. Inner.

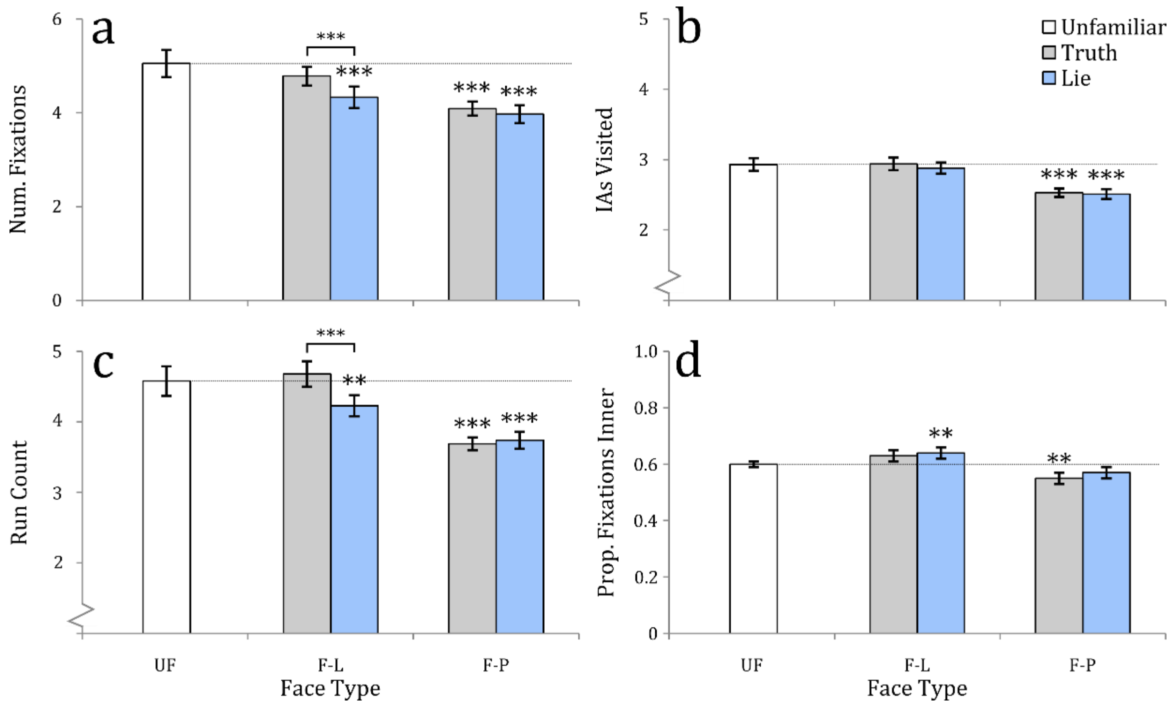


Figure 3. 5. RM ANOVAs for fixation measures, Num. Fixations, Run Count, IAs Visited, Prop. Fixations Inner (*d.f.* = 26 in each case, no effect of condition order), with Bonferroni adjustments for multiple paired sample t-tests (α=0.017). The y-axis shows data for unfamiliar faces (UF), newly learned faces (F-L), and personally familiar (F-P) faces. In each graph, the unfamiliar (UF) irrelevants (white bars) are the comparison point for all truth (grey) and lie data (blue). p<0.001***, p<0.01**. Error bars represent M±SEM.

Lies: (Irrelevants and Probes).

Significant effects of task instruction manipulation were found in all eye four measures; Num. Fixations, $F(2,50) = 25.55$, $p < 0.001$, $\eta p2 = 0.51$, Run Count, $F(2,50) = 18.90$, $p < 0.001$, $\eta p2 = 0.43$, IAs Visited, $F(2,50) = 17.82$, $p < 0.001$, $\eta p2 = 0.42$ and Prop. Fixations Inner, $F(1.49,37.26) = 7.32$, $p = 0.004$, $\eta p2 = 0.23$. Effect sizes varied. Largest effects were found for Num. Fixations and smallest for Prop. Inner (see Figure 3.5).

Personally known. There were large, significant decrease in fixation quantity during recognition of personally familiar faces also during lie trials: Num. Fixations, $t(26) = 6.37$, $p < 0.001$, $d = 0.85$ and Run Count, $t(26) = 5.80$, $p < 0.001$, $d = 0.93$, IAs Visited, $t(26) = 5.31$, $p < 0.001$, $d = 1.03$. Medium sized effects of memory were also found in the measure Proportion Fixations Inner, $t(26) = 1.93$, $p = 0.065$, $d = 0.41$, but this did not meet criteria for typical levels of significance ($p < 0.05$) despite effect size calculations that approached a moderate effect size.

Newly learned. There were significant differences in two of the fixation measures; Num. Fixations, $t(26)$ 4.43, $p < 0.001$, $d = 0.53$, and Run Counts, $t(26) = 2.72$, $p = 0.011$, $d = 0.36$ were significantly fewer during recognition of newly learned faces. Significant differences were found for Prop. Inner, $t(26) = 2.88$, $p = 0.008$, $d = 0.48$ but in the direction opposite to predicted. A larger proportion of fixations were directed to the inner face regions when lying about newly learned faces compared to telling the truth about unknown faces. There was no significant difference for IAs Visited, $t(26) = 0.85$, $p = 0.402$, $d = 0.12$. Effect size was largest for Num. Fixations (medium).

Truths and Lies (Targets and Probes)

The interaction between task instruction (2 levels: truth, lie) x 2 face type (2 levels: Familiar-Learned, Familiar-Personal) revealed significant differences in Num. Fixations, $F(1,26) = 7.30$, $p = 0.012$, $\eta p2 = 0.22$, and Run Counts, $F(1,26) = 9.60$, $p = 0.005$, $\eta p2 = 0.27$ (see Figure 3.5).

Participants made less fixations, $t(26) = 4.03$, $p < 0.001$, $d = 0.41$, and less runs, $t(26) = 3.77$, $p = 0.001$, $d = 0.53$ during concealed recognition of newly learned faces, compared to honest, revealed recognition. No such effects were present in comparisons of concealed and revealed recognition of personally known faces in either Num. Fixations, $t(26) = 0.90$, $p = 0.376$, $d = 0.13$, or Run Count, $t(26) = 0.50$, $p = 0.623$, $d = 0.10$.

3.3.5. Fixation Duration

Separate RM ANOVAs were performed on the fixation data for (1) The First Three Fixations and (2) The Last 1500 ms. Within subjects factors for the first three fixations were Task Instruction (3 levels: Truth-Irrelevant, Truth-Target, Lie-Probe) x Fixation (3 levels: First, Second, Third). Within subjects factors for the last 1500 ms were Task Instruction (3 levels: Truth-Irrelevant, Truth-Target, Lie-Probe) and Time Bin (-1500, -1000, -500) (see Figure 3.6).

First three fixations

Newly learned. Analyses revealed no main effect of Task Instruction condition, $F(2,52) = 0.42$, $p = 0.657$, $\eta p2 = 0.02$, a significant main effect of Fixation, $F(2,52) = 17.28$, $p < 0.001$, $\eta p2 = 0.40$), but no interaction, $F(2.27,59.10) = 2.26$, $p = 0.107$, $\eta p2 = 0.08$). The main effect of fixation revealed that fixation two was longer than both fixation one, $t(26) = 6.94$, $p < 0.001$, $d = 1.34$, and fixation three, $t(26) = 2.66$, $p = 0.013$, $d = 0.55$, suggesting most cognitive processing occurred in the second fixation.

Personally known. Analyses revealed a main effect of task instruction, $F(2,52) = 3.20$, $p = 0.049$, $\eta p2 = 0.11$, a main effect of Fixation, $F(2.52) = 20.35$, $p < 0.001$, $\eta p2 = 0.44$), but no interaction, $F(3.43,89.19) = 1.22$, $p = 0.307$, $\eta p2 = 0.05$). Significantly shorter fixations on Irrelevants than on Probes, $t(26) = 2.58$, $p = 0.016$, $d = 0.41$, suggest that response intentions were more effortful for lies than truth. There were no significant differences between Irrelevants and Targets, $t(26) = 0.74$, $p = 0.467$, $d = 0.16$). The main effect of fixation revealed that fixation two was longer than both fixation one, $t(26) = 6.78$, $p < 0.001$, $d = 1.50$ and fixations three, $t(26) = 2.77$, $p = 0.010$, $d = 0.47$.

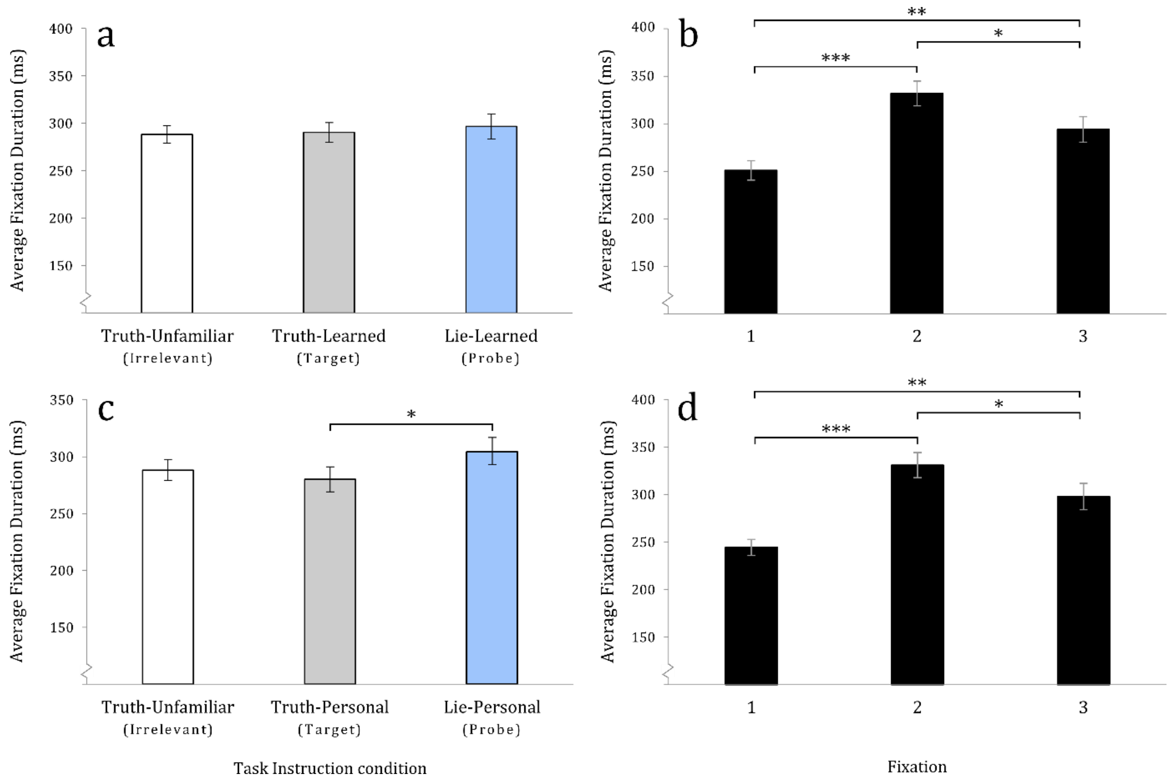


Figure 3. 6. Fixation duration data are presented for honest responses to familiar targets (Truth) and concealed recognition of familiar probes (Lie). Both Truth and Lie conditions are compared to the unknown irrelevant items (Truth-Unfamiliar). Fixation durations are presented according to task instruction condition (Truth-Unfamiliar, Truth-Familiar, Lie-Familiar) (a) for newly learned faces and (c) personally known faces. Figures (b) and (d) illustrate fixation durations each of the first three fixations individually, collapsed across task instruction conditions. Bonferroni Correction, α 0.017. Error bars represent M±SEM.

Last 1500 ms before response.

RM ANOVAs with two independent within subjects factors were entered for analyses: Task Instruction condition (3 levels: Truth-Irrelevant, Truth-Target, Lie-Probe) x Time Bin (3 levels: -1500, -1000, -500) (see Figure 3.7).

Newly learned faces.

Analyses performed on the data for newly learned faces revealed main effects of task instruction, $F(1.53,39.84) = 25.18$, $p < 0.001$, $\eta p2 = 0.49$, and time bin,

$F(1.54,39.93) = 42.47$, $p < 0.001$, $\eta p2 = 0.62$), but no interaction, $F(2.85,74.19) = 2.11$, $p = 0.109$, $\eta p2 = 0.08$).

The main effect of task instruction revealed longer fixation durations during truthful recognition of newly *learned* targets, $t(26) = 8.16$, $p < 0.001$, $d = 1.48$) compared to *unfamiliar* irrelevants. Lies about newly learned faces also produced significantly longer fixations compared to unfamiliar irrelevants, $t(26) = 5.44$, $p < 0.001$, $d = 1.14$. There was no difference in fixation duration during recognition of newly learned faces between truths about familiar targets and lies about familiar probes, $t(26) = 0.79$, $p = 0.439$, $d = 0.13$). The data suggest a recognition effect between targets and irrelevants, but no further cognitive load effect of response intention between truths and lies for this lesser known face type.

Personally known faces.

Analyses performed on the data for personally known faces also revealed a main effect of task instruction, $F(2,52) = 18.61$, $p < 0.001$, $\eta p2 = 0.42$, a main effect of time bin, $F(1.38,35.81) = 44.33$, $p < 0.001$, $\eta p2 = 0.63$), but no interaction, $F(2,50) = 1.52$, $p = 0.201$, $\eta p2 = 0.06$).

Similar to the truth data, fixation durations were significantly longer in duration during recognition of personally known targets compared to unfamiliar irrelevants, $t(26) = 3.65$, $p = 0.001$, $d = 0.86$). There was also a trend to suggest that fixation durations were longer when lying about recognition of personally known probes compared to telling the truth about recognition of personally known targets, $t(26) = 2.16$, $p = 0.040$ $d = 0.42$). The data suggest that increased fixation durations indicate effects of recognition and response intention separately contribute to changes in fixation duration during recognition of personally known faces.

Significant main effects of time bin (3 levels; -1500, -1000, -500) on fixation duration were observed for newly learned, $F(1.54,39.93) = 42.47$, $p < 0.001$, $\eta p2 = 0.62$), personally known faces, $F(1.37,35.81) = 44.33$, $p < 0.001$, $\eta p2 = 0.63$). Fixation durations increased in each 500 ms time bin prior to the familiarity judgement (Time bin 1; -1500>-1000, Time bin 2; -1000>-500, Time bin 3; -500>0). For newly learned faces, AFD significantly increased from the first to the second time bin, $t(26) = 8.06$, $p < 0.001$, $d = 0.94$, and again from the penultimate to the last time bin prior to the familiarity judgement, $t(26) = 2.90$, $p = 0.008$, $d = 0.36$. The same pattern of results emerged in the time bins for personally known faces, $t(26) = 6.20$, $p < 0.001$, $d = 0.99$, and $t(26) = 4.80$, $p < 0.001$, $d = 0.44$ respectively.

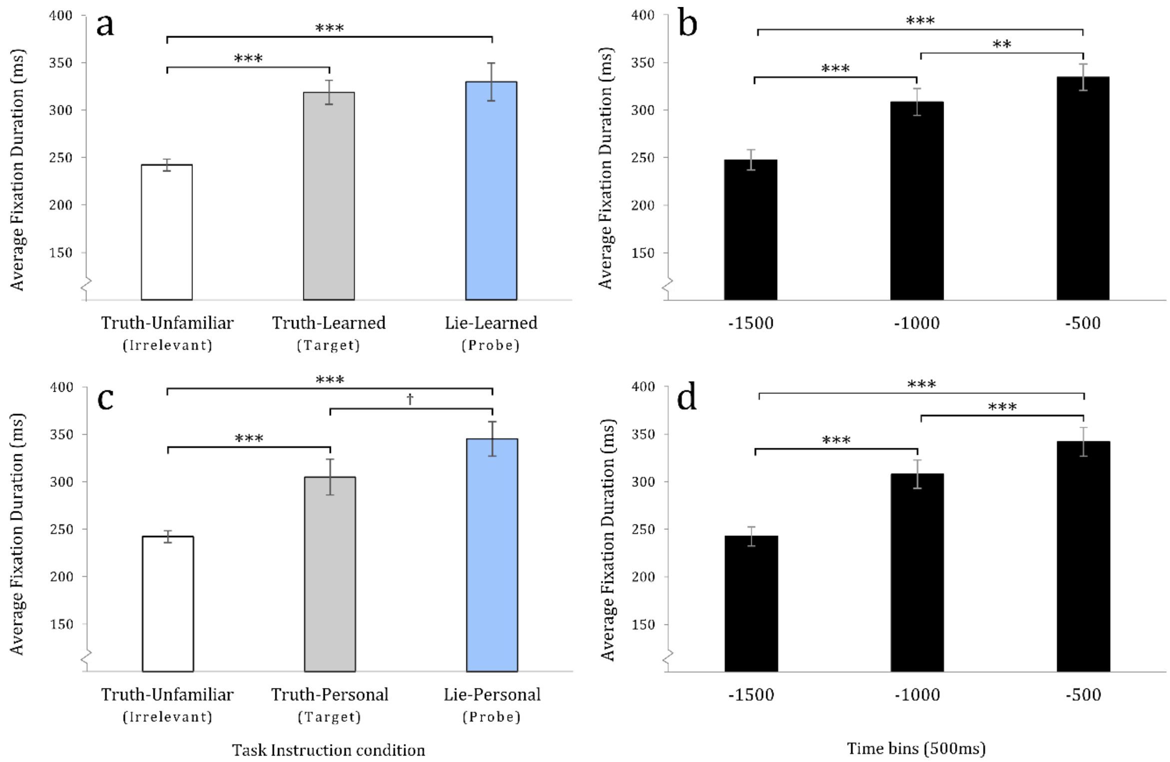


Figure 3. 7. Fixation duration data are presented for the last 1500 ms before recognition response (500 ms time bins) for each task instruction condition (Truth-Unfamiliar, Truth-Familiar, Lie-Familiar) (a) for newly learned faces and (c) personally known faces. Figures (b) and (d) illustrate fixation durations each 500 ms time bin individually in the last 1500 ms before the recognition response (collapsed across task instruction conditions). Bonferroni corrections for three multiple comparisons (α = 0.017), p<0.001***, p<0.017*. Error bars represent M±SEM.

3.3.6. Deception Strategies Questionnaire

Confidence reporting.

The majority of liars (70%) specifically reported using a high confidence strategy when concealing recognition of known faces, six reported that they tried to vary their confidence ratings and two simply reported trying to do the same during both revealed and concealed recognition.

Mean confidence ratings were high for all stimuli for all conditions; irrelevants, *M* = 91.95 (10.14), newly learned targets, *M* = 93.58 (7.78), newly learned probes, *M* = 92.36 (9.57), personally known targets, *M* = 96.18 (7.61) and personally known probes, *M* = 94.16 (1.46). RM ANOVAs performed on the mean verbal confidence judgements did not reveal significant differences between task instruction conditions for irrelevants and targets, $F(2,50) = 2.88$, $p = 0.066$, $\eta p2$ = 0.10, or irrelevants and probes, F(2,50) = 2.27, $p = 0.114$, $\eta p2$ = 0.08.

Face viewing strategies. Out of 27 participants, three reported trying to look more at the face when lying, six reported trying to look less and the remainder reported trying to maintain similar eye movement behaviour during concealed and revealed recognition trials. Strategy reported during deception (Look more, N = 3; Look less, N = 6, Look the same, N = 18) was entered as a between subjects factor for the analyses for Num. of Fixations and Run Count to explore if eye movement behaviour was explained by the explicit strategy adopted.

There was no between subjects effect of strategy on number of fixations, $F(2,24) = 1.30$, $p = 0.294$, $\eta p2$ = 0.10, no interaction with task instruction condition (2 levels: conceal recognition, reveal recognition), $F(2,24) = 0.23$, $p = 0.796$, $\eta p2$ = 0.02, and no interaction with face type (2 levels: newly learned, personally known), $F(2,24) = 0.39$, $p = 0.68$, $\eta p2$ =0.03. The data consistently revealed that less fixations were made during concealed recognition trials irrespective of reported strategy (Look less; truth, *M* = 4.81 (0.68), lie, *M* = 4.39 (0.76), look more; truth, *M* = 3.88 (0.68), lie, *M* = 3.39 (0.26); maintain same, truth, *M* = 4.93 (1.126), lie, *M* = 4.46 (1.38).

There was also no effect of strategy on run counts, $F(2,24) = 0.28$, $p = 0.760$, $\eta p2$ = 0.02, no interaction with task instruction (2 levels: conceal recognition, reveal recognition), $F(2,24) = 0.03$, $p = 0.971$, $\eta p2 = 0.00$, and no interaction with face type, $F(2,24) = 0.08$, $p = 0.928$, $\eta p2 = 0.01$. The data consistently revealed that less runs were made during concealed recognition trials irrespective of reported strategy (gaze aversion; truth, M= 4.74 (1.03), lie, M = 4.35 (0.60), deliberate gaze; truth, M= 4.27 (0.77), lie, M = 4.13(0.12); maintain same, truth, M = 4.73 (0.94), lie, M = 4.21 (0.91).

Face most difficult to lie about. Participants were also asked which group of faces posed most effort for concealed recognition; newly learned or personally known. The majority (70%) of participants reported finding it hardest to conceal recognition of personally known faces. The overall consensus was that recognition was stronger and more automatic for personally known faces, making concealment a more conflicting process. Participants also reported that the 'lie' seemed more real for persons whom they knew and interacted with in real life. The remaining participants reported that concealed recognition of newly learned faces was hardest. For example, one participant reported that more cognitive effort was required to actively recall memories of newly learned faces and that this effort was further increased by remembering which face to conceal recognition and correctly execution the appropriate response.

3.3.7. Discussion

Experiment 2 aimed to assess the impact of emphasising cognitive awareness of meta-memory and eye movement monitoring on fixation behaviour during recognition-based and confidence judgements. The experiment was novel and exploratory in two aspects: (1) No other published work has explicitly explored how liars might manipulate confidence reports based on lies about person recognition. (2) No deception based research has explored whether emphasising eye movement monitoring during recognition of known persons might interfere with memory effects in eye movement behaviour. The experiment also was a replication of the evaluation of the effect of lying on eye-movement behaviour in Experiment 1.

Confidence judgements

Predictions that liars would exhibit less variation in confidence ratings (0-100%) when lying about a known face compared to an unknown face were supported by the data. Confidence judgements based on lies about personally known faces clearly displayed less variation than the patterns of confidence to correct rejection of unknown faces. There was a similar but not quite significant trend for the same pattern of responses for newly-learned faces. No significant differences were found in verbal confidence ratings when comparing identification of known target faces compared to unknown, irrelevant faces.

The data suggest that patterns of verbal confidence ratings might present a novel way to identify concealed memory of well-known faces when individuals explicitly deny recognition of them. Interestingly, the Deception Strategy Questionnaire revealed that 70% of participants explicitly reported using a high confidence strategy to appear convincing when lying about recognition (six reported that they tried to vary their confidence ratings and two simply reported trying to do the same during truths and lies). The present data suggests that participants were utilising a simplistic strategy to appear convincing, typical of real-world liars (DePaulo et al., 1997; Tetterton, 2005) and that they did not or could not calibrate their confidence ratings to represent the variations in confidence displayed when correctly rejecting unknown faces. The present finding is a novel addition to existing research that has explored distributions or patterns in responses over multiple tests rather than single response data only (Morgan, Rabinowitz, Leidy, & Coric, 2014; Shaw, Vrij, Mann, Leal, & Hillman, 2014).

The eye movement data also showed less variability in the mean number of areas on the confidence scale viewed when lying about recognition-based memory confidence. Less variability in fixation behaviour was observed in confidence ratings for personally known and newly learned faces, both with moderate effect sizes. Additionally, less variability in eye movement behaviour was also evident when participants revealed recognition of personally known faces compared to unknown irrelevants. This finding is the first to report differences in eye movement behaviour associated with manipulated confidence judgements during concealed person recognition.

Replication of results of Experiment 1

Consistent with predictions about the effect of recognition, there were fewer fixations, fewer interest areas visited, fewer runs and less time spent fixating inner features when participants lied about recognising *personally known faces* compared to unknown faces. The same pattern of results emerged when comparing honest recognition of personally known faces to rejection of unknown faces. Effect sizes were large for both *irrelevant-target* and *irrelevant-probe* differences in all but one fixation measure; the proportion of fixations made to the inner region of the face (moderate effect size). The results were consistent with the fixation data from Experiment 1, which also found large *irrelevant-target* and *irrelevant-probe* differences in all but one fixation measure, the exception also being the proportion of fixations made to inner face regions. Overall, the results suggest that recognition of personally known faces produces large effects of memory of fixation behaviour that can be used to identify memory for well-known faces in spite of cognitive efforts required to suppress truthful responses (Experiment 1 and 2) and attempts to control eye movement behaviour as reported in the present experiment (Experiment 2).

Although, overall effect sizes were numerically smaller for irrelevant-probe comparison during lies, compared to the equivalent irrelevant-target comparisons for truths, personally known faces produced large and consistent effects of memory in multiple eye movement behaviours potentially making it a robust method for memory detection. The results support that memory changes the nature of visual processing as reflected in fixation behaviour, that these effects are most robust for well-known faces (Althoff et al., 1999; Althoff & Cohen, 1999; Althoff, 1998; Hannula et al., 2010; Heisz & Shore, 2008), and that fixation behaviour can be used to reveal recognition when individuals deny recognition of known faces (Schwedes & Wentura, 2012). Experiments 1 and 2 extend the work of Schwedes & Wentura (2012) by demonstrating that fixation behaviour reveals recognition despite intentional efforts to control eye movements to evade detection.

Experiment 1 and 2, however, highlight caution in the use of proportion of fixations to the inner regions of the face as a measure of memory detection. This fixation measure produced smaller effect sizes that appeared vulnerable to change between truths and lie conditions. These changes were also inconsistent in Experiments 1 and 2 (probe numerically smaller than target in Experiment 1, but larger than probe in Experiment 2). Although the increase in the proportion of fixations during concealed recognition of the personally familiar probe impacted the Irrelevant-Probe difference such that the *p* value was no longer significant, the proportion was still smaller than the irrelevant with a medium effect size. A possible explanation might be that the conditions of Experiment 2 produced an increase in load that resulted in increased fixation behaviour (Cook, Hacker, Webb, Osher, Kristjansson, Woltz, Kircher, et al., 2012; Zenzi M Griffin & Oppenheimer, 2006) and that the measure proportion of fixations was more vulnerable to this change than the other fixation measures. In support of this assertion, the *Deception Strategies Questionnaire* revealed that 70% of participants reported finding it hardest to conceal recognition of a personally known face. A number of participants explicitly stated that cognitive difficultly during concealed recognition of personally known faces was due to the automatic nature of recognition for these well-known faces and the conflict in rejecting them as familiar as they had real-world significance. The data suggest that the proportions of inner fixations may be a less stable measure for memory detection (albeit an important region for information extraction during face recognition in general; Clutterbuck & Johnston, 2002) than the other eye movement measures recorded.

The finding that the proportion of fixations was more vulnerable to differences in task demands is not consistent with Althoff and Cohen (1999) who found that the proportion of fixations directed to inner face regions was a consistent measure of memory. This was true whether the task was recognition-based (famous, not famous), emotion-based (happy, not-happy) or whether participants were instructed to engage in specific eye movement strategies (e.g., move eyes across the face from left to right, starting at the top and finishing at the bottom). The difference in the present data may be a consequence of cognitive difficulties that are specific to lying about recognising a person known in the real-world as reported in the *Deception Strategies Questionnaire.* (Althoff & Cohen's research used famous celebrity faces). As in experiment 1, the data suggest that proportion of fixations made to the inner face regions are not a reliable measure for memory detection.

The findings for newly learned faces were partly consistent with predictions. Significant less fixations and run counts were recorded during concealed recognition of newly learned faces compared to unknown faces, with moderate and small effects sizes. This result is initially encouraging given that differences in fixation behaviour for newly learned faces compared to unknown faces in Experiment 1 only revealed a small effect size difference between newly learned probes and unknown irrelevants in one fixation measure, number of fixations. At first look, the clear distinction between newly learned probes and irrelevants in the present experiment may be attributed to the more intensive learn-to-criterion procedure used in the study phase for face learning. The interpretation becomes more complicated, however, when we observe that there are no significant differences between newly learned targets and unknown irrelevant, to both of which participants both responded honestly. This pattern is the opposite to that found in Experiment 1 where significant decreases were observed in multiple fixation measures during revealed recognition of newly learned faces compared to correct rejection of unknown faces. It appears that some other executive processing demands are interfering with the pattern of results as observed in Experiment 1.

One possible explanation is that participants' efforts to exert control over their eye movements and to continuously monitor memory during recognition and confidence judgements produced a cognitive carry-over effect that emerged during recognition of newly learned faces during honest trials. The data suggest clear differences in mental efforts and attempted control between truth and lie trials, observed in significant target-probe differences.

The Deception Strategy Questionnaire Reports revealed that, out of 27 participants, 22 participants (81%) reported attempting to employ a strategy to maintain similar responding in both truth and lie trials. Two reported trying to look less when lying (gaze aversion) and three reported trying to look more (deliberate gaze). The questionnaire data suggest the modified instruction brief that emphasised and incentivised the monitoring and control of eye movements to evade detection was effective. Approximately a third of participants in Experiment 1 reported attempting to employ an eye movement strategy, whereas all participants in Experiment 2 reported attempts to control eye movements. The lie data seem to support that participants were trying to manipulate fixation patterns during concealed recognition. Although additional analyses revealed no differences in the fixation according to reported strategies the data suggest the attempts of the majority to maintain similar eye movement behaviour in both truth and lie trials resulted in the opposite effect of that intended, and served to further augment the difference between probes and irrelevants (Wegner et al., 1998). For example, if participants believed that liars hesitate (taking longer to respond and generating more eye movement behaviour) they might try to reduce this behaviour in comparison to genuine *unfamiliar* responses made to actual unknown faces. In a bid to maintain similar behaviour they might over compensate whilst failing to realise that reprocessing effects for familiar faces already result in reductions in sampling behaviour compared to unknown irrelevant items. However, as the number of participants for each strategy was small future research should directly examine the effect of specific strategies on fixations with equal numbers of each strategy to draw more confident conclusions on the effect of specific strategies on fixation patterns.

The fact that significant reductions in the number of fixations are present only in the data for newly learned faces, and not for personally known faces, is likely a consequence of the nature of familiarity and recollection as defined by Yonelinas' (2002) dual process model of memory. According to this model, active recollection of less familiar faces is a slower, more conscious process, requiring more cognitive effort in terms of working memory. It may be that this more conscious experience (as opposed to fast, automatic recognition of highly familiar faces) may render eye movements more vulnerable to intentional control in relation to strategies. And that the intention of maintaining similar patterns of eye movement behaviour resulted, ironically, in the augmentation of the reprocessing effect during concealed recognition of newly learned faces.

Finally, an explanation why this augmenting effect appeared in the data for fixation count are likely due to the measure being a more global measure of memory and, as such, may be more susceptible to general strategies such as *look less* (Rayner, 1998). The measure run count is closely linked to fixation count and thus it is not surprising that a reduction in run count would follow a decrease in mean number of fixations made. The idea that some eye movement measures might be more vulnerable to strategic control than others is suggested in two particular eye movement studies (Althoff & Cohen, 1999; Cook et al., 2012).

Althoff and Cohen (1999) revealed that some measures (i.e., number of fixations) were more sensitive to intentional eye movement strategies chosen to mimic pattern of eye movement similar to those engaged during viewing of unfamiliar faces. Although the effects of memory were no longer present in some eye movements (number fixations, number of regions, first return fixations) during intentional strategies, the reprocessing effect was still intact for one particular eye movement measure (proportion internal) when viewing famous faces. The proposition that average fixation duration might be an obligatory and possibly involuntary measure of recognition memory is particularly supported by the work of Ryan and colleagues (Ryan et al., 2007) who found a recognition effect for fixation duration within the first fixation, and often irrespective of changes in task demands. This lack of conscious control (perhaps particular to fixation duration) suggests the potential for eye movements to objectively measure memory during revealed and concealed recognition.

The first three fixations revealed very little about processes of recognition and response intention for the different task instruction conditions. Only one significant result emerged for the three different task instruction conditions; an increase in AFD when comparing truths (targets) and lies (probes) to personally known faces suggested an effect of response intentions that was higher for concealed recognition.

Collapsing task instruction conditions, we find that average fixation durations are longest during the second fixation, suggesting that information processing is most active in the second fixation (reflecting a combination of efforts for both recognition and response intentions). This present data is partially consistent with Experiment 1, which found an effect of response intention (but not recognition) in the second fixation, and previous research (Schwedes & Wentura, 2012), which found an effect of recognition (but not response intention) in the second fixation. The data highlight that changes in task demands in different experimental designs and procedures impact fixation durations in subtle ways. Future research might benefit from analysing the data in more finite time bins to better dissociate processes of recognition and response intentions.

Consistent with predictions, comparisons of eye movements for irrelevants and targets revealed recognition effects for both newly learned and personally known faces in the 1500 ms prior to the execution of recognition response. A comparison of eye movements for targets and probes revealed a significant effect of cognitive load for personally known faces but not for newly learned faces. Because the recollection of less familiar faces is more likely to be a more involved and conscious process, it may be that cognitive effort was already high such that the additional effect of lying were not significantly detected. The relative difference in effort between fast and automatic recognition of well-known faces, and the concealment of these likely required a greater increase in cognitive effort and thus a larger difference in fixation durations compared to that for newly learned faces.

A main effect of time bin also indicated that AFD significantly increased in each 500 ms time bin in the 1500 ms preceding the familiarity response, when task instruction conditions were collapsed for in turn newly learned and personally familiar faces. In the present data there was no clear interaction between task instruction and time bin, and this we did not observed the steep increase in AFD from irrelevants to targets to probes as we observed in Experiment One. The fact that participants were made aware that they might want to control eye movements when lying likely activated high load working memory demands from the onset. In contrast, in Experiment 1 participants were not so conscious of the monitoring component of the task and thus an increase in fixation duration (cognitive load) required for concealed recognition did not appear until directly before a manual button response was required action planning.

In conclusion, the data suggest that monitoring both confidence choices and behaviour during the ratings has the potential to distinguish deceitful from honest patterns of confidence in relation to person recognition. Further research might develop more sophisticated ways of tapping into cognitive processing via monitoring of associated eye movements during deliberation of confidence reports.

The data also further supports the potential usefulness of eye movements for identifying memory for well-known (personally familiar) faces even in the face of high cognitive demands when lying. Multiple eye movement measures indicate reprocessing effects for personally known faces that are robust irrespective of the differences in cognitive demands between revealed and concealed recognition. The eye movement records highlight, however, that at least one measure (proportion of fixations inner) might be particularly vulnerable to cognitive interference during lies, resulting in diminished reprocessing effects during concealed recognition. In the present experiment, increases in proportion of fixations were observed during concealed recognition of both newly learned and personally know faces. This resulted in no significant reprocessing effect that distinguished between unknown and known faces. The indication that proportion of fixations directed to inner regions of the face may be sensitive to changes in load is also consistent with Experiment 1 that found a compromised reprocessing effect (smaller effect size) for concealed recognition of newly learned faces (as a result of increased eye movement behaviour perhaps due to load). Although the inner regions of the face are particularly sensitive to intricacies in face processing and recognition (and thus highly informative to experts that wish to learn more about the subtleties of face perception), they made not be the most reliable eye movement measure for the identification of reprocessing effects as means of memory detection.

CHAPTER 4.

The effect of deception on fixation-based memory effects during concealed recognition of objects and scenes.

4.1. Introduction

Extending Experiment 1 and 2, which examined whether memory effects were observed during concealed recognition of faces, Experiment 3 also explored the effect of deception on fixation-based memory effects. The aim of Experiment 3 was to establish whether markers of recognition in eye moments during recognition of objects and scenes might also expose concealed recognition, as was found for face recognition in Experiments 1 and 2.

The identification of objects connected to a crime (such as a weapon or stolen bank card), or knowledge of a particular crime scene, is just as important as detecting knowledge of persons linked to that crime. Memory detection researchers have successfully identified concealed recognition of photographs of objects that were encountered during mock crime scenarios via autonomic based measures of arousal such as increased skin conductance responses (e.g., Ambach, Stark, Peper, & Vaitl, 2008) and incremental discriminative ability for crime objects using combined SCR and ERP-P300's (Ambach et al., 2010). Furthermore, research that combined SCR and ERP has observed that SCR were larger for central crime details, whereas the P300 was stable for both central and peripheral crime details (Gamer & Berti, 2012). Recent research has also explored fixation behaviour as a potential indicator of memory for concealed recognition of objects other than faces with varying success (Peth et al., 2013; Twyman, Moffitt, Burgoon, & Marchak, 2010).

The present experiment explores whether memory effects found in fixation patterns for familiar faces that varied in familiarity, might also be found for objects and scenes that also vary in depth of encoding. The assumption that humans possess specialist skills for recognising familiar faces (Farah, Wilson, Drain, & Tanaka, 1998; Farah, 1996; Robbins & McKone, 2007) might suggest less consistent memory reprocessing effects during recognition of familiar object and scenes compared to faces. Indeed, elements that comprise whole objects and scenes tend to be more variable than for faces, which have common components, such as the eyes, nose, mouth, ears etc. Although the processing of faces and more general objects are not necessarily processed in a qualitatively different manner, face features are thought to be recognised in a more holistic fashion (Burton, Jenkins, & Schweinberger, 2011; Farah, Levinson, & Klein, 1995; Farah et al., 1998; Farah, 1996; Hancock et al., 2000; Tanaka & Farah, 1993) that also might rely more heavily on local spatial relations known as configurations (Leder & Bruce, 2000; Helmut Leder & Carbon, 2006; Young, Hellawell, & Hay, 1987), whereas non-face object tend to be recognised using part-based representations.

Despite alleged differences in processing of faces compared to objects in general, consistent memory reprocessing effects have been documented in eye movements during viewing of familiar and non-familiar buildings by Althoff and colleagues as well as for faces. Consistent with changes in viewing behaviour for familiar faces, participants made fewer fixations to fewer regions and with less constrained (more random) viewing to photographs of familiar buildings (own campus buildings) than to unfamiliar buildings (unknown campus); (Althoff, 1998; Althoff et al., 1999). It is interesting, however, that in Althoff and colleagues (1998,

1999) studies the mean number of fixations made before recognition of familiar buildings were fewer than for recognition of famous faces, which is consistent with the idea that we are better and faster at face recognition than for other objects. Nevertheless, the difference in number of fixations when viewing familiar and unfamiliar items was significant for both famous versus non-famous faces and personally familiar buildings versus unfamiliar buildings. Research that explored eye movements during viewing of scenes also observed a decrease in sampling of previously viewed scenes compared to those that were novel (Ryan, Althoff, Whitlow, & Cohen, 2000; Ryan, Hannula, & Cohen, 2007). Taken together, the findings presented in these elementary eye movement studies suggest that eye movement reprocessing effects observed for faces are generalisable to non-face stimuli.

In more applied research, two deception-based studies (Peth et al., 2013; Twyman et al., 2010) explored fixation-based markers of memory during concealed recognition of familiar objects following a mock crime scenario. Twyman et al. (2010) recorded number of fixations to crime critical photographs of objects as part of an enacted mock crime (e.g., a *key* was removed from a *cup* on a desk that was used to open a *cash box from* which a *ring* was taken. During the crime a *cordless phone* also rang). The results, however, revealed that only the cup received fewer fixations when viewed by guilty participants compared to innocents and, even then, effect size calculations were small. The authors suggest these findings were a possible consequence of probe saliency, such that the guilty participant had more exposure time to the cup as it was visible on the desk during the full course of the crime. This is a plausible explanation given that the effect of memory on eye movements for previously unfamiliar faces scales with amount of exposure (at least three exposures to produce a robust effect of memory; Althoff et al., 1999; Heisz & Shore, 2008). Experiment 1 in the present thesis also showed that recognition of faces after only one brief exposure produced the weakest (but observable) memory effects than more familiar faces. The authors also remark that their lack of significant results may be a consequence of viewing patterns for objects being more variable than that for faces (which all share the same general features). It is perhaps more informative to note that the photographs of each object presented in Twyman et al.'s (2010) study were markedly different in size. For example, the proportion of space taken by the ring or key in the photographic images presented at test were quite noticeably smaller than that of the cup. The lack of results, therefore, may present more of a methodological issue in the preparation of stimulus materials as opposed to an issue with detecting recognition of objects in general. Furthermore, because the researchers only measured number of fixations, it is possible the effect of lying diminished memory effects for less salient objects as was observed in the Experiments 1 and 2 in the current thesis.

More recent research has successfully documented memory effects in participants' fixations when viewing photographs of objects that they previously experienced as part of a mock crime scenario that had taken part in. Peth and colleagues (2013) measured number of fixations and fixation durations to ten photographs of crime critical objects that were incidentally encoded by guilty participants during an enacted mock crime. The ten objects were classified by the experimenters as either central or peripheral to the crime dependent on whether guilty participants physically handled them during the crime (central) or if there were only located close by (peripheral). Consistent with memory effects in eye movement behaviour, the fixation data revealed fewer fixations of longer durations when guilty participants viewed crime critical objects that were central to the crime (handled) but not for objects that were only peripheral to the crime. The results of Peth et al. (2013) suggest a lack of sensitivity of fixations to reveal memory for items for which strength of encoding is weaker. This is somewhat consistent with the experiments presented in the current thesis where results for visually exposed or newly learned faces were less evident in number of fixation and fixation durations.

In a design similar to Experiment 2, Experiment 3 examines fixation behaviours during concealed recognition of objects and the effect of familiarity (newly learned versus personally known) on a larger range of fixation measures than previously studied. The present experiment also explores the effect of memory on fixation behaviours during concealed recognition of whole scenes. Twyman et al. (2010) and Peth et al (2013) explored memory effects in fixations during concealed recognition of objects from a mock crime scene, but concealed recognition of whole scenes are as yet unexplored. The present research also takes a closer look at the impact of deception on memory effects using three different time course analyses: (1) the full trial period, the first three fixations, the last 1500 ms. The main aim of the study was to determine whether fixations exposed concealed recognition of objects and scenes that varied in familiarity.

Based on the extant literature, the main predictions were that memory effects would be observed in fewer fixations (number of fixations, run counts, interest areas viewed, proportion of fixations inner) and longer fixation durations during viewing of familiar objects (Peth et al., 2013) and scenes (Althoff et al., 1999; Ryan et al., 2007). Also consistent with previous research, we predicted that memory effects would be strongest and most reliable for more familiar objects and scenes (personally familiar) compared to those that were less richly encoded (learned-to-criterion during a study phase before test) (see Althoff, 1998; Peth et al., 2013; Ryan et al., 2007).

4.2. Method

4.2.1. Participants

38 undergraduate students (36 females, 2 males) from The University of Portsmouth participated in the experiment. Participant ages ranged from 19 to 27 years (M = 20.31, SD = 1.59). All participants had normal or normal-to-corrected vision. All participants received £5 remuneration for taking part.

4.2.2. Design

In a within subjects design, participants were instructed to lie and tell the truth about recognising different types of familiar objects. Each participant completed one block of practice trials followed by two lying blocks (lie about newly learned photographs, lie about personally known photographs). In each block participants viewed 30 single photographs of objects and scenes, with equal numbers of unfamiliar, newly learned and personally familiar photographs. In the two different lying blocks participants were instructed to lie about a specific group of familiar photographs whilst telling the truth about all other photographs. In one block, participants were instructed to lie when presented with photographs of newly learned objects and scenes, whilst telling the truth about personally familiar and unfamiliar photographs (irrelevants). In the other block, participants were instructed to lie about recognition of personally familiar photographs whilst telling the truth about photographs that were newly familiar or unfamiliar (irrelevants). Because concealed recognition is specific to familiar photographs, participants were only instructed to lie in turn about recognition of photographs that were newly learned and personally known. All participants completed both lying blocks. Participants were instructed to always tell the truth about unfamiliar photographs (control). The eye movement data from viewing of unfamiliar photographs served as a baseline to identify different patterns of viewing behaviour during recognition from familiar targets (honest responses to familiar photographs) and probes (lies about recognition of familiar photographs). The design, therefore, represents a nested within subjects design wherein veracity (truth, lie) is nested within newly learned and personally familiar objects and scenes.

4.2.3. Apparatus and Materials

A total of 90 colour photographs of scenes and objects were presented to each participant over 3 blocks of trials. Each set of 30 photographs were unique to each block of trials. In each block of 30 trials, there were 10 unfamiliar photographs, 10 newly learned photographs and 10 personally known photographs. Personally known photographs were specific to The University of Portsmouth Psychology students (who were participants in this experiment) and comprised Portsmouth City Guildhall, entrance to psychology department, entrance to student Union, entrance to university library, coursework submission point, university logo, log-in to electronic resources webpage, coursework submission cover sheet, university hoodie, student ID card. The first five items represented scenes, whereas the last five more generally represented objects, all of which would be immediately recognisable to participants. For consistency, the photographs for irrelevant and newly learned categories followed the same structure (e.g, photographs of libraries and sweatshirts from other universities). All images were taken with a SONY Cybershot camera specifically for the purpose of the experiment. Photographs were re-sized to 640 x 480 pixels and presented on a blue background (HEX: #5DBCD2) using Adobe Photoshop CS5.1.

4.2.4. Procedure

The procedure was the same as Experiment 2, except that 30 photographs were presented in each block of trials (10 unfamiliar, 10 newly learned, 10 personally known).

Prior to each study block, participants completed a study phase where they learned-to-criterion 10 photographs of previously unfamiliar objects and scenes (matched to personally familiar items). Participants were first shown 10 unfamiliar photographs of objects and scenes and asked to view them until they had committed them to memory. The experimenter than placed a name label (e.g. *Ellerman library)* next to the appropriate photograph and participants were then instructed to learn the correct label for each photograph. The photographs and name labels were then shuffled and given to the participant for matching. The participant had to match all photograph and labels 100% correct, twice consecutively to satisfy the learn-to-criterion

In each test block, each set of 30 photographs were presented randomly on the Eyelink II display monitor (SR Research, Ontario, Canada) using a sequential presentation. Participants made dichotomous button press responses to familiar and unfamiliar photographs of objects and scenes at the same time as verbalising their response selection (e.g., *familiar*). Participants made a confidence rating (0-100%) after each scene/object identification by pressing any button on the selection pad whilst vocalising their chosen confidence rating *(e.g., fifty)*. Confidence ratings were chosen from a scale presented on the display screen that range from 0-100% in numerators of ten. For an illustration of the sequence display see Figure 4.1 below). The button assigned to a familiar responses was counterbalanced so that approximately half pressed the left button for a familiar response (N = 17). 30 participants were right handed and 5 left handed. Condition blocks were counterbalanced and all trials fully randomised.

The Eyelink II (SR Research, Ontario, Canada) recorded retinal and corneal reflections induced by an infrared source at a frequency of 250Hz (Pupil-CR mode, N = 34) and 500Hz (Pupil only, N = 1) to obtain participants points of fixation on the screen (error of resolution: 0.5°-1.0°). The Pupil only mode was used when Pupil-CR modes could not be successfully tracked. 17 participants' eye movements were tracked using their left eye and 18 with the right eye. The degree of visual angle was 11.06.

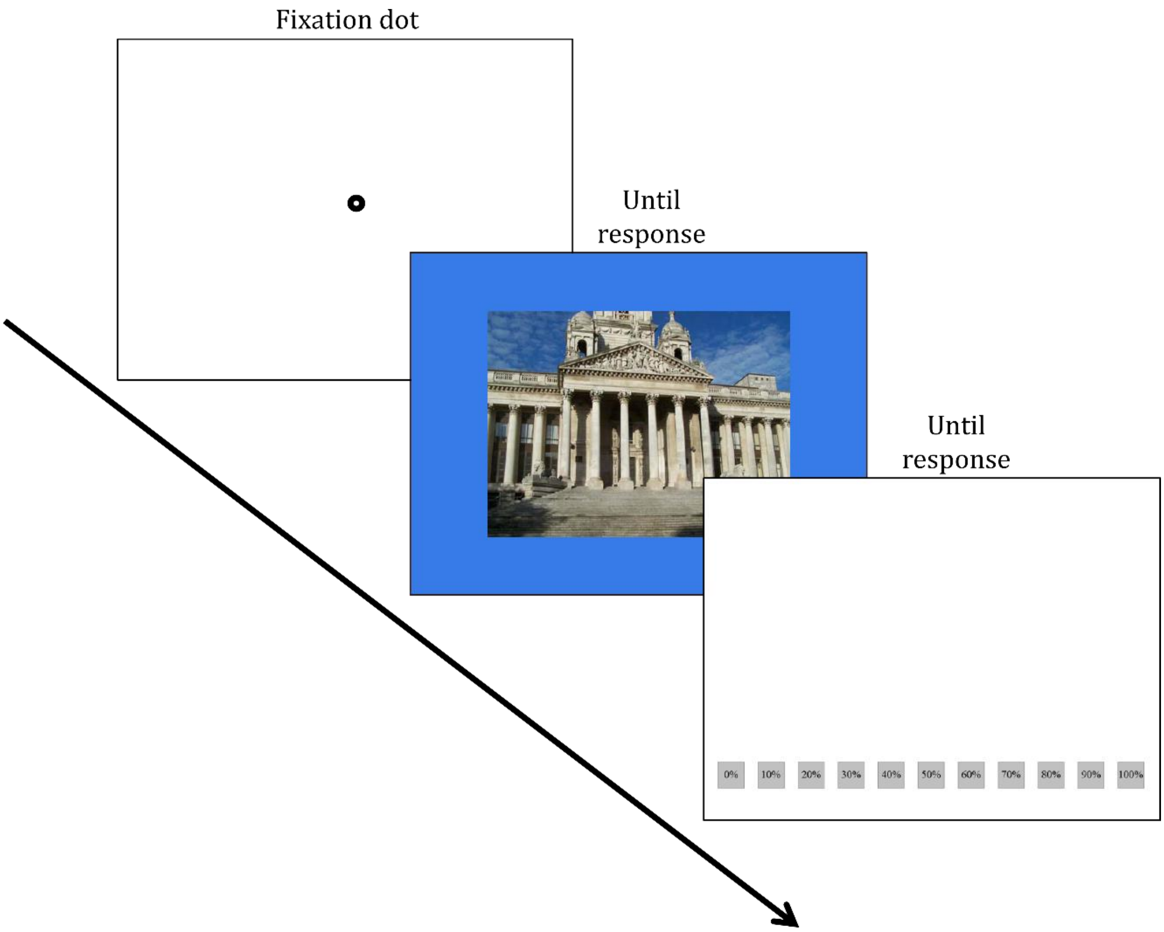


Figure 4. 1. Display sequence of for each trial.

4.2.5. Data preparation: Defining a-Priori Interest Areas (IAs)

Objects and Scenes: Using a method consistent with previous research on visual processing of scenes and objects (e.g., Smith & Squire, 2008), a fixed 4 x 4 grid was applied to each photograph to create 16 equally sized interest areas. The central 4 sections of the grid (top left, top right, bottom left, bottom right) formed the inner 4 inner regions of the photograph. The 12 remaining sections that surrounded the inner regions were grouped and merged to create one outer region.

Each image therefore presented 5 interest areas for analyses, consistent with the defining of interest areas for faces in Experiments 1 and 2 (see Figure 4.2a).

Confidence Screens: As in Experiment 2, interest areas on the confidence screens were defined by marking a box around each confidence option (0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100%) to created 11 interest areas: This allowed calculation of the number of interest areas (IAs) fixated on viewed during deliberation of each confidence rating (see Figure 4.2b).

Figure 4. 2. Illustration the defining of interest areas applied to (a) scenes and objects, and (b) the interest areas defined for analyses of viewing during confidence judgements.

4.2.6. Dependent Measures and Analysis Strategy

As in Experiments 1 and 2, the dependent measures were number of fixation, run counts, number of interest areas visited, and proportion of fixations to the inner region of the image (as defined in figure 4.2). Fixation durations were also analysed for the first three fixations and the last 1500 ms before response selections (500 ms time bins).

Also the same as Experiments 1 and 2, RM ANOVAS were first performed on irrelevant and truth data with one within subjects factor (3 levels: tell the truth about irrelevants, tell the truth about newly learned targets, and tell the truth about personally known targets). RM ANOVAs performed on irrelevant and probe data also had one within subjects factor (3 levels: tell the truth about irrelevants, lie about newly learned probes, lie about personally familiar probes). To explore interactions between familiar targets and familiar probes a 2 x Task Instruction (2 levels: truth, lie) by 2 x (Familiarity: newly learned, personally familiar) was performed.

Further analyses were performed on Fixation Durations for the first three fixations with 2 within subjects factors, Task instruction (2 levels: tell the truth about irrelevants, tell the truth about targets and lie about probes) and Fixation (3 levels: first, second, third).

Analyses were also performed on Fixation Durations for the last three time bins before the response with 2 within subjects factors, (2 levels: tell the truth about irrelevants, tell the truth about targets and lie about probes), and Time Bin (3 levels: -1500, -1000, -500).

4.3. Results

4.3.1. Exclusion Criteria

Data was analysed for 35 (33 females, 2 males) participants. Three of the original 35 participants (all female) were removed from the data due to technical difficulties that resulted in loss of data and failure to complete all trial blocks. As in

Experiment 1, individual trials were also removed from the analyses if the participant responded incorrectly to the face or presented outliers in the reaction time data (less than 300 ms or more than 5000 ms).

Error rates were low across all trials: Familiar-Learned (truths, 10%, lies, 1.14%) Familiar-Personal (truths 1.14%, lies 2.57%) and unknown faces (truths 7.04%). This left 2028 trials out of the original 2100. Similar to previous research (Greenwald, Nosek, & Banaji, 2003; Verschuere, Spruyt, Meijer, & Otgaar, 2011) outliers in the reaction time data were removed if they were faster or slower than specific set thresholds (acceptable range for present data, <300 ms or >5000 ms). This removed a further 174 trials (8.29%) leaving a total of 1858 trials out of the original 2100.

4.3.2. Fixation Quantity

Truth trials (Irrelevants and Targets)

Omnibus Repeated Measures ANOVAs were performed on truth trials with three independent levels of task instruction; tell the truth about unfamiliar irrelevants, tell the truth about newly learned targets, and tell the truth about personally known targets. Analyses revealed a main effect of task instruction for all four eye movement parameters; Number of Fixations, $F(2,66) = 46.29$, $p < 0.001$, $\eta_p^2 = 0.58$, Run Counts, $F(2,66) = 15.52$, $p < 0.001$, $\eta_p^2 = 0.32$, IAs Visited, $F(2,66) = 4.84$, $p = 0.011$, $\eta_p^2 = 0.13$, Proportion Inner, $F(1.57,51.93) = 18.72$, $p < 0.001$, $\eta_p^2 = 0.36$ (see Figure 4.3). There was no effect of the order in which lying blocks were presented for any of the four measures; Number of Fixations, $F(1,33) = 0.08$, p = 0.775, η_p^2 = 0.003, Run Counts, $F(1,33) = 0.30$, p = 0.591, η_p^2 = 0.01, IAs Visited, $F(1,33) = 0.24$, p = 0.629, η_p^2 = 0.01, Proportion Inner, $F(1,33) = 0.44$, p = 0.511, η_p^2 = 0.01.

Irrelevants and Newly Learned Targets. There were no significant differences in fixation measures when participants revealed recognition of newly learned targets compared to unknown irrelevants on any of the four fixation quantity measures, Number of Fixations, $t(34) = -0.25$, $p = 0.806$, $d = -0.03$, Run Counts, t(34) = -0.60, $p = 0.552$, $d = -0.09$, IAs Visited, $t(34) = 0.15$, $p = 0.884$, $d = 0.03$, Proportion Inner, $t(34) = -1.74$, $p = 0.091$, $d = -0.03$.

Irrelevants and Personally Known Targets. When participants revealed recognition of personally known targets they made significantly less fixations compared to unknown irrelevants for three out of four parameters, Number of fixations, $t(34) = 8.37$, $p < 0.001$, $d = 1.26$, Run Counts, $t(34) = 4.84$, $p < 0.001$, d = 0.79, IAs Visited, $t(34) = 3.36$, $p = 0.002$, $d = 0.51$. Contrary to predictions, proportion of fixations inner were significantly higher when viewing personally familiar targets compared to irrelevants, $t(34) = 5.84$, $p < 0.001$, $d = 0.99$.

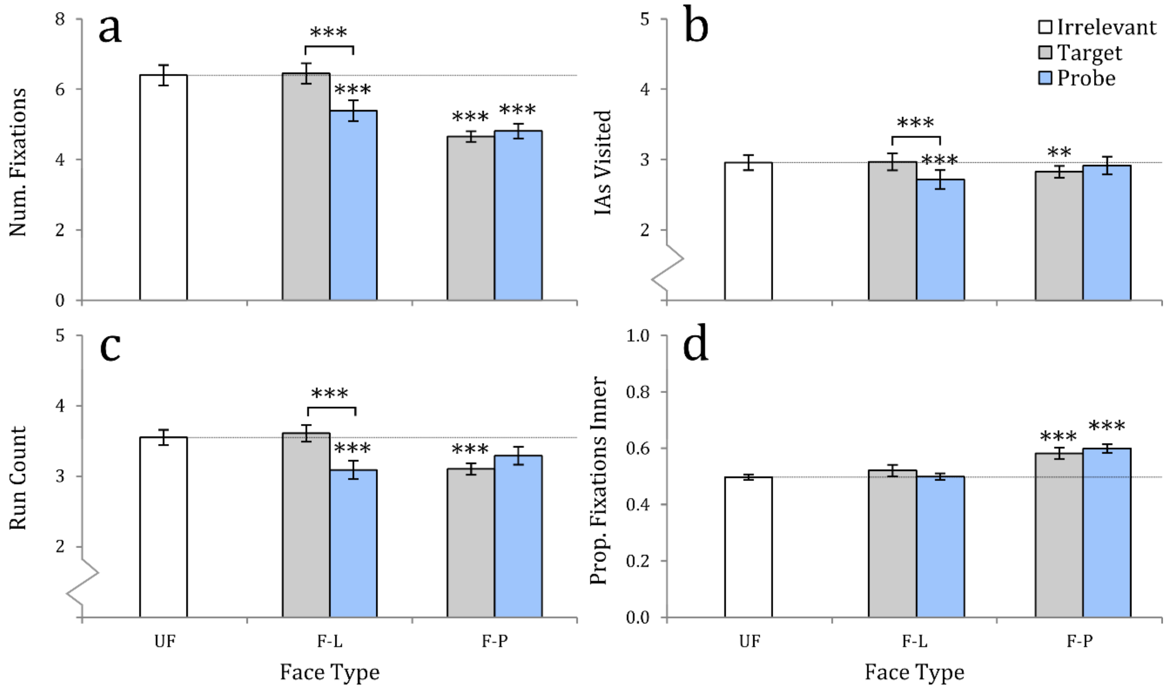


Figure 4. 3. RM ANOVAs for measures of fixation quantity; Num. Fixations, Run Counts, IAs Visited, Proportion Fixations Inner (*d.f.* = 34 in each case, no effect of condition order), with Bonferroni adjustments for multiple paired sample t-tests (α=0.017). The y-axis shows data for objects and scenes for three categories of familiarity, Unfamiliar (UF), Familiar-Learned (F-L), Familiar-Personal. In each graph, the unfamiliar irrelevants (UF) data (white bar) are the comparison point for all truth targets (grey) and lie probes (blue). P<0.001***, p<0.01**. Error bars represent M±SEM.

Lies trials (Irrelevants and Probes)

Omnibus Repeated Measures ANOVAs were also performed on lie trials with three independent levels of task instruction; tell the truth about unfamiliar irrelevants, lie about newly learned targets, lie about personally known targets. The order in which the lying condition blocks were administered was also entered as a between subject factor (2 levels: lie about learned faces first, lie about personally known faces first). Analyses revealed a main effect of task instruction for all four eye movement parameters; Number of Fixations, $F(2,66) = 46.29$, $p < 0.001$, $\eta_p^2 = 0.58$, Run Counts, $F(2,66) = 10.53$, $p < 0.001$, $\eta_p^2 = 0.24$, IAs Visited, $F(2,66) = 9.95$, $p = < 0.001$, $\eta_p^2 = 0.23$, Proportion Inner, $F(2,66) = 29.41$, $p < 0.001$, $\eta_p^2 = 0.47$ (see

Figure 4.3). There was no effect of the order in which lying blocks were presented, Number of Fixations, F(1,33) = 0.50, p = 0.483, η_p^2 = 0.02, Run Counts, F(1,33) = 1.10, p = 0.302, η_p^2 = 0.03, IAs Visited, F(1,33) = 1.70, p = 0.201, η_p^2 = 0.05, Proportion Inner, F(1,33) = 0.03, p = 0.862, η_p^2 = 0.001 (see also Figure 4.3).

Irrelevants and Personally Known Probes. When participants concealed recognition of personally known probes they made significantly less fixations compared to unknown irrelevants in only one eye movement measures, Number of fixations, t(34) = 7.67, p < 0.001, d = 1.05. Run Counts, t(34) = 2.32, p < 0.026, d = 0.37 and IAs Visited, t(34) = 0.89, p = 0.381, d = 0.17 were not significantly reduced when comparing irrelevants and personally known probes. Although the Run Count data show a trend for reduced fixations with a small effect size this does not meet significance after Bonferroni corrections for three multiple comparisons. Also contrary to predictions, proportion of fixations inner were significantly higher when viewing personally familiar targets compared to irrelevants, t(34) = -6.12, p < 0.001, d = -1.26.

Irrelevants and Newly Learned Probes. When participants concealed recognition of newly learned probes they made significantly less fixations compared to unknown irrelevants in three out of four eye movement measures, Number of Fixations, t(34) = 5.23, p < 0.001, d = 1.05, Run Counts, t(34) = 4.14, p < 0.001, d = 0.37, IAs Visited, t(34) = 5.08, p < 0.001, d = 0.86. There was no significant difference in the proportion of fixation made to the inner regions between Irrelevants and newly learned probes, t(34) = 0.27, p = 0.790, d = 0.05.

Targets and Probes. Repeated Measures ANOVAS with the factors Task Instruction (2 levels: truth, lie) and Familiarity (2 levels: Newly Learned, Personally Known) were performed on the dependent measures Number of Fixations, Run Counts, IAs Visited, Proportion Inner (see also Figure 4.3).

Analyses of Number of fixations revealed a main effect of Task Instruction, $F(1,33) = 22.52$, $p < 0.001$, $\eta_p^2 = 0.41$, a main effect of Familiarity, $F(1,33) = 48.18$, $p < 0.001$, $\eta_p^2 = 0.60$ and a significant interaction between Task Instruction and Familiarity, $F(1,33) = 46.31$, $p < 0.001$, $\eta_p^2 = 0.58$. The main effect of Task Instruction revealed that fewer fixations were made during lie trials ($M = 5.10$, $SEM = 0.24$, SD = 1.40) than truth trials ($M = 5.56$, $SEM = 0.21$), $t(34) = 4.50$, $p < 0.001$, . The main effect of Familiarity revealed that fewer fixations were made during viewing of personally familiar objects and scenes ($M = 4.74$, $SEM = 0.17$) than those that were newly learned ($M = 5.92$, $SEM = 0.28$), $t(34) = 7.14$, $p < 0.001$, $d = 0.86$. The interaction between Task Instruction and Familiarity revealed that fewer fixations were made when lying ($M = 5.39$, $SEM = 0.29$) about recognition of newly learned objects and scenes compared to truthful trials ($M = 6.45$, $SEM = 0.29$), $t(34) = 7.24$, $p < 0.001$, $d = 0.62$. There was no significant different between lie trials ($M = 4.81$, $SEM = 0.21$) and truth ($M = 4.66$, $SEM = 0.15$) for personally familiar objects and scenes, $t(34) = 1.24$, $p = 0.224$, $d = 0.14$.

Analyses of Run Counts revealed a main effect of Task Instruction, $F(1,33) = 4.97$, $p = 0.033$, $\eta_p^2 = 0.13$ with fewer Run Counts during lie trials ($M = 3.19$, $SEM = 0.12$) than truth trials ($M = 3.36$, $SEM = 0.09$). There was no significant effect of familiarity, $F(1,33) = 4.00$, $p = 0.054$, $\eta_p^2 = 0.11$. A significant interaction between

Task Instruction and Familiarity, $F(1,33) = 43.75$, $p < 0.001$, $\eta_p^2 = 0.29$, revealed that Run Counts were fewer during lies about newly learned objects and scenes (M = 3.09, SEM = 0.13) than truth trials (M = 3.61, SEM = 0.12), $t(34) = 5.58$, $p < 0.001$, d = 0.70. There was no significant difference between lie trials (M = 3.29, SEM = 0.13) and truth trials (M = 3.11, SEM = 0.08) when viewing personally familiar objects and scenes, $t(34) = 1.81$, $p = 0.079$, $d = 0.30$.

Analyses of IAs Visited revealed no main effect of Task Instruction, $F(1,33)$ = 2.59, $p = 0.117$, $\eta_p^2 = 0.07$, or Familiarity, $F(1,33) = 0.51$, $p = 0.482$, $\eta_p^2 = 0.02$. However, a significant interaction between Task Instruction and Familiarity, $F(1,33)$ = 15.30, $p < 0.001$, $\eta_p^2 = 0.32$, revealed that the fewer interest areas of newly learned scenes and objects were viewed during lie trials (M = 2.70, SEM = 0.05) than truth trials (M = 2.95, SEM = 0.06). There was no significant difference in the number of interest areas viewed of personally familiar objects and scenes between lies (M = 2.89, SEM = 0.07) and truths (M = 2.81, SEM = 0.05).

Analyses of Proportion of Fixations Inner revealed no main effect of Task Instruction, $F(1,33) = 0.02$, $p = 0.89$, $\eta_p^2 = 0.00$. There was, however a main effect of Familiarity, $F(1,33) = 51.66$, $p < 0.001$, $\eta_p^2 = 0.61$ that a smaller proportion of fixations were made to the inner areas of objects and scenes when viewing newly learned objects and scenes (M = 50.48, SEM = 0.90) than those that were personally familiar (M = 58.37, SEM = 1.31). The was no significant interaction between Task Instruction and Familiarity, $F(1,33)$ =2.96, $p = 0.095$, $\eta_p^2 = 0.08$.

In sum, significant interactions between task instructions and familiarity reveal that liars tend to reduce their viewing behaviour when they lie about recognising newly learned objects and scenes. This reduction in viewing behaviour emerged in the number of fixations, run counts and number of interest areas visited. Interestingly, no such reduction in viewing was observed during lies about personally familiar objects and scenes. The data suggest that liars might be trying to control or reduce fixation behaviour to evade lie detection. It is possible that the effect of attempted control is more evident when viewing newly learned objects and scenes that require more effortful recollection. Whereas recognition of more familiar objects and scenes are likely more automatic in nature and thus fixations might be less vulnerable to attempted control.

4.3.3. Fixation Durations

First three fixations

Newly learned objects and scenes. A Repeated Measures ANOVA performed on fixation durations with the factors Task Instruction (3 levels: tell the truth about unknown irrelevants, tell the truth about newly learned targets, lie about newly learned probes) and Fixation (3 levels: first, second, and third) revealed a main effect of Task Instruction, $F(2,68) = 5.26$, $p = 0.007$, $\eta_p^2 = 0.13$, a main effect of Fixation, $F(1.61,54.94) = 70.92$, $p < 0.001$, $\eta_p^2 = 0.68$, and a significant interaction between Task Instruction and Fixation, $F(2.5,85.03) = 3.12$, $p = 0.039$, $\eta_p^2 = 0.08$ (Figure 4.4).

The main effect of task instruction revealed that, over the first three fixations, fixations durations were longer when lying about recognition of newly learned probes (M = 261.49, SEM = 6.55) than unknown irrelevants (M = 238.32, SEM = 4.40), $t(34) = 3.84$, $p = 0.001$, $d = 0.70$. Fixation durations did not significantly differ when comparing honest identification of newly learned targets (M = 249.06, SEM = 7.45) to unknown irrelevants (M = 238.32, SEM = 4.40), $t(34) = 1.56$, $p = 0.13$, $d = 0.41$). Honest identification of newly learned targets (M = 249.06, SEM = 7.45) also did not differ in fixation duration to lies about newly familiar probes (M = 261.49, SEM = 6.55), $t(34) = 1.50$, $p = 0.144$, $d = 0.30$.

The main effect of fixation revealed that fixation durations did not differ from the first to the second fixations, $t(34) = 1.64$, $p = 0.11$, $d = 0.31$. Fixation durations did significantly increase, however, from the second to the third fixations, $t(34) = 9.00$, $p < 0.001$, $d = 1.65$. The third fixation was also longer than the first, $t(34) = 9.43$, $p < 0.001$, $d = 1.98$.

Investigation of the interaction between Task Instruction and Fixation revealed that there were no significant differences in fixation duration in the first fixation between irrelevants and targets, $t(34) = 0.89$, $p = 0.382$, $d = 0.12$, irrelevants and probes, $t(34) = 0.71$, $p = 0.480$, $d = 0.14$, or targets and probes, $t(34) = 1.36$, $p = 0.182$, $d = 0.24$. In the second fixation, there were also no significant differences in fixation durations between irrelevants and targets, $t(34) = 0.37$, $p = 0.71$, $d = 0.06$. There was, however, a trend in the data to suggest that fixation durations were longer when lying about newly learned probes compared to irrelevants, $t(34) = 2.62$, $p = 0.013$, $d = 0.44$. Fixation durations were not significantly different when comparing honest identification of newly learned targets to lies about recognising newly learned probes, $t(34) = 0.85$, $p = 0.400$, $d = 0.32$. In the third fixation, there was a trend in the data towards longer fixation durations during recognition of newly familiar targets compared to irrelevants, $t(34) = 2.04$, $p = 0.049$, $d = 0.43$. Also in the third fixation, fixation durations to probes were significantly longer than to irrelevants, $t(34) = 3.55$, $p = 0.001$, $d = 0.75$. There was no significant difference in fixation durations between targets and probes, $t(34) = 0.85$, $p = 0.400$, $d = 0.18$.

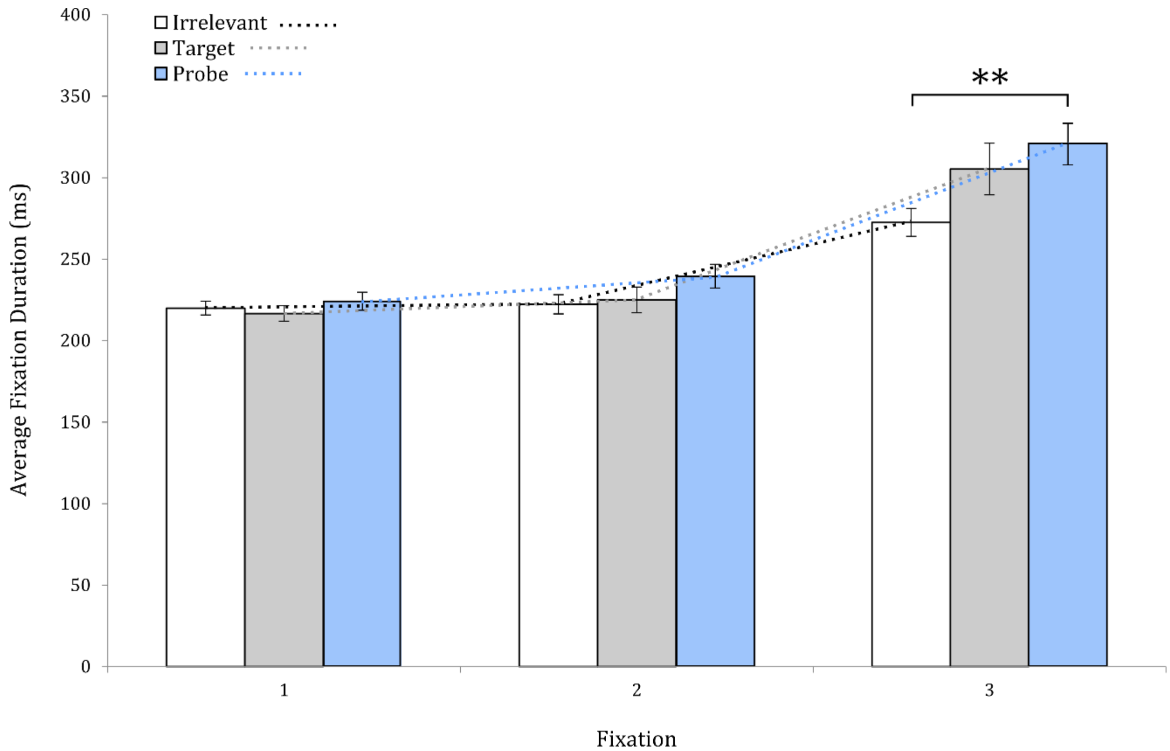


Figure 4. 4. RM ANOVAs performed on average fixation durations recorded during viewing of unfamiliar and newly familiar objects and scenes (*d.f.* = 34 in each case), with Bonferroni adjustments for nine paired samples t-tests (α=0.006). The y-axis shows data for the first three fixations individually. In each graph, the irrelevant data (white bar) are the first comparison point for all truth targets (grey) and lie probes (blue). Further t-tests were performed to compare fixation durations between targets and probes to assess if deception significantly increased fixation duration when viewing familiar faces only. P<0.001***, p<0<006**. Error bars represent M±SEM.

Personally familiar objects and scenes. A Second Repeated Measures ANOVA performed on fixation durations with the factors Task Instruction (3 levels: tell the truth about unknown irrelevants, tell the truth about personally familiar targets, lie about personally familiar probes) and Fixation (3 levels: first, second, and third) revealed a main effect of Task Instruction, $F(2,68) = 11.22$, $p < 0.001$, $\eta_p^2 = 0.25$, a main effect of Fixation, $F(1.59,54.07) = 49.57$, $p < 0.001$, $\eta_p^2 = 0.59$, and a significant interaction between Task Instruction and Fixation, $F(2.79,94.79) = 4.06$, $p = 0.011$, $\eta_p^2 = 0.11$ (Figure 4.5).

The main effect of task instruction revealed that, over the first three fixations, fixation durations were longer during honest identification of personally known targets (M = 255.97, SEM = 7.53) compared to correct rejection of unknown irrelevants (M = 238.32, SEM = 4.40), $t(34) = 2.54$, $p = 0.016$, $d = 0.48$). Fixations durations were also longer when lying about recognition of personally familiar probes (M = 279.19, SEM = 10.80) compared to unknown irrelevants (M = 238.32, SEM = 4.40), $t(34) = 4.08$, $p < 0.001$, $d = 0.84$. Trials where participants lied about recognition of personally familiar probes (M = 279.19, SEM = 10.80) also produced longer fixation durations compared to honest recognition of personally familiar targets (M = 255.97, SEM = 7.53), $t(34) = 2.66$, $p = 0.012$, $d = 0.42$.

The main effect of fixation revealed that a trend towards a significant increase in fixation durations from the first to the second fixation, $t(34) = 2.18$, p = 0.036, $d = 0.38$. Fixation durations did significantly increase, however, from the second to the third fixations, $t(34) = 6.80$, $p < 0.001$, $d = 1.28$. The third fixation was also longer than the first, $t(34) = 8.46$, $p < 0.001$, $d = 1.76$.

Paired sample t-test performed to explore the interaction between Task Instruction and Fixation revealed no significant differences in the first fixation between irrelevants and targets, $t(34) = 0.10$, $p = 0.920$, $d = 0.02$. There was, however, a trend revealing an increase in fixation duration when lying about personally familiar probes (M = 230.36, SEM = 5.69) compared to correct rejection of unfamiliar irrelevants (M = 220.03, SEM = 4.21), $t(34) = 2.06$, $p = 0.047$, $d = 0.35$. There was no significant difference in fixation duration during responses to targets and probes, $t(34) = 1.34$, $p = 0.190$, $d = 0.27$.

In the second fixation, there were also no significant differences in fixation durations between irrelevants and targets, $t(34) = 0.10$, $p = 0.277$, $d = 0.23$. There was, however, a trend in the data to suggest that fixation durations were longer when lying about personally familiar probes (M = 258.76, SEM = 14.41) compared to irrelevants, $t(34) = 2.74$, p = 0.010, $d = 0.56$. Fixation durations were not significantly different when comparing honest identification of personally familiar targets to lies about recognising personally familiar probes, $t(34) = 1.96$, $p = 0.059$, $d = 0.34$.

In the third fixation, there was a trend in the data towards longer fixation durations during recognition of personally familiar targets (M = 313.79, SEM = 14.50) compared to irrelevants (M = 272.59, SEM = 8.55), $t(34) = 2.82$, $p = 0.008$, $d = 0.59$. Also in the third fixation, fixation durations to probes (M = 348.45, SEM = 20.09) were significantly longer than to irrelevants (M = 272.59, SEM = 8.55), $t(34) = 3.52$, $p = 0.001$, $d = 0.83$. There was also a trend towards a significant difference in fixation durations between targets (M = 313.79, SEM = 14.50) and probes (M = 348.45, SEM = 20.09), $t(34) = 0.2.10$, $p = 0.044$, $d = 0.33$.

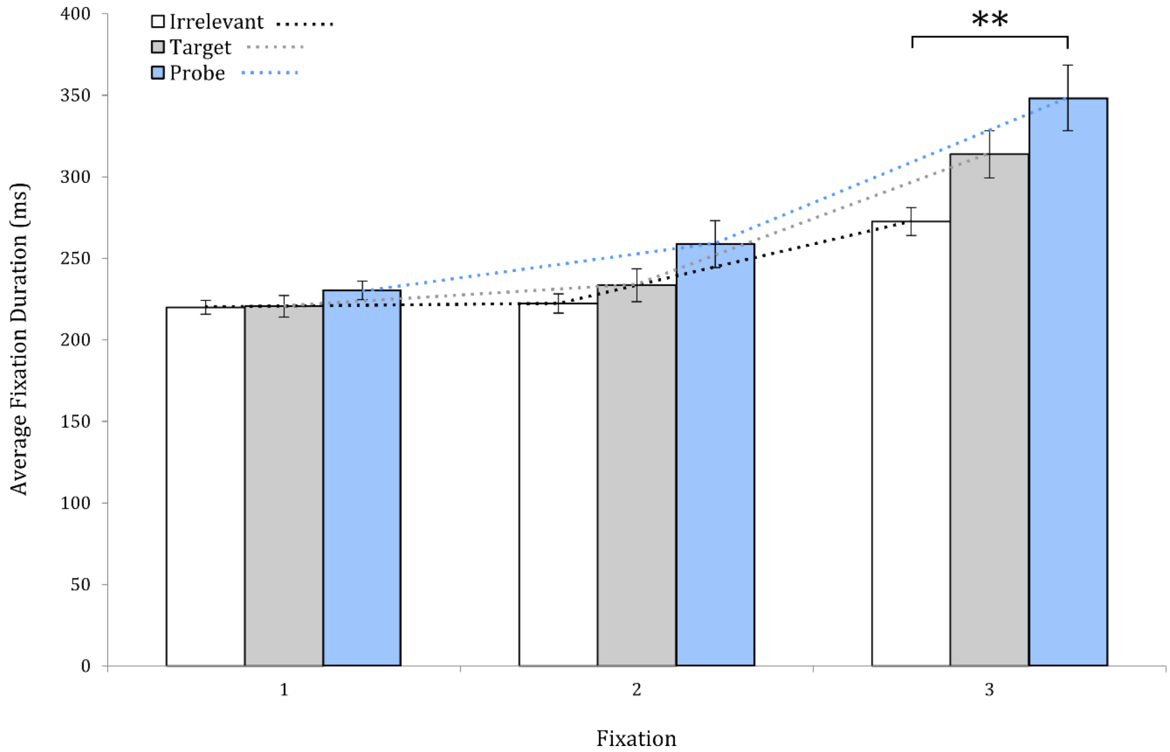


Figure 4. 5. RM ANOVAs performed on average fixation durations recorded during viewing of unfamiliar and personally familiar objects and scenes (*d.f.* = 34 in each case), with Bonferroni adjustments for nine paired samples t-tests (α=0.006). The y-axis shows data for the first three fixations individually. In each graph, the irrelevant data (white bar) are the first comparison point for all truth targets (grey) and lie probes (blue). Further t-tests were performed to compare fixation durations between targets and probes to assess if deception significantly increased fixation duration when viewing familiar faces only. P<0<006**. Error bars represent M±SEM.

In sum, longer fixation durations were observed during recognition of familiar objects and scenes in the third fixation (compared to unfamiliar irrelevants) after presentation of the test display. Results were clearest during lies about familiar objects and scenes for both newly learned and personally familiar objects and scenes. Increases in fixations observed during trials in which participants honestly identified targets, statistically speaking, only produced a trend in the data after Bonferroni corrections for multiple nine comparisons (α = 0.005). It should also be noted that a trend in the data revealed a tendency for fixations durations also to be longer in the first and second fixation during trials in which participants lied about recognition of personally familiar objects and scenes. A similar trend was observed in fixations durations when lying about newly familiar probes, but not until the second fixation.

Last 1500 ms

Newly learned familiarity. A Repeated Measures ANOVA was performed on fixation duration with the factors, Task Instruction (3 levels: tell the truth about unknown irrelevants, tell the truth about newly learned targets, lie about newly learned probes) and Time Bin (3 levels: -1500>-1000, -1000>500, and -500>0). The results revealed no main effect of Task Instruction, $F(2,68) = 1.60$, $p = 0.209$, $\eta_p^2 = 0.05$. There was, however, a main effect of Time Bin, $F(2,68) = 31.34$, $p < 0.001$, $\eta_p^2 = 0.48$, and a significant interaction between Task Instruction and Time Bin, $F(4,136) = 3.14$, $p = 0.017$, $\eta_p^2 = 0.09$ (see Figure 4.6).

The main effect of Time Bin revealed that fixation durations increased across bins as time approached response selections, [-1500 to -1000], $t(34) = 5.36$, $p < 0.001$, $d = 0.79$, [-1000 to -500], $t(34) = 3.09$, $p = 0.004$, $d = 0.59$. Fixation Duration was also longer in Time Bin -500 compared to -1500, $t(34) = 7.22$, $p < 0.001$, $d = 1.45$.

The interaction between Time Bin and Task Instruction revealed that, in the time bin farthest from the response selection [-1500 to -1000], there were no significant differences in fixation duration between irrelevants and targets, $t(34) = 0.07$, $p = 0.946$, $d = 0.01$, irrelevants and probes, $t(34) = 0.94$, $p = 0.354$, $d = 0.13$, or targets and probes, $t(34) = 0.69$, $p = 0.49$, $d = 0.13$. In the penultimate time bin before response selection [-1000 to -500] there were also no significant differences in fixation duration between irrelevants and targets, $t(34) = 0.98$, $p = 0.34$, $d = 0.17$, irrelevants and probes, $t(34) = 0.24$, $p = 0.813$, $d = 0.04$, or targets and probes, $t(34) = 0.68$, $p = 0.50$, $d = 0.11$. However, in the last 500 ms time bin before the response selection was made [-500 to 0] there was a trend in the data that indicated longer fixation durations during recognition of newly familiar targets ($M = 268.93$, SEM = 8.06) compared to unknown irrelevants ($M = 250.71$, $SEM = 5.43$), $t(34) = 2.05$, $p = 0.048$, $d = 0.45$. Fixation durations were significantly longer when lying about recognition of newly familiar probes ($M = 280.07$, $SEM = 8.45$) compared to correct rejection of unknown irrelevants ($M = 250.71$, $SEM = 5.43$), $t(34) = 0.69$, $p = 0.002$, $d = 0.70$. There was no significant difference in fixation duration between newly familiar targets and probes, $t(34) = 1.10$, $p = 0.280$, $d = 0.23$.

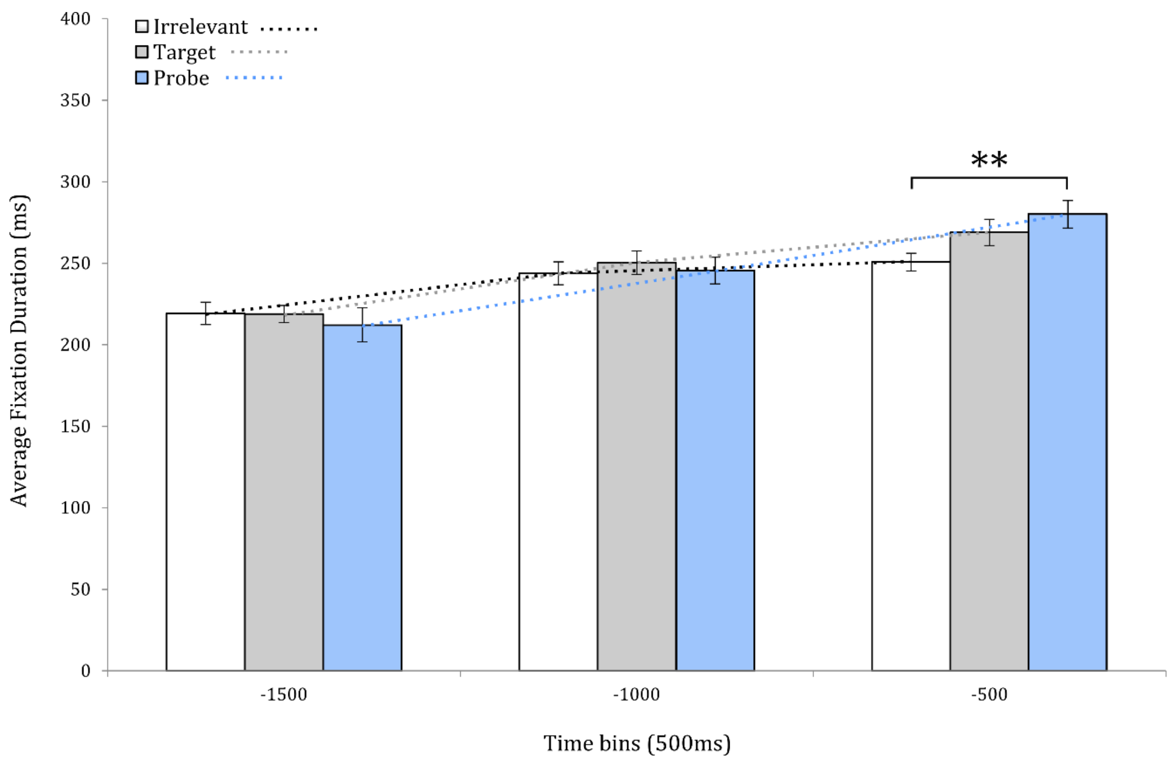


Figure 4. 6. RM ANOVAs performed on average fixation durations recorded during viewing of unfamiliar and newly familiar objects and scenes (*d.f.* = 34 in each case), with Bonferroni adjustments for nine paired samples t-tests (α=0.006). The y-axis shows data for the last three time bins (500 ms)

before a response selection; -at 1500, -1000, -500 ms. In each graph, the irrelevant data (white bar) are the first comparison point for all truth targets (grey) and lie probes (blue). Further t-tests were performed to compare fixation durations between targets and probes to assess if deception significantly increased fixation duration when viewing familiar faces only. P<0.001***, p<0.006**. Error bars represent M±SEM.

Personally known familiarity. A Repeated Measures ANOVA was performed on fixation duration with the factors, Task Instruction (3 levels: tell the truth about unknown irrelevants, tell the truth about personally known targets, lie about personally known probes) and Time Bin (3 levels: [-1500>-1000], [-1000>500], and [-500>0]). The results revealed no main effect of Task Instruction, $F(2,68) = 2.53$, p = 0.087, $\eta_p^2 = 0.07$. There was, however, a main effect of Time Bin, $F(2,68) = 49.40$, $p < 0.001$, $\eta_p^2 = 0.59$, and a significant interaction between Task Instruction and Time Bin, $F(2.96,100.70) = 10.06$, $p < 0.001$, $\eta_p^2 = 0.29$ (see Figure 4.7).

The main effect of Time Bin revealed that fixation durations increased across time bins as the time neared response selections, each time bin, [-1500 to -1000], $t(34) = 5.13$, $p < 0.001$, $d = 0.83$, [-1000 to -500], $t(34) = 5.88$, $p < 0.001$, $d = 0.98$. Fixation Duration was also longer in Time Bin -500 compared to -1500, $t(34) = 8.50$, $p < 0.001$, $d = 1.83$.

The interaction between Time Bin and Task Instruction revealed that, in the time bin farthest from the response selection [-1500 to -1000], there was an unexpected trend in the data to suggest that fixation durations were shorter during recognition of personally familiar targets (M = 197.06, SEM = 8.19) compared to unfamiliar irrelevants (M = 219.29, SEM = 6.84), $t(34) = 2.78$, $p = 0.009$, $d = 0.50$. Also contrary to predictions, there was a trend in the data that suggested fixations were shorter when participants lied about recognising personally familiar probes (M = 202.57, SEM = 9.46) compared to correct rejection of unfamiliar irrelevants (M = 219.29, SEM = 6.84), $t(34)$ = 0.2.24, p = 0.032, d = 0.34. There was no significant difference in fixation duration between targets and probes, $t(34)$ = 0.61, p = 0.544, d = 0.11. In the penultimate time bin before response selection [-1000 to -500] there was an unexpected trend in the data that suggested fixation durations were shorter when participants made honest recognition judgements to personally familiar targets (M = 225.83, SEM = 6.73) compared to unfamiliar probes (M = 243.85, SEM = 7.03), $t(34)$ = -2.58, p = 0.014, d = -0.44. Also unexpectedly, fixations were no longer in duration when participants lied about recognition of personally familiar probes compared to correct rejection of unfamiliar irrelevants, $t(34)$ = 0.41, p = 0.682, d = 0.06. However, fixation durations were longer during lies about recognition of personally familiar probes (M = 246.58, SEM = 8.78) compared to honest recognition responses to personally familiar targets (M = 225.83, SEM = 6.73), $t(34)$ = 0.3.07, p = 0.004, d = 0.45.

Consistent with predictions, in the last 500 ms time bin before the response selection was made [-500 to 0] fixation durations were significantly longer during recognition of personally familiar targets (M = 283.75, SEM = 7.75) compared to unfamiliar irrelevants (M = 250.71, SEM = 5.44), $t(34)$ = 4.12, $p < 0.001$, d = 0.83. Also consistent with predictions, fixation durations were significantly longer when lying about recognition of newly familiar probes (M = 289.24, SEM = 9.58) compared to correct rejection of unknown irrelevants (M = 250.71, SEM = 5.44), $t(34)$ = 3.07, p = 0.001, d = 0.84. There was no significant difference in fixation duration between newly familiar targets and probes, $t(34)$ = 0.67, p = 0.507, d = 0.11.

In sum, analyses revealed that fixation durations were longer during the 500 ms that preceded participants' response selection during honest identification of familiar targets as well as during lies about familiar probes. Results were similar for both newly familiar and personally known objects and scenes, with the exception that the increase in fixation durations observed during honest identification of newly familiar targets, statistically speaking, only produced a trend after correction for multiple comparison (α = 0.005).

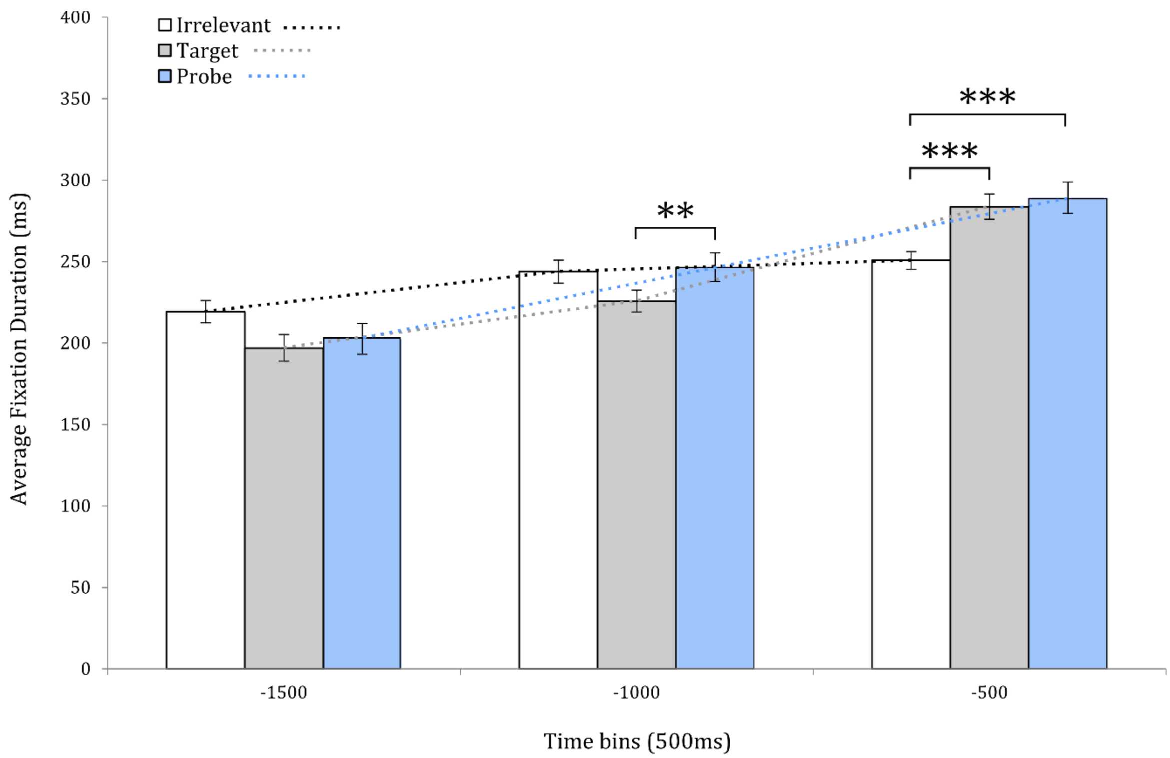


Figure 4. 7. RM ANOVAs performed on average fixation durations recorded during viewing of unfamiliar and personally familiar objects and scenes (*d.f.* = 34 in each case), with Bonferroni adjustments for nine paired samples t-tests (α=0.006). The y-axis shows data for the last three time bins (500 ms) before a response selection; -at 1500, -1000, -500 ms. In each graph, the irrelevant data (white bar) are the first comparison point for all truth targets (grey) and lie probes (blue). Further t-tests were performed to compare fixation durations between targets and probes to assess if deception significantly increased fixation duration when viewing familiar faces only. P<0.001***, p<0<006**. Error bars represent M±SEM.

4.3.4. Verbal Confidence Ratings

Truth trials (Irrelevants and Targets)

Repeated Measures ANOVAs were performed on truth trials with three independent levels of task instruction; tell the truth about unfamiliar irrelevants, tell the truth about newly learned targets, and tell the truth about personally known targets. Analyses revealed a main effect of task instruction, $F(2,66) = 15.22$, $p < 0.001$, $\eta_p^2 = 0.32$ (Figure 4.8). There was no effect of the order in which lying blocks were presented, $F(1,33) = 0.00$, $p = 0.997$, $\eta_p^2 = 0.00$ (see Figure 4.8).

Post hoc tests revealed no significant differences in confidence rating variability between irrelevants ($M = 8.03$, $SEM = 1.11$) and newly familiar targets ($M = 7.22$, $SEM = 0.89$), $t(34) = 0.73$, $p = 0.470$, $d = 0.14$. However verbal confidence ratings displayed less variability when participants correctly identified personally familiar faces ($M = 2.55$, $SEM = 0.69$) compare to unfamiliar irrelevants ($M = 8.03$, $SEM = 1.11$), $t(34) = 5.08$, $p < 0.001$, $d = 1.00$.

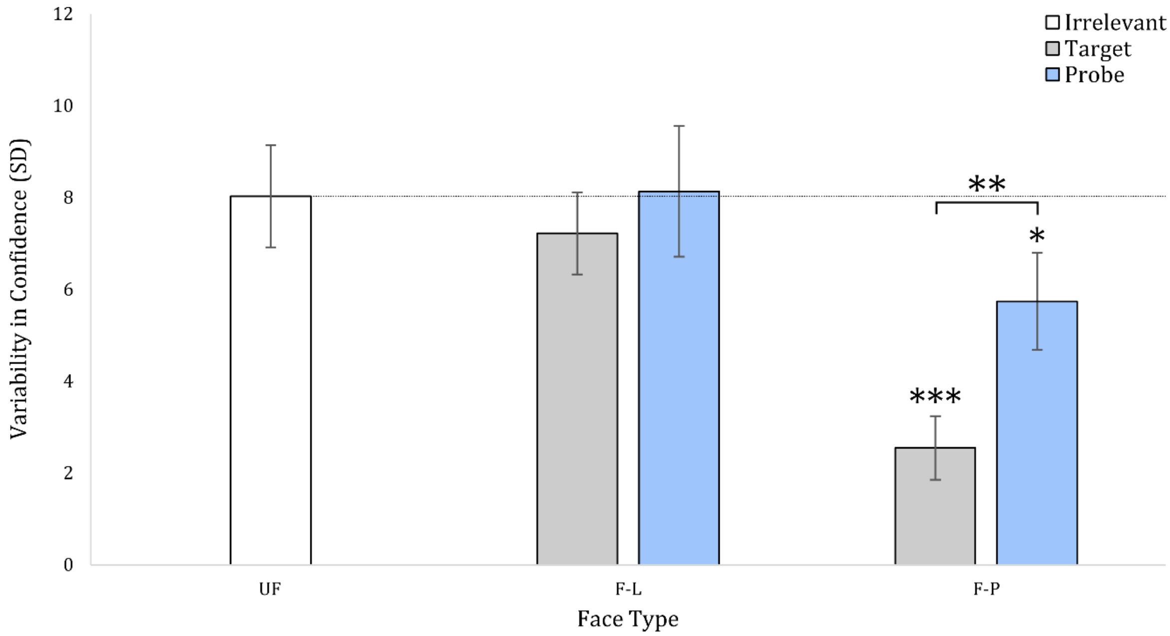


Figure 4. 8. RM ANOVAs performed on variability in confidence ratings (SD) recorded during viewing of unfamiliar, newly familiar and personally familiar faces (*d.f.* = 34 in each case), with Bonferroni adjustments for three paired samples t-tests for each RM ANOVA (α=0.017). The y-axis shows data for objects and scenes for three categories of familiarity, Unfamiliar (UF), Familiar-Learned (F-L), Familiar-Personal. In each graph, the unfamiliar irrelevant (UF) data (white bar) are the first comparison point for all truth targets (grey) and lie probes (blue). p < 0.001***, p < 0.01**, p < 0.017*. Additional t-test were performed on confidence variability between targets and probes. Error bars represent M±SEM.

Lie trials (Irrelevants and probes).

Repeated Measures ANOVAs were performed on truth trials with three independent levels of task instruction; tell the truth about unfamiliar irrelevants, lie about newly learned probes, and lie about personally known probes. Analyses revealed a main effect of task instruction, $F(2,66) = 3.78$, $p = 0.028$, $\eta_p^2 = 0.10$ (Figure 4.8). There was no effect of the order in which lying blocks were presented, $F(1,33) = 0.03$, $p = 0.862$, $\eta_p^2 = 0.00$ (see Figure 4.8).

Post hoc tests revealed that revealed no significant difference in variability of verbal confidence ratings between irrelevants (M = 8.03, SEM = 1.11) and newly familiar probes (M = 8.13, SEM = 1.42), $t(34) = 0.10$, $p = 0.923$, $d = 0.01$. However, when participants lied about recognition of personally familiar probes their confidence ratings displayed less variability (*M* = 5.74, *SEM* = 1.06) than when correctly rejecting irrelevant faces that were actually unknown (*M* = 8.03, *SEM* = 1.11), $t(34) = 2.73$, $p = 0.10$, $d = 0.36$.

A final RM ANOVA was performed to determine if there were significant differences in variability without the inclusion of the irrelevant items. Two within subjects factors were entered for analyses, Task Instruction (2 levels: Truth-Targets, Lie-Probes) and Familiarity (2 levels: Newly learned, Personally familiar). A main effect of Task Instruction revealed that variability in verbal confidence ratings were higher when lying about familiar probes (*M* = 6.94, *SEM* = 1.10) than telling the truth about targets (*M* = 4.88, *SEM* = 0.61), $t(34) = 2.47$, $p = 0.019$, $d = 0.39$. A main effect of Familiarity revealed that variability in verbal confidence ratings were lower when rating personally familiar faces (*M* = 4.14, *SEM* = 0.74) compared to newly learned faces (*M* = 7.68, *SEM* = 1.02), $t(34) = 4.18$, $p < 0.001$, $d = 0.67$. A significant interaction between Task Instruction and Familiarity revealed that variability in verbal confidence ratings for newly learned familiarity did not significantly differ between truths (*M* = 7.22, *SEM* = 0.89) and lie trials (*M* = 8.13, *SEM* = 1.42), $t(34) = 0.76$, $p = 0.455$, $d = 0.13$. However, variability on verbal confidence ratings for personally known probes were higher during lie trials (*M* = 5.74, *SEM* = 1.06) compared to ratings for targets during truth trials (*M* = 2.55, *SEM* = 0.69), $t(34) = 3.20$, $p = 0.003$, $d = 0.60$ (see Figure 4.8).

In sum, less variability was displayed during verbal confidence ratings during honest recognition of personally familiar targets, and during lies about personally familiar probes, compared to unknown irrelevants. Thus lower variability in verbal confidence ratings expose memory strength for personally familiarity when liars claim that they do not recognise well known faces. Unexpectedly lairs increased variability in their verbal confidence ratings of probes compared targets which was opposite to predictions, although variability for probes was still lower than irrelevants.

4.3.5. Variability in number of regions of the confidence scale viewed.

Irrelevants and Targets: A RM ANOVA was performed on the variability in the number of regions of the confidence scale viewed with one within subjects factors, Task Instruction (3 levels: tell the truth about unfamiliar irrelevants, tell the truth about newly learned targets, and tell the truth about personally familiar targets). The order of block counterbalancing was also entered as a between subjects factor. There was no main effect of Task Instruction, $F(2,66)$ = 1.22, p = 0.157, η_p^2 = 0.06, or of block counterbalancing order, $F(1,33)$ = 2.10, p = 0.702, η_p^2 = 0.00.

Irrelevants and Probes: A RM ANOVA performed on the variability in the number of the regions viewed on the confidence scale with one within subject factor, Task instruction (3 levels: tell the truth about unknown irrelevants, lie about newly learned probes, lie about personally familiar probes) revealed no main effect of Task Instruction, $F(2,66)$ = 2.67, p = 0.077, η_p^2 = 0.08, or of block counterbalancing order, $F(1,33)$ = 0.36, p = 0.552, η_p^2 = 0.01.

Targets and Probes: A RM ANOVA performed with two within subjects factors, Task Instruction (2 levels: Truth, Lie) and Familiarity (2 levels: Newly learned, Personally familiar) revealed no main effect of Task Instruction, $F(1,33) = 0.13$, $p = 0.723$, $\eta_p^2 = 0.00$, Familiarity, $F(1,33) = 0.16$, $p = 0.695$, $\eta_p^2 = 0.00$, or any interaction between Task Instruction and Familiarity, $F(1,33) = 0.58$, $p = 0.452$, $\eta_p^2 = 0.01$. There was also no effect of block counterbalancing order, $F(1,33) = 1.36$, $p = 0.252$, $\eta_p^2 = 0.04$.

4.3.6. Deception Questionnaires.

Face viewing strategies. 28 out of 35 (80%) participants reported trying to use some sort of eye movement strategy when they were lying about recognition. However, 14 out of 28 (50%) reported that they simply tried to look at the photographs in the same way during both truths and lies, but they did not explicitly state how. 10 out of 28 (36%) said that they explicitly tried to look less when lying about recognition. Three participants explicitly reported trying to keep their fixations focussed to the centre of the photographic image during lie trials, which might also be indicate a reduction in viewing behaviour. One remaining participant reported trying to look more at the photographs during lie trials.

Verbal confidence rating strategies. All 35 participants reported some sort of strategy when lying about confidence ratings. Forty-three per cent of participants said that they intentionally reported high confidence ratings to appear convincing when lying about recognition. 14 (40%) said they tried to keep confidence ratings the same during truths and lies. Four participants reported trying to vary confidence ratings during lies so as not to appear too obvious to the experimenter, and two participants said they reported lower confidence ratings during lies.

Only 40% of liars thought they were successful in evading lie detection during recognition trials and confidence ratings. Two participants explained why they thought they failed at evading lie detection: 1. *It is very difficult to moderate eye* movements, and 2. *I do not believe myself to be conscious of my eye movements whilst lying so I wouldn't know what to do in a natural situation thus I could not apply real experience to my attempt at deceit*. Furthermore, the majority of participants reported that they found it hardest to lie about recognition of photographs of personally familiar objects and scenes.

Examples of why participants found it hard to lie about personally familiar photographs generally referred to the automatic nature of recognition for well-known scenes and objects:

> "*Because I naturally recognised them and had to consciously switch the answer in my head, then tell my hands and voice to do the opposite of what they did instinctively.* 3. *You couldn't just forget them, they were encoded in my LTM, learned objects were still in my working memory, I attempted to scrap them."*

> "*Harder to lie about things you know so well."*

One example of one participant's reason for finding it most difficult to lie about newly learned objects and scenes:

> *"Because I was having to think about them more during the experiment because I had only just learnt them so took longer to identify them as familiar and in turn longer to figure out whether to lie or not."*

4.3.7. Discussion

The present experiment tested whether fixation quantity and duration would expose memory for recognised scenes and objects that varied in familiarity despite explicit denial of recognition. It also explored whether patterns of confidence ratings would reveal memory for familiar scenes and objects despite explicit confidence reports indicating that they were unfamiliar.

During lies, a significant decrease in the number of fixations, with a large effect size, indicated memory for personally familiar scenes and objects despite explicit denial of recognition via button presses and verbal reports. A trend in the data also revealed a reduction in run counts that suggested memory for familiar scenes and objects, with a small to medium effect size. These results support predictions that a decrease in fixation quantity would reveal memory for personally familiar scenes and objects. These results are also consistent with basic eye movement research that also found a decrease in number of fixations when viewing photographs of personally familiar buildings during a standard recognition task (Althoff et al., 1999). These findings support and extend evidence of memory effects found by Althoff et al. (1999) to include the measure run count and most importantly provide new evidence that memory effects can reveal recognition when liars attempt to conceal recognition of personally familiar scenes and objects. The results are also consistent with mock crime studies that found memory effects observed in fewer fixations for objects that were central to a mock crime event (Peth et al., 2013).

The present research also found a decrease in number of fixations, run counts and number of interest areas visited (large effect sizes for fixation count and IAs visited) during lies about newly learned photographs of scenes and objects. However, comparison of the same fixation measures for honest recognition of newly learned scenes and objects do not reveal the same pattern in fixations which suggests that the reduction in fixations during lies might be a result of participants attempting to control their eye movements during lies. This is a very similar result to that found for faces in Experiment 2. Thus, although lying produces significant difference in fixations to newly familiar photographs compared to fixations to photographs that were actually unfamiliar it would be presumptuous to assume that these were a product of recognition for the newly familiar scenes and objects. They are, however, an indirect effect of memory considering that participants would have to remember the scene or object in order to suppress the response to that item.

Considering that previous mock crime research has failed to uncover memory effects for photographs of objects that were only peripheral to the mock crime task. The results suggest that participants may be exerting volitional control over eye movements. Consistent with this idea, 80% percent of the participants in the present experiment reported attempts to adopt strategies that involved control of eye movements although these strategies varied with half of the participants reporting that they simply tried to maintain similar eye movement behaviour during truth and lie trials and a further 36% explicitly reported that they attempted to reduce eye movement behaviour during lies about recognition.

It is pertinent to note that the newly learned items in the current experiment were learned to criterion and thus should be similarly familiarly encoded to the central crime details in the study of Peth et al (2013). However, it is also possible that the learning of ten newly familiar items at the start of each test block was too high a memory load for participants, according to information theory that states that human memory has limits for information processing for approximately seven items (Miller, 1956). Despite all participants learning all ten items to the satisfactory criterion it is possible that they forgot the items soon after. Forgetting combined with cognitive effort for recollection and lying may have resulted in participants averting their gaze (Doherty-Sneddon et al., 2002; Doherty-Sneddon & Phelps, 2005). The effort of both tasks combined may well have produced the significant decrease (with large effect size) in number of fixation, run counts and interest areas visited observed in the present experiment and in addition to Experiment 2. Future research might reduce the load of the memory task to directly examine the effect of memory load on gaze during deception in addition to examine deceptive strategies more carefully also with the inclusion of a between subjects factor for different strategies.

The present experiment also explored the ability of fixation duration to reveal recognition of newly learned and personally familiar scenes and objects.

Fixation durations were longer during concealed recognition of both newly learned and personally familiar objects and scenes showing robust and large memory effects by the third fixation after presentation of photographs. Although it should be noted that honest recognition of newly learned and personally familiar scenes and objects only produced a trend for increased fixation durations, and thus the significant effects for found for lies about probes appear to be a combined product of memory effects and efforts for deception (Griffin & Oppenheimer, 2006; Hannula et al., 2007). It is also noted that the combined effects of memory and deception produced trends in the fixation duration data during lies about personally familiar scenes and objects as early as the first fixation. A similar trend was observed in fixations durations when lying about newly familiar probes, but not until the second fixation. Furthermore, longer fixation durations also clearly distinguished lies about probes compared to irrelevants in the last 500 ms before liars explicitly denied recognition via a button press and accompanying verbal response. These results provide new findings for the ability of fixation durations to reveal recognition of both newly learned and personally familiar scenes and objects. It also suggests that memory and efforts for deception are closely linked in the time-course of the present experiment as no effect of memory appeared in the first three fixations during truth trials. Peth et al. (2013) found increases in fixation duration during concealed recognition of objects central to a mock crime but found no evidence for effects of memory or deception for objects that were peripheral to the mock crime and less well encoded. The research suggests that fixation duration might be a better measure for memory detection such that it distinguished lies about recognition in the first three fixations as well as directly before explicit responses (500 ms) with large effect sizes, and are less likely to be vulnerable to intentional manipulation

(Rayner, 1998). Also, since increases in effort during deception serve to augment differences in fixation duration, they do not pose the same vulnerability as memory effects manifested in fixation quantity, which are potentially diminished by increases in fixation during cognitive effort.

Furthermore, predictions that liars would display more variability in verbal confidence ratings for objects and scenes that were unfamiliar, compared to familiar objects and scenes where familiarity was denied, were partially supported by the data. Less variability was found in verbal confidence ratings for personally familiar objects and scenes but not for those that were newly learned. Thus reduced variability in the patterns of verbal confidence ratings for personally significant items might potentially be used to indicate concealed memory but not for lesser known items. Also, an unexpected interaction occurred in variability of verbal confidence ratings between honest responses to personally familiar items and deceptive confidence ratings. Liars produced significantly more variability when lying about confidence of personally familiar scenes and objects compared equivalent truthful responses to personally familiar items. Assessment of the Deception Strategies Questionnaire revealed that all participants reported some sort of confidence reporting strategy. The majority (43%) said they intentionally reported high confidence during lies which would suggest that there would be less variability in their confidence ratings. A further 40% reported that they tried to give similar ratings during both truths and lies. Despite attempted strategies, variability in verbal confidence ratings still distinguished lies stating no recognition of personally familiar objects and scenes from those that were actually unfamiliar. The results suggest that participants did not or could not produce patterns of confidence variability that reflect truly unfamiliar items. Assessment of variability in patterns of confidence ratings show promise as a future approach for memory detection, but future research should address how best to access patterns of confidence during lies about less familiar items.

In conclusion, the present experiment supports that memory effects generalise also to non-face objects. This finding is consistent with Althoff and Cohen (1998) and Peth et al (2013). Memory effects were reliably found in fixation durations and reliably distinguished lies about recognition with a large effect sizes that appeared to be a result of combined effects of memory and deception. Fixation quantity also revealed reliably memory effects in the number of fixations also with large effects sizes for personally known probes compared photographs of objects and scenes that were actually unfamiliar. The current experiment, however advises caution in the interpretation of reduced number of fixations during concealed recognition of newly learned items as the data suggest they are a consequence of cognitive effort and attempted strategies to reduce eye movement behaviour as opposed to effects of memory *per se*. Future research should directly explore the vulnerability of fixation quantity to intentional strategies. Overall, the present research concludes that fixations can be used to identify concealed recognition of objects and scenes in addition to the findings for faces in the previous experiments. Furthermore, memory effects are most reliably found in fixation durations and that, in the present experiment, the effect of deception further augmented differences between honest responses to irrelevants and lies about probes.

CHAPTER 5.

Faces in context: Do fixations reveal memory for faces associated with specific scenes?

5.1. Introduction

Experiment 4 posed a different set of challenges than defined in Experiments 1-3, wherein the focus was if fixations could distinguish between familiar and unfamiliar faces. However, real-world scenarios may be more challenging than identifying between known and unknown persons. Consider the following scenario: Investigators have identified two suspects to a particular crime. Both suspects are equally known to the witness but only one suspect is linked to the crime in context. The examiners task is to identify the real culprit (crime-relevant probe) and reject the innocent (familiar, but crime-irrelevant target). The deceptive witness chooses to protect the culprit (perhaps a friend or criminal associate) and thus conceals identification of the culprit in relation to the crime in question. As part of the lie, the deceptive witness chooses to falsely incriminate the innocent suspect (perhaps to distract attention from the real culprit). The central question is whether fixation location and durations can reveal recognition of the correct face-scene relationship when a witness is intentionally trying to incriminate the wrong person. Additionally, fixations are analysed to further explore whether cognitive load during lies about associations also increases fixation quantity and duration as suggested in Experiments 1-3.

The study of relational memory effects in patterns of fixation behaviour is relatively new in the eye movement monitoring literature (Hannula & Ranganath, 2009; Hannula, Ryan, Tranel, & Cohen, 2007; Hannula, Ranganath, et al., 2010; Ryan, Althoff, Whitlow, & Cohen, 2000). Memory effects, as discussed in the thesis so far, have supported assertions that eye movements are capable of revealing memory for newly familiar and well-known faces when contrasted with viewing of unknown faces using both single face displays (Althoff & Cohen, 1999; Althoff, 1998; Heisz & Shore, 2008) and multiple face displays (Ryan et al., 2007; Schwedes & Wentura, 2012) even when these faces have a high degree of perceptual overlap (Hannula et al., 2012). However, the question central to the present experiment is whether fixations can reveal memory for inter item relations among equally familiar faces and scenes. Two published studies have explored evidence of relational memory for arbitrary face-scene pairings in viewer's eye movements behaviour (Hannula & Ranganath, 2009; Hannula et al., 2007).

Hannula et al. (2007) explored relational memory effects in fixation behaviour to presentations of faces superimposed on scenic background photographs that they had previously been paired with during a study phase (face-scene relations). Prior to the recognition test, Hannula and colleagues (2007) presented participants with 36 arbitrary face-scene pairings during a study block. Participants were first presented with a scene for 3 secs, followed by the presentation of a single face superimposed on the centre of the scene (face-scene pair) for a further 5 secs. Participants were instructed to learn the face-scene pairs so that they would be able to identify the face that matched each specific scene during the recognition test. At test, participants were presented with a 3 sec preview of an earlier studied scene (scene preview) followed by presentation of three faces superimposed on that same scene for 10 sec. The scene preview was intended to encourage retrieval of the associated face prior to the test display to guide viewing behaviour among the three faces so that differential viewing to the matching face might emerge earlier in the test trial (typically memory for inter-item relations becomes available later in time than memory for individual items; Dietl et al., 2005; Gronlund & Ratcliff, 1989).

Three different display types were presented in each test block; *match*, *re-pair* and *novel* displays. In match displays all three faces were equally familiar from the study phase, only one face matched the scene on which they were presented. In re-pair displays all three faces were equally familiar from the study phase, but none matched the scene on which they were presented. In novel displays, none of the faces had been seen before. Participants were instructed to identify the matching face in each three-face display type (match, re-pair, novel) even if they did not think a match was present by pressing a button corresponding to the spatial location of the face. The results within *match* test displays revealed that participants viewed the matching face disproportionately more (proportion of fixations and proportion of time) compared to the other equally familiar faces in *match* displays, revealing memory for the critical face-scene match. This preferential viewing of the matching face reached nearly 57% (significantly greater than predicted by 33% chance) of total viewing time as early as 500-750 ms after the test screen was presented and 1500 ms prior to response selection. Similar results were found in a second experiment where participants were instructed simply to study the three faces along with the associated scene for a later recognition test. The findings in the second experiment further suggest that relational memory effects are spontaneous or involuntary in nature, as are memory effects for single items (i.e., Althoff & Cohen, 1999).

To explore whether fixation behaviour might expose lies about face scene relations, three changes were made to the experimental design from Experiments 1-3 presented in the current thesis. The most important design change was to exclude the use of unknown (irrelevant) items typically used for memory detection, and instead attempt to identify memory based on the relationship between faces and scenes. With this change, the present experiment moved away from designs based on CIT three stimulus protocols to a design more representative of a differentiation of deception paradigm (Dionisio, Granholm, Hillix, & Perrine, 2001; Furedy, Davis, & Gurevich, 1988). The differentiation of deception paradigm aims to identify specific patterns in behavioural or physiological variables that differ systematically between truthful and deceptive behaviour. Participants are asked to lie on half the items and tell the truth on the other half, sometimes using the same items in both conditions.

In the current experiment, the learning procedure was modified so that all faces and scenes were learned to a criterion that produced similar familiarity (Hannula et al., 2007). In lie trials, deceptive participants had to specifically identify and select the familiar face that did not match the scene. In terms of response planning this differs from single button presses made to single faces in Experiments 1-3. Selecting an alternative face might require more complex decision making processes than in the previous experiment (Lefebvre et al., 2009), but also potentially offers further opportunity to detect deceit based on pattern of fixations to both faces. This design posed a new challenge for eye movements as markers of memory. It is unknown whether, if all other factors are considered equal, memory of a particular face-scene relation and cognitive efforts required for the suppression of the true match are distinct enough to effect change on fixation behaviour to differentiate deception when lying about similarly familiar faces. Experiment 4 addresses this previously untested question.

The experimental design, based on Hannula et al. (Hannula et al., 2010), was adapted to address questions related to lies about face-scene relations. The present experiment was the first to explore memory for faces associate with specific scenes via the monitoring of fixation behaviour. Specifically, Experiment 4 aimed to explore the effect of both information processing linked to memory retrieval as well as explicit choices based on deceptive response selections. To achieve this goal, the present experiment analysed the proportion of trials made to the matching face (Hannula et al., 2010) in the first and last fixations as well as the mean duration of these individual fixations (Ryan et al., 2007; Schwedes & Wentura, 2012). Furthermore, the present research also examined the effects of memory and cognitive load overall in the number of fixations and run counts made to the different faces during truths and lies. Analyses directly compared fixation behaviour between truthful trials (correct identification of matching face) and lie trials (intentional misidentifications of non-matching face).

Based on Hannula et al.'s (2007) findings that viewers preferentially view faces matched to specific scenes and claims that relational memory effects might be involuntary in nature, our first predictions were that both truth-tellers and liars would display a preference to fixate the matching face in the first fixation (Prediction 1a) as well as longer fixation durations to the matching face during that first fixation (Prediction 1b). Also based on Hannula et al (2007; see also Hannula 2009), it was predicted that liars would preferentially fixate the to-be-selected face in the last fixation (Prediction 2a) in addition to longer fixations during that last fixation just prior to response selection (Ryan et al., 2007) (Prediction 2b). More general predictions were that task demands would be greater for liars than truth tellers as observed in more fixations behaviour overall during deceptive selection choices (Cook, Hacker, Webb, Osher, Kristjansson, Woltz, & Kircher, 2012), specifically it is predicted that deception would produce an increase in both number of fixations (Prediction 3a) and run counts (Prediction 3b). A final supplementary prediction, although not central to the question in the present experiment, is that liars' reported confidence based on their deceptive recognition judgements will be inflated as compared to ratings based on honest judgements (Prediction 4).

5.2. Method

5.2.1. Design

A within subjects design independently manipulated task instruction (2 levels of veracity: honestly identify matching face, deceptively select non-matching face). On each trial participants were presented with a single display that comprised one scene with two faces displayed centrally on the background scene: a familiar face that matched the scene in the display (match) and another face that was familiar but did not match the scene in the display (non-match) (see Figure 5.2). There were six unique test screens in each block of trials. The six test screen were repeated twice within each test block so that all participants told the truth (correctly identified matching face) and lied (misidentified non-matching face) about which face that matched the scene in each test screen. There were three blocks in total.

Unique pairs of faces and scenes were learned prior to each block of trials. The order in which each block of trials was presented was fully counterbalanced. The location of the matching face was counterbalanced so that the position of the matching face was on the left side of the display for half the trials.

5.2.2. Participants

Sixty-four undergraduate psychology students (47 females, 17 males) from The University of Portsmouth participated in the study. Mean ages ranged from 18 – 42 years (M = 19.47, SD = 3.94). All participants had normal or normal-to-corrected vision. All participants received course credit for participation.

5.2.3. Apparatus and Materials

Eye tracker

As in Experiments 1-3, eye movements were recorded with the Eyelink II head mounted eye tracker (SR Research, Ontario, Canada) at a sampling rate of 250 Hz. Sixty-one participant's eye movements were tracked using both retinal and corneal reflection. The remaining 3 participants were tracked using Pupil only mode due to difficulties detecting corneal reflections. Forty-three participants were tracked using the left eye, and 21 with the right eye. Button presses were recorded with the Microsoft sidewinder Plug and Play game pad.

Photographs

Photographic stimuli for the experiment were 36 scenes and 36 photographs of previously unseen faces. All faces were male with eye gaze directed towards the camera with neutral expressions (faces were sourced from the database created for the present thesis as cited in Experiment 1 (see section 2.2.3). Photographs of scenes required for the study phase were printed on A4 photographic paper, four per page, cut to the same size and laminated. Faces for the study phase were also printed on A4 photographic paper, six per page, cut to the same size and laminated. For the test screen, all faces were re-sized to 333 x 250 pixels and superimposed centrally and side-by-side on the background scene measuring 800 x 600 pixels. All test screens were presented centrally on the display screen with a blue background (HEX: #5DBCD2).

Deception Questionnaires

The deception questionnaire included four open ended questions: 1. In general what behaviours do you think people do when they (a) lie, (b) tell the truth? 2. What behaviours do you think you actually do when you (a) lie, (b) tell the truth? 3. What did you do to try and convince the experimenter you were telling the truth about the face that matched the scene during (a) lies, (b) truths? 4. What did you do to try and convince the experimenter you were telling the truth about the confidence of your judgement during (a) lies, (b) truths? The participant was also asked to report if they thought they were successful in their attempt to deceive the experimenter when lying (yes or no) and to explain why. In addition the participant was asked to indicate when they did *more* of specific behaviours (such as looking more at the matching face or looking more at the confidence scale) by circling one of three options; lying, truth-telling or no difference. In the final part of the questionnaire participants were presented with an image that displayed two faces, one which was marked as a matching face. Participants were instructed to mark on the image whether they think they looked more during lie and truth trials; the matching face, the non-matching face or the background (see Figure 5.1 below for an example of one participant's data).

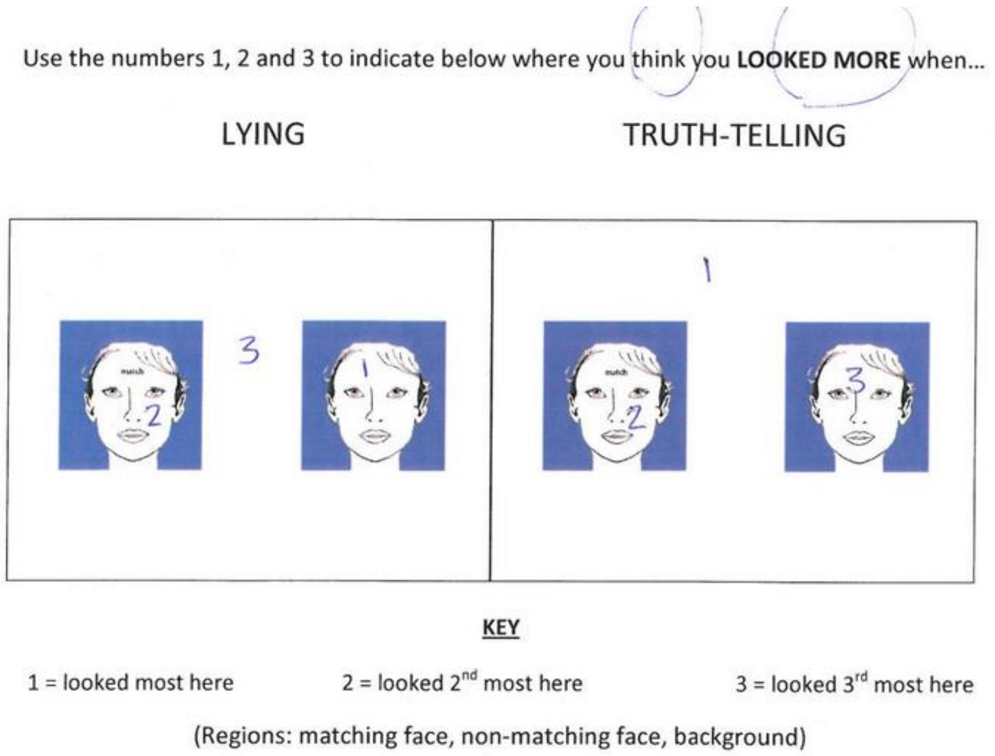


Figure 5. 1. Example of one participant's report about their face viewing behaviour during truths and lies. In each diagram, the face on the left is the matching face as indicated by the word 'match' on the forehead of the image.

5.3. Procedure

Participants were seated in a chair at a desk to the side of the eye tracker. Following completion of the brief and consent forms participants were presented with twelve scenes and asked to look at them and familiarise themselves with each scene individually. When the participant indicated that they had adequately inspected each scene, a face was placed on top of each of the twelve scenes. The participant was asked to commit to memory each face-scene pair and again indicate when they had learned the matching pairs. The experimenter then shuffled the scene and face cards, spread the scenes out on the desk and handed the participant the face cards. The participant was instructed that they must correctly match all face-scene pairs 100% correctly twice consecutively before proceeding to the test.

Once the criterion-for-learning was met the participant was seated in a chair in front of the eye tracker, approximately 80 cm from the display screen. The height of the seat was adjusted so that the participant's eyes rested at approximately two thirds of the height of the screen. The Eyelink II headband was comfortably secured to the participants' head before carrying out a calibration procedure using a 3 x 3 spatial dot array as in previous experiments.

At test, the participant was sequentially presented with six different test screens in each block of trials. There were three blocks in total. Prior to each test screen the participant was presented first with a fixation dot, followed by a scene cue screen (2 seconds), then a screen that instructed whether the participant was to tell the *Truth* or *Lie* (2 seconds), followed by the test screen that was displayed until the participant made the appropriate response (see Figure 5.2). On each test screen was a scene and two faces from the study phase positioned, side by side, in the centre of the scene. The six scenes presented at test were selected randomly from the twelve presented during the study phase. The remaining six scenes from the study phase were not presented. On each test screen, one of the faces always matched the scene presented as learned during the study phase, the other face was also familiar from the study phase but was not the correct match for the scene displayed. Participants selected the left or right face based on the task instruction by pressing the left or right button on the game pad whilst verbally reporting the location of the selected face (e.g, *left*) at the same time as the button press. Following each test screen, participants were presented with a confidence scale to which reported how confident they were about their previous recognition judgement whilst at the same time pressing any of the two buttons on the game pad. The instructions for both recognition and confidence judgements were that they should try to appear honest even when lying and that their eye movements (fixation locations and durations), button presses and verbal reports were being recorded to assess veracity. When all three blocks were finished, participants completed a Deception Strategies Questionnaire.

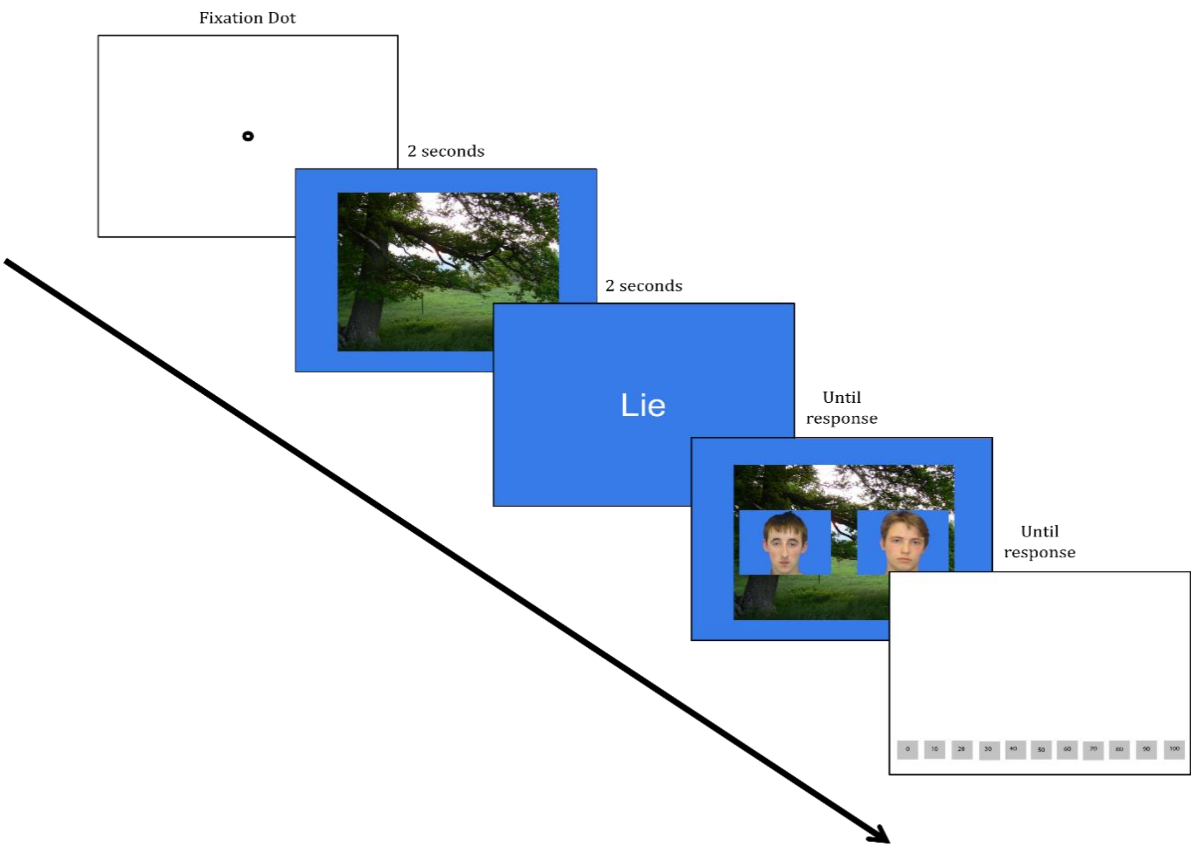


Figure 5. 2. The sequence of display screens for each trial commenced with presentation of a fixation dot that remained until the participant accurately fixated the central point. The next screen presented the scene preview for two seconds followed by the task instruction for two seconds. The test screen was then displayed until a response was made. The final screen presented a confidence scale that prompted participants to make a confidence rating (0-100%) based on their previous recognition judgement.

5.3.1. Dependent measures and Analysis Strategy

Separate Repeated Measures ANOVAs were performed on the proportion of trials made to the matching face, the average duration of individual fixations, number of fixations and run counts. For fixation durations, RM ANOVAs were performed separately for the first and last fixations of each test trial. Number of fixations and run counts were analysed over the full trial period. Two within subjects factors were entered into the analyses, Task Instruction (2 levels: truth, lie), and Interest Area (2 levels: match, non-match). The counterbalanced order in which the three blocks of trials were presented was also entered for analysis as a between subjects factor with six possible combinations (123, 132, 213, 231, 312, 321).

5.4. Results

5.4.1. Exclusion Criteria

Two of the original 64 participants were removed from the data set due to problems with calibration and loss of data. Incorrect responses were also removed from the data before analyses. In truth trials errors were defined as selection of the non-matching face instead of the correct face-scene match. In lies trials errors were recorded if participants selected the matching face when they were supposed to identify the non-matching face as the critical match. Out of a total 2232 trials for 62 participants, 31 trials were removed in the lie condition (2.8%) and 11 trials from the truth condition (0.9%). This left a total of 2190 trials for analyses.

5.4.2. Fixation Durations.

First fixation

Likelihood of fixating the matching face. Both liars (53%) and truth-tellers (61%) preferentially viewed the matching face in the first fixation. One sample t-tests reveal both values to be above chance, $t(61) = 2.11$, $p = 0.039$ and $t(61) = 8.83$, $p < 0.001$ respectively. Furthermore, a paired sample t-test revealed that the proportion of fixations directed to the matching face in the first fixation was significantly higher in the truth trials (*M* = 0.61, *SEM* = 0.01) than in the lie trials (*M* = 0.53, *SEM* = 0.01), *t*(61) = 5.37, *p* < 0.001, *d* = 0.90.

Fixation Duration. The RM ANOVA performed on the *first fixation* revealed no main effect of task instruction to tell the truth or lie, *F(*1,56) = 0.02, p = 0.90, η_p^2 < 0.001. A main effect of interest area, *F(*1,56) = 5.83, p = 0.02, η_p^2 = 0.09 revealed that fixation durations were significantly longer when viewing the matching face (*M* = 282.34, *SEM*= 9.41) than the non-matching face (*M*= 264.54, *SEM*= 9.27), *t(*61) = 2.66, p = 0.01, d = 0.24. There was also a significant interaction between task instruction and interest area, *F(*1,56) = 59.26, *p* < 0.001, η_p^2 = 0.51 (see Figure 5.3).

Paired comparisons performed to explore the interaction between task instruction and interest area revealed that within truth trials, first fixation durations were always longer on the selected face: (selected and matched, *M* = 320.12, *SEM*= 13.09; not selected and non-matched, *M* = 226.56, *SEM* = 8.14), *t(*61) = 8.22, p < 0.001, *d* = 1.09 (see Figure 5.3a). The same pattern of results was found for selected faces in lie trials (non-match, *M* = 302.52, *SEM* = 13.42; match, *M* = 244.57, *SEM* = 8.42), *t(*61) = 4.95, *p* < 0.001, *d* = 0.66). Further paired comparisons showed that within selected faces (matching face in the truth condition, non-matching within the lie condition) there was no significant difference in fixation durations when lying versus telling the truth, *t(*61) = 1.42, *p* = 0.16. There was, however, a significant difference in fixation durations for the non-selected faces in truth and lie conditions, *t(*61) = 2.87, *p* < 0.006, *d* = 0.28. Fixations durations were longer when viewing the matching face that was not selected in lie trials (*M* = 244.57, *SE*M= 8.42) than when viewing the non-matching face that was not selected in truth trials (M= 226.56, *SE*M= 8.14). The presentation order of trial blocks had no effect on the results, $F(5, 56) = 0.16$, $p = 0.98$, $\eta_p^2 = 0.01$.

Last fixation

Likelihood of fixating the matching face. The proportion of trials in which liars looked at the matching face last was significantly below chance ($M = 0.46$, $SEM = 0.01$), $t(61) = -4.28$, $p < 0.001$, indicating that the majority of last fixations were directed to the non-matching face that was selected. However, truth-tellers' likelihood of looking at the matching face in the last fixation was no different to chance ($M = 0.51$, $SEM = 0.01$), $t(61) = 0.64$, $p = 0.52$. A paired-sample t-test revealed that the proportion of fixations to the matching face in truth trials was significantly higher than lie trials, $t(61) = 3.00$, p = 0.004, $d = 0.57$.

Fixation Duration. The same RM ANOVA was performed on the *last fixation* before participants selected their response. A main effect of task instruction, $F(1,56) = 10.80$, $p < 0.002$ $\eta_p^2 = 0.16$, revealed that fixation durations were longer during lie trials ($M = 370.08$, *SE*M= 11.28) than truth trials ($M = 339.90$, *SE*M= 8.25), $t(61) = 3.63$, p < 0.001, $d = 0.39$. There was, however, no main effect of interest area, $F(1, 56) = 0.50$, $p = 0.48$. As in the previous analysis of the first fixation, there was also a significant interaction between task instruction and interest area, $F(1,56) = 122.53$, $p < 0.001$, $\eta_p^2 = 0.67$ (see Figure 5.3b), paired sample tests discussed below.

Paired comparisons showed that participants always made longer fixations to the faces that were consistent with response selections. Fixation durations on the selected matching face in truth trials, $t(61) = 10.87$, $p < 0.001$, d = 1.83 and selected non-match (non-match): $t(61) = 10.04$, $p < 0.001$, d = 1.48. Further paired comparisons found that for selected faces, fixations were longer when lying (non-matching faces, M= 450.97, SEM= 17.03) than when telling the truth (match, M = 419.42, SEM= 13.12), $t(61) = 2.46$, $p = 0.017$, $d = 0.26$. This is suggestive of higher cognitive load for liars than truth tellers for response selection intentions. Analysis of fixation durations to non-selected faces showed the same pattern of results as the first fixation. Fixation durations were longer during viewing of the non-selected face in lie trials (match; M = 289.18, SEM= 9.71) than truth trials (non-match; M = 260.37, SEM= 8.44), $t(61) = 3.12$, $p < 0.003$, $d = 0.40$. Presentations order of trial blocks had no effect on the results, $F(5,56) = 0.36$, $p = 0.88$, $\eta_p^2 = 0.03$ (see Figure 5.3b).

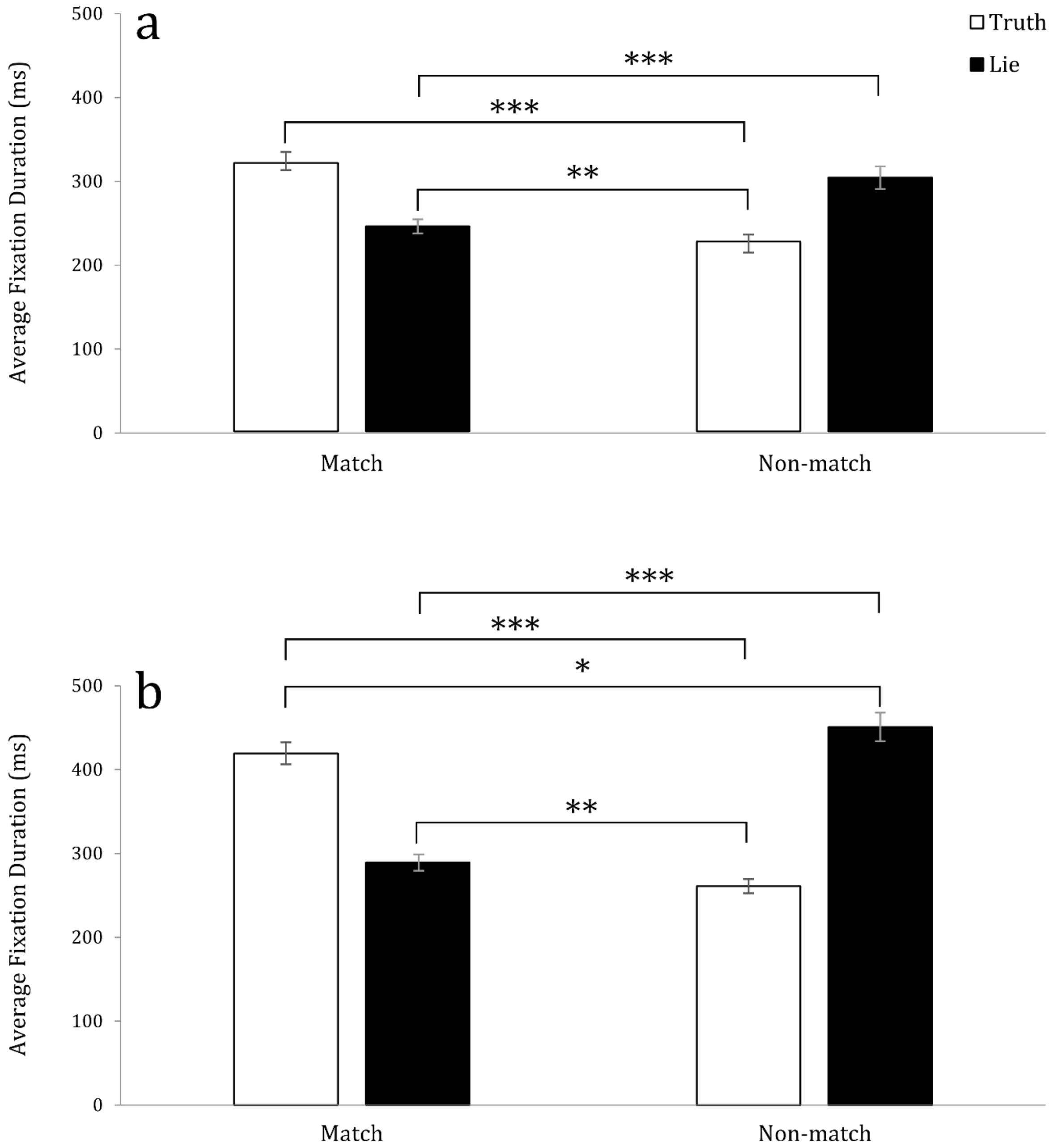


Figure 5. 3. Average fixation duration by truth (white bars) and lie (black bars), split by interest areas viewed (match, non-match): (a) First fixation; b: Last fixation. Error bars represent standard error from the mean (SEM). Post-hoc comparisons are paired samples t-tests with Bonferroni corrections for four comparisons ($\alpha = 0.012$); *$p < 0.012$; **$p < 0.01$, ***$p < 0.001$.

5.4.3. Quantity of Fixations (full trial period)

Proportion of fixations. Over the course of the full trial period, the proportion of fixations made to the matching face in lie trials was below chance (*M* = 0.31, *SEM* = 0.01), $t(61)$, -25.270, p = < 0.001, thus the majority (59%) of fixations were made to the nonmatching face. However, the proportion of fixations made to the matching face in truth trials was significantly above chance (56%) indicating that truth-tellers preferentially view the matching face over the full trial period (*M* = 0.56, *SEM* = 0.01), $t(61) = 6.94$, $p < 0.001$. A paired sample t-test revealed that the proportion of fixations directed to the matching face in truth trials was significantly higher than in lie trials, $t(61) = 20.55$, $p < 0.001$, $d = 3.90$.

Total Number of Fixations. A RM ANOVA conducted on fixation count revealed a main effect of task instruction (truth, lie), $F(1,56) = 31.87$, $p < 0.001$, η_p^2 = 0.36; significantly more fixations were made during lie trials (*M* = 2.39, *SEM* = 0.11) than truth trials (*M* = 2.15, SEM = 0.09), $t(61) = 5.58$, $p < 0.001$, $d = 0.31$. A main effect of interest area (match, non-match), $F(1,56) = 6.26$, $p = 0.015$, $\eta_p^2 = 0.10$, revealed that more fixations were made to the matching face (*M* = 2.32, *SEM* = 0.10) than the non-matching face (*M* = 2.22, *SEM* = 0.10), $t(61) = 2.30$, $p = 0.004$, $d = 0.14$).

A significant Interaction between task instruction and interest area, $F(1,56)$ = 306.25, $p < 0.001$, $\eta_p^2 = 0.85$, showed that in both truths and lies trials, participants always make the most fixations to the *selecte*d image, truth (match, non-match), $t(61) = 17.36$, $p < 0.001$, d = 1.85 and lie (non-match, match), $t(61) = 16.91$, $p <$ 0.001, $d = 1.35$. Comparing truth and lie comparisons of the selected responses alone, (truth, match; lie, non-match) more fixations were made when lying (*M* = 3.00, *SEM* = 0.13) than telling the truth (*M* = 2.87, *SEM* = 0.17), *t(*61) = 2.39, *p* = 0.020, *d* = 0.13. Interestingly, comparison of the number of fixations made to the non-selected faces, more fixations were, again, made in the lie condition to the matching faces (*M* = 1.78, *SEM* = 0.09) than to the non-matching faces in the truth condition (*M* = 1.43, *SEM* = 0.61), *t(*61) = 6.09, *p* < 0.001, *d* = 0.52. Presentation of trial order had no effect on results, *F(*5,56) = 0.94, p = 0.464, η_p^2 = 0.08 (see Figure 5.4a).

Run Count. A main effect of task instruction, *F(*1,56) = 9.61, *p* < 0.003, η_p^2 = 0.15 revealed that more runs were made in lie trials (*M* = 1.33; *SEM* = 0.04) than truths (*M* = 1.23, *SEM* = 0.04), *t(*61) = 3.63, *p* = 0.001, *d* = 0.33. There was no main of effect interest area, *F(*1,56) = 0.61, *p* = 0.44, η_p^2 = 0.01. Number of runs made to the matching face (*M*= 1.29, *SEM* = 0.04) were not significantly more than to the non-matching face (*M* = 1.27, *SEM* = 0.04), *t(*61) = 1.06, *p* = 0.30 (see Figure 5.4b).

Interactions between task instruction and interest area, *F(*2,112) = 808.26, *p* < 0.001, η_p^2 = 0.94, show that in both truths and lies, participants always make the most runs to the *selecte*d image, truth (match, *M* = 1.45, SEM = 0.04; non-match, M = 1.01, SEM = 0.04), *t(*61) = 20.25, *p* < 0.001, *d* = 1.52 and lie (non-match M = 1.54, SEM = 0.05; match, M = 1.13, SEM = 0.04), *t(*61) = 25.00, *p* < 0.001, d = 1.18. Comparing truth and lie comparisons of the selected responses alone, (truth, match; lie, non-match) more runs were made when lying (*M* = 1.54, *SEM* = 0.05) than telling the truth (*M* = 1.45, *SEM* = 0.04), *t(*61) = 3.20, *p* = 0.002, d = 0.28. Comparing number of runs made to the non-selected faces, more runs were, again, made in the lie condition to the matching faces (M = 1.13, SEM = 0.04) than to the non-matching faces in the truth condition (M = 1.01, SEM = 0.04), $t(61) = 3.47$, $p = 0.001$, $d = 0.37$ (see Figure 4.4b).

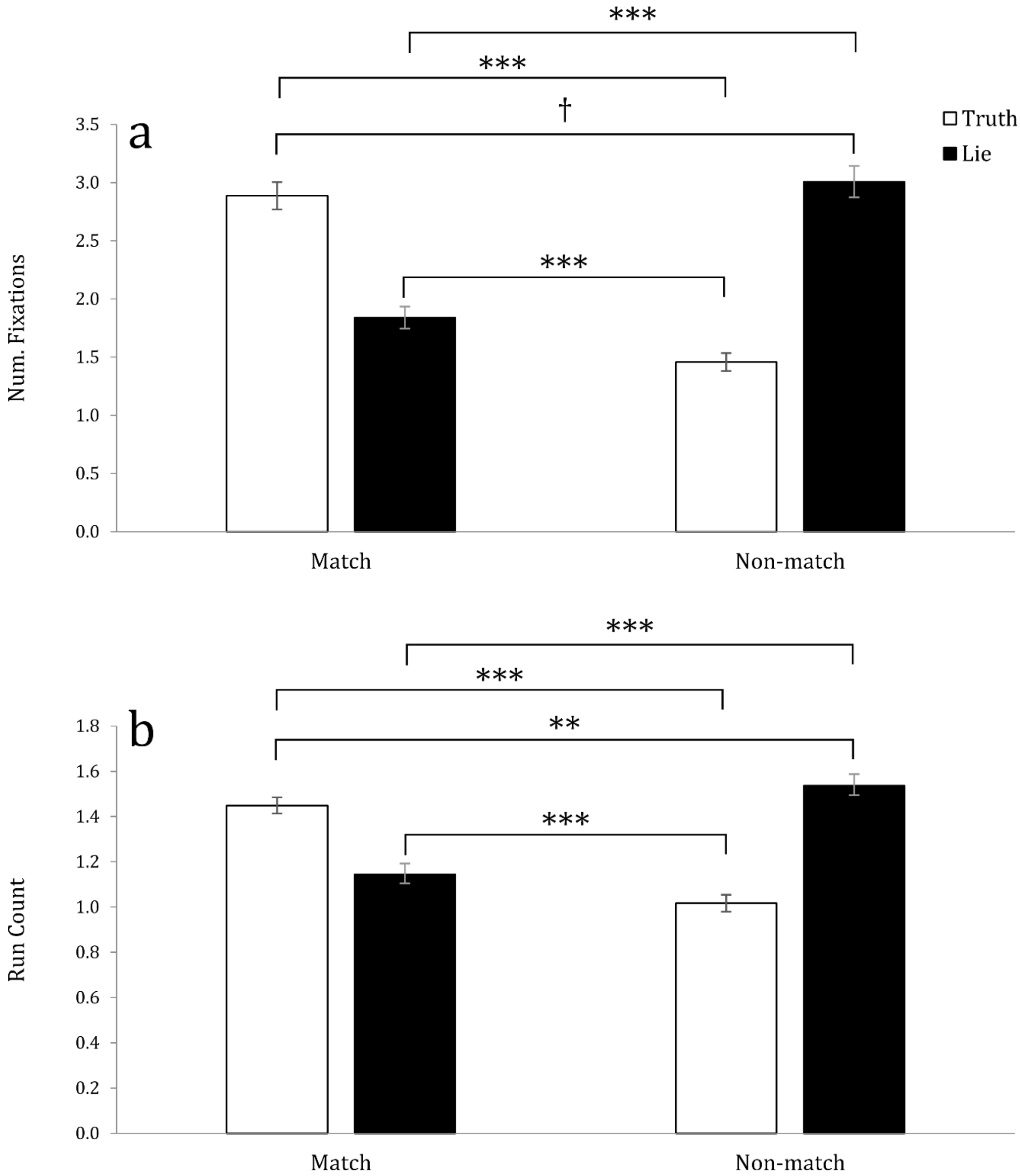


Figure 5. 4. Number of fixations (a) and Run Counts (b) by truth (white bars) and lie (black bars), split by interest areas viewed (match, non-match): Error bars represent standard error from the mean (M±SEM). Post-hoc comparisons are paired samples t-tests with Bonferroni corrections for four comparisons (α= 0.012); †$p < 0.05$, *$p < 0.012$; **$p < 0.01$, ***$p < 0.001$

5.4.4. Verbal Confidence Ratings

Repeated Measures ANOVAs revealed that task instruction manipulation (truth, lie) had no significant effect on the variability of confidence judgements, $F(1,56) = 5.61$, $p = 0.064$, $\eta_p^2 = 0.53$. Task instruction manipulation also had no effect on the variability in the number of regions of the confidence scale viewed whilst deliberating the verbal confidence rating, $F(1,56) = 3.85$, $p = 0.11$, $\eta_p^2 = 0.44$.

5.4.5. Questionnaires.

Face viewing strategies. Thirty-nine out of 62 (63%) participants reported attempts to adopt eye movement strategies to evade detection when lying. Sixteen of the 39 participants (41%) explicitly tried to look less at the matching face when lying, whereas 23 (58%) reported trying to look the same at both matching and non-matching faces. When asked which faces they thought they actually looked at more during the lie trials, 21 out of 39 (53%) said they thought they looked more at the matching face, whereas the remainder thought they looked more at the face they selected. Out of the 30 participants who reported trying to employ eye movement strategies, 14 (46%) thought that they were successful.

Out of all the 62 participants tested, 34 (55%) reported that they thought they looked more at the matching face. Only a quarter of these participants thought they were successful in deceiving the experimenter and evading lie detection. For honest responses, all participants reported that they thought they looked more at the matching face.

Confidence rating strategies. Out of all 62 participants tested 33 (53%) reported using a high confidence reporting strategy when lying, whereas 4 (6%) simply reported that they tried to report similar confidence ratings in both truths and lies. A further 13 (21%) specifically reported trying to vary confidence ratings when lying and 2 (3%) said they made lower confidence ratings during lies. Ten reported no strategies at all.

5.5. Discussion

The aim of the present experiment was to investigate whether fixation behaviours would reveal memory for critical face-scene associations as well as deceptive response intentions in different fixation analyses (first, last and total fixations) during an associative recognition task for face-scene relations.

First fixation

Prediction 1a that first fixations would be preferentially directed to a critical matching face based on its association with a co-presented scene, irrespective of truths or lies, was supported by the data. Across all trials, the proportion of first fixations directed to the matching face during lies was significantly above chance (53%), compared to the fixations to the non-matching face in the display. It should be noted, however, that this proportion was significantly lower than in truth trials where 61% of all first fixations were made to the matching face. The result suggests that intentions to falsely select the non-matching face later in the trial interfere with orienting responses to the matching face as early as the first fixation resulting in a lower proportion of first fixations to the matching face as compared to truth trials.

Prediction 1b that fixation durations would be longer to the matching face irrespective of honesty was not fully supported by the data. Analyses of fixations duration in lie and truth trials were always longer to the face governed by response intentions (the matching face in truth trials and the non-matching face in lie trials). These results suggest that response intentions impact fixation durations as early as the first fixations. However, comparison of fixation durations to the faces that were not selected revealed that fixation durations were longer to the matched face that was not selected in lie trials compared to first fixations to faces that were not matched and not selected in truth trials.

The finding that deceptive response intentions influence viewing behaviour in the first fixation was unexpected, however this may be partly due to the presentation of the scene cue followed by the instruction to deceive prior to the presentation of the test screen. The scene cue was presented prior to the test screen to facilitate memory for the associate face-scene relation early in viewing behaviour as previous research has indicated that memory retrieval for inter-item relations occur later than that for single items (Gronlund & Ratcliff, 1989). However, it seems that the combination of the scene cue to trigger memory of the associated face and the instruction screen to signal the action to lie prompted an early influence of response intentions that was not predicted. It is also possible that longer fixations predicted when viewing the matching face were diminished in lie trials due to attempts to reduce viewing to the matching face (41% of participants reported attempting to look less at the matching face in lie trials) although previous research suggests that voluntary control over characteristics of individual fixations is extremely difficult - if possible at all (Rayner, 1998). Despite the finding that effect of relational memory did not emerge as strongly in first fixations as was predicted, fixations durations between non-selected faces in truth and lie conditions in the present experiment still effect a measurable difference in fixation durations that could potentially be used to distinguish differences in the fixation behaviour of liars and truth tellers during recognition of related face-scene pairs. Furthermore, the finding that the liars preferentially orient to the matching face in the first fixation suggest the difference in average fixation duration between the non-selected faces are, at least part, due to memory for face-scene relations.

In sum, first fixations reveal that participants are more likely to fixate the matching face during initial viewing of the test screen during both truth and lie trials, although this tendency is strongest during truths. Fixations durations to the matching face are longer during truth trials reflecting both relational memory and effects of planning response selections. Fixation durations to the matching face in lie trials were significantly shorter. However, fixation durations to the matched but not selected face in lie trials was longer then the fixations to the non-matched and non-selected face in truth trials. The comparison of faces that were not selected allows an evaluation relational memory effects in the absence of response selection effects, thus providing a purer index of memory.

Last Fixation

Prediction 2a that the last fixation would be directed to the stimulus being responded to was partially supported by the data. The majority of liars (54%) preferentially viewed the to-be-selected face (non-matching face) in the last fixation before making their response intention. Unexpectedly, the same finding did not occur during truth trials. The proportion of last fixations to the matching face in truth trials was not significantly above chance (51%). Although no definitive conclusions can be drawn from the present data as to why liars gaze tended to be more fixed to the face that they selected, it is possible is that, because of the effort of lying, the last fixation on a lie trial was held on the stimulus that was lied about while the response was made. Accordingly, because of the relative ease of telling the truth, participants in truth trials may have allowed their eyes move on after planning their response, and thus were less likely to be gazing at the matching stimulus in the final fixation. This explanation is consistent with research that supports that gaze is proactive and thus often moves on before the last action is complete and tends to happen when a specific motor skill has become accomplished (Land, 2006). It might also be possible that during truth trials participants were less concerned with the monitoring of their eye movement behaviour and thus spent more time freely viewing each face before selecting a response.

Prediction 2b that the duration of the last fixation would be longer on the to-be-selected face, thus reflecting response intentions to select that face, was fully supported by the data. Fixation durations were longer when the last fixation was on the face that was later selected during both truths (match) and lies (non-match). Comparing viewing of the selected faces, fixation durations were longer during lie trials than truth trials also indicating suggesting higher cognitive load for the planning of deceptive response intentions. In addition, a similar finding to the first fixation was found; when the last fixation was made to the non-selected matching face in lie trials, it was longer than the equivalent fixation made to non-matching face that was not selected in truth trials. The effect size of this difference in the last fixation was larger than in the first fixation (approaching a medium effect), suggesting that additional load during the suppression of the intentions to select the matching face produced a longer fixation. Main effects in the analyses of the last fixation revealed significantly longer fixations during lies but no main effect of interest area, suggesting that fixation durations in the last fixations were largely driven by cognitive efforts to prepare deceptive response intentions.

In sum, in lie trials last fixations were preferentially made on the non-matched and selected face with longer fixation durations than on the matched face that was not selected. In truth trials, there appeared no preference to view the selected and matched face in the last fixation, although fixation duration were longest to the matched and selected face. Also in the last fixation, comparing faces that were not selected, fixation duration were longer in lie trials than truth trials.

Full trial period

Analysing data over the full trial period revealed no preferential viewing of matching faces in lie trials. Preferential viewing to matching faces was, however, found in truth trials (56% of all fixations were made to the matching face).

Predictions that fixation durations would be longer during lies was evident in comparison of non-selected faces in truth and lie comparisons in both number of fixations (Prediction 3a) and run counts (Prediction 3b). Again fixation durations were longest overall to the faces that were selected faces at the end of the trial. The pattern of findings in the number of fixations and run counts were the same as those found in the last fixation durations before a selected response was made with one exception; the difference in fixation durations between truths and lies for selected faces did not quite meet the level of significance after Bonferroni corrections. Comparison of effect sizes for differences between truths and lies for selected faces were .26 for the fixation duration of the last fixation, .13 for the total number of fixations and .28 for the number of runs made. Although the analysis of fixation number and run counts provide additional support for differences in fixations behaviours they do not appear to add anything to the analysis of fixation durations during the last fixation of viewing before a response selection. Effect sizes for the last fixation, total number of fixation and run counts are larger than for the first fixation (approaching a medium effect size) suggesting an incremental effect of cognitive load of deception over the time course of the trial. It is interesting to note that effect size differences were larger when comparing fixation behaviour to non-selected faces between truths and lies than to the faces that were selected. The results suggest that it might be more valuable to compare fixation behaviour to non-selected faces when attempting to distinguish differences between honest and deceptive responses.

In future research it might also be beneficial to manipulate motivation in test conditions to assess whether larger differences in fixation behaviour might occur in the first fixation when participants are not attempting to control fixation behaviour. Modern eye tracking technology allows relatively covert recording of eye movement behaviour using video based eye trackers that may facilitate a purer analysis of orienting responses in the first fixation when attempts to evade lie detection by the monitoring of eye movements are not made explicit as they were in the present experiment.

Confidence Ratings

No significant differences were found in the variability of verbal confidence ratings or in variability of on screen viewing behaviour when examining regions of the confidence scale prior to the verbal response. This finding was not consistent with predictions that liars would inflate confidence to appear convincing and thus display less variability in their verbal confidence ratings and associated eye movements during deliberation of ratings. This finding is perhaps not surprising given that all the stimuli in the present experiment were equally learned-to-criterion during a study phase and thus all stimuli were similarly familiar. Findings from Experiment 2 revealed differences in confidence ratings but they were based on comparison of confidence ratings to known compared to unknown faces, and were most distinct when comparing ratings between personally known faces and unfamiliar faces. Experiment 2 did not reveal significant differences in confidence ratings when comparing truths and lie to the same face types. Also, just over half of the participants (53%) in the present experiment reported giving high confidence ratings during lies, the remainder reported a variety of different strategies in the *Deception Strategy Questionnaire* such as reporting the same as truth, varying confidence ratings and also giving lower ratings than in truth trials. The results suggest differentiating deception based on confidence is most successful when comparing ratings to honest judgements to unknown faces as in Experiments 1, 2 and 3.

Conclusion

The present findings supports the notion hypothesis that differences would be found in fixation behaviour as early as the first fixation to distinguish truths and lies about memory face scene relations. Liars preferentially viewed the face that matched the scene in a display as measured by the proportion of trials in which fixations were directed to the matching face as well as making longer fixations to non-selected faces compared to truth trials. The last fixation was a reliable indicator of response intentions and efforts to deceive, although cognitive demands in the last fixation appeared larger when comparing responses to non-selected faces, perhaps as a cumulative effect of both orienting responses and deceptive response intentions in the last fixation. Analyses of number of fixations and run counts across the full trial period did not add a lot more to the findings except that the effects size for differences between truths and lie for non-selected faces was largest in the measure number of fixations. This finding is similar to large effect sizes for differences in the Experiments 1-3 in the present thesis.

The results in the current experiment present novel findings on the way in which fixation behaviours to reveal memory and response intentions during intentional misidentifications corresponding to memory associations for specific faces and scenes. Such an exploration of relational memory effects in eye movements have not previously been explored in the deception and memory detection literatures. In fact, the use of eye movements to reveal memory for inter-item or co-occurring relations is a relatively understudied phenomenon (Hannula et al., 2007; Hannula, Ranganath, et al., 2010), although previous behavioural research has shown that face processing in-context results in faster and more accurate recall for face recognition decisions (Memon & Bruce, 1983).

The use of relational memory paradigms to re-instate memory associations specific to particular contexts (here faces and scenes) could provide a useful tool not only when trying to identify people known to be related to a specific crime scene when a person is lying but also to stimulate memory in eye witness recall. The present research also suggests that future studies attempt to further isolate orienting responses to critical items from cognitive load as well as strategies during lies to facilitate clearer distinctions between the mechanisms that modulate fixation behaviour. The research supports that early fixation behaviour can reveal valuable information about memory and response selection processes, some components of which appear involuntary in nature. Finally, the present research explored a more complex deception strategy, misidentification a non-critical face as guilty. Few research studies have explored alternative deceptive response strategies such as intentional selection of known or unknown faces to divert attention from a known culprit (Lefebvre et al., 2009; Schwedes & Wentura, 2012). The present research also suggests that using multiple face displays to extract information relating to knowledge of culprits co-displayed with innocent faces might be more effective in identifying differences in eye movement behaviour that was not evident in the previous experiments when attempting to differences in fixation behaviour between less perceptually distinct faces (e.g, unknown compared to newly learned faces).

CHAPTER 6.

General Discussion

6.1. Aims of Thesis

The overarching aim of this thesis was to evaluate a new approach to detect recognition memory in liars, when recognition of familiar photographs was intentionally concealed. Eye tracking methodology was selected as a novel experimental approach to memory detection in a deceptive context for two key reasons. First, elementary eye movement research consistently shows that fixation patterns and characteristics change as a result of previous exposure, and thus reveal information encoded in memory (for review see Hannula et al., 2010). Second, memory effects reported in basic recognition studies suggest that the effect of previous exposure on visual reprocessing might be involuntary in nature, which is an attractive feature for methodologies that aim to detect memory in applied forensic contexts when interviewees are uncooperative (see Verschuere, Ben-Shakhar, & Meijer, 2011).

More specifically, the thesis examined the effect of deception on fixation-based measures of memory to determine whether memory effects were robust in the face of cognitive efforts required for lying. To achieve this goal, a range of different fixation behaviours displayed by lying participants during concealed recognition of familiar photographs (faces, scenes and objects) that varied in familiarity (newly learned, famous celebrities, personally familiar) were systematically examined. Given the novelty of this research in the field, the paucity of prior research, and the nature of the experimental predictions, this systematic analytic approach (involving the analyses of full trial periods, first fixations, and fixations made just prior to response selections) is fully warranted.

Importantly, the work presented here is the first systematic programme of research to explore the suitability of different fixation measures for the purpose of memory detection whilst systematically manipulating degree of familiarity across different classes of photographic stimuli (faces, scenes and objects). It is also the first research to assess which fixations measures might be best for memory detection given that efforts for lying might disrupt typical visual processing of familiar items. The present research explored whether hypothesised increases in fixation quantity as a result of cognitive load during lies (Cook, Hacker, Webb, Osher, Kristjansson, Woltz, Kircher, et al., 2012) might diminish memory effects in fixation quantity, and whether hypothesised increased fixation durations during lies (Griffin & Oppenheimer, 2006) might magnify memory effects in fixation durations.

At the conception of this doctoral work, there was no published research that explored fixations as a potential measure for memory detection during lying, thus the work was entirely novel in its approach. Since then only two peer reviewed articles have been published on the topic (Peth et al., 2013; Schwedes & Wentura, 2012). However, the main findings presented here remain entirely novel in their contribution to an exciting field of research that is still in its infancy.

6.2. Key findings of the thesis: Reliability of different fixation measures.

Given the findings of the research conducted for this thesis, the question is which fixation measure might be best for memory detection of liars in real-world field applications? Of all the measures, the number of fixations most consistently identified differences between lies about familiar probes and truths about unfamiliar irrelevants. Fewer fixations consistently distinguished lies about recognition of probes, compared to truths about irrelevants, across familiar faces, objects and scenes. Decreased fixations during recognition displayed large significant effects of memory for personally familiar items in addition to memory effects for items that had only been viewed once briefly, albeit notably smaller in effect size. However, the number of fixations also appear somewhat vulnerable to cognitive load during lies in Experiment 1 although this did not change the pattern of significant results overall. In Experiments 2 and 3 there was also a suggestion that cognitive load was interfering with memory effects in the truth data as significant results observed in Experiment 1 were not observed in experiment 2 and 3. Furthermore, Experiments 2 and 3 also suggested that number of fixations was vulnerable to efforts to control fixations during lies about newly learned items as there was a marked decrease in number of fixation during lies about probes but not truths about targets. Experiment 4 primarily examined fixation durations and revealed no unexpected variations in fixation duration that indicated confounding effects of cognitive load or deceptive strategies. The results showed memory effects for face-scene matches in the first fixations as well as longer fixations when making deceptive responses in the last fixation.

The present research suggests that fixation durations might be a better indicator of concealed memory than fixation quantity, since effects of memory and deception would accumulate to produce larger predictive differences during lies about recognition. Furthermore, although fixation durations represent both memory and deceptive efforts, the effect of memory are not likely to be weakened by cognitive efforts during lies. Eye movement research also suggests that individual fixation durations are also less likely to be vulnerable to intentional control (Rayner, 1998). The present research examined the effect of both memory and deception on fixation durations and found them to be intricately linked in first fixations and fixations made just prior to response selections. It was informative to investigate the relative contribution of memory and deception on fixation durations in the present research. In fact some researchers have recently explored the possibility of increasing cognitive load during CITs with the goal of making liars easier to distinguish from truth tellers (Visu-Petra et al., 2013). Since forensic practitioners are mainly concerned with the discriminative ability of the test it is not a main concern whether it is memory, cognitive effort or the two combined as long as the detection of deception is reliable.

6.3. Integration of Empirical Findings

Experiments 1-3 first replicated memory effects found in eye movement studies of basic recognition (Althoff et al., 1999; Althoff & Cohen, 1999; Althoff, 1998; Ryan, Hannula, & Cohen, 2007). In truth trials (standard recognition), memories of previously encoded faces, scenes, and objects changed the way participants viewed photographs of the same items on subsequent viewings. Overall, the resulting effect of memory was a decrease in fixation quantity and an increase in fixation duration during recognition of faces, scenes and objects (henceforth referred to collectively as *items)*. Effect sizes of memory on fixations were large and most reliable for personally familiar items and small and more limited for newly learned items (in terms of number of fixations; but see below for consideration of effects of attempted gaze control). Establishing these initial results allowed examination of deceptive efforts on memory effects during lying within each experiment.

Lies about recognition of well known (personally familiar) photographs produced robust effects of memory in multiple fixation measures. This finding is consistent with memory effects during honest face identifications of personally known items in Experiments 1-3. Slightly smaller memory effect sizes were observed in fixation quantity during lies about personally known faces compared to truths about personally known items, but these tended not to change the overall pattern of results.

Interesting results, however, emerged across Experiments 1-3 patterns when participants lied and told the truth about photographs of less familiar, newly learned, faces and objects and scenes. In Experiment 1 participants lied about recognition, but monitoring of eye movements was not explicitly emphasised as a cue for memory detection. Small memory effects revealing recognition were also observed during both truth and lies about newly learned faces, although the difference between irrelevants and probes did not meet significance after corrections for multiple comparisons. The results suggest that cognitive effort during lies about newly learned faces might have increased the number of fixations made before a response and thus moderated the difference in number of fixations made during honest rejection of unfamiliar faces (irrelevants) and lies about newly familiar faces (probes).

In Experiments 2 and 3, the experimenter explicitly emphasised monitoring of eye movements for the purpose of memory detection during lies. The pattern of fixations during truths and lies about newly learned items (faces, scenes and objects) in Experiments 2 and 3 differed to Experiment 1. In truthful trials memory effects were no longer observed during viewing of newly familiar items, but in lie trials a significant decrease was observed in fixation quantity that could be interpreted as large memory effects. Considering that no memory effects were observed during honest recognition of newly familiar items, it is plausible that participants were in fact attempting to control their gaze that resulted in a marked decrease in fixation quantity during lies (not observed in Experiment 1) and that this effort carried over to the effect of memory in fixations during truthful recognition trials.

In Experiments 2 and 3, participants' apparent efforts to control fixations made it easier to distinguish trials in which participants claimed they did not recognise familiar items from trials in which they honestly rejected unknown items. The observation that apparent attempts to control gaze to evade lie detection in fact made it easier to distinguish lies from truths is consistent with ironic effects of attempted mental control over actions (Wegner et al., 1998) and deception research suggesting that people who invest more effort in trying to evade lie detection paradoxically are less successful at doing so (DePaulo, Kirkendol, Susan, Tang, & O'Brien, 1988; Vrij, Fisher, et al., 2006; Vrij, Mann, et al., 2008). Confirmation that participants made more attempts to control fixations in Experiments 2 and 3 was bolstered by the findings of the *Deception Strategies Questionnaire.* In Experiments

2 and 3, 61% and 80% of participants reported attempting to employ some kind of eye movement strategy to evade lie detection, whereas only 32% reported trying to control their gaze in Experiment 1.

It is also possible that the overall load of Experiment 2 and 3 was much higher than in Experiment 1 and that this cognitive difficulty resulted in participants visually disengaging from the photographs to process the lying task at hand (Doherty-Sneddon et al., 2002; Doherty-Sneddon & Phelps, 2005). However, responses in the *Deception Strategies Questionnaires* for Experiments 1 and 2 suggested that participants found it most difficult to lie about personally familiar items (70 % and 63% respectively). Overall, Experiments 2 and 3 found fewer fixations, fewer run counts and longer fixations presented markers of memory during lies about faces, scenes and objects. Further research, however, is required to elucidate the relative role of memory, cognitive load during lies, and strategies to evade lie detection on characteristics of fixations during lies about recognition.

The verbal confidence ratings that participants reported after each deceptive recognition judgement in Experiments 2 and 3 also suggested memory for personally familiar items (face, objects and scenes) when recognition was denied. Variability in confidence ratings (0-100%) when participants lied about recognising personally familiar items displayed less variability than ratings for faces that were actually unfamiliar. Thus, confidence ratings with low variability observed in Experiments 2 and 3 tended to indicate memory for well-known faces. Although some participants reported attempting to vary their confidence ratings during lies so that their lies were not transparent it seems that participants were not successful in doing so. Thus, patterns of confidence ratings might provide an additional means to index memory when a person is lying about recognition. Significant differences in variability were not found, however, during lies about newly learned items, suggesting that memory for items have to be well-encoded to produce different patterns in confidence variability. Future research might look to the eye witness identification literature to develop more sophisticated techniques such as confidence accuracy classification algorithms to diagnose memory accuracy (Juslin, Olsson, & Winman, 1996; Sauer et al., 2008).

The aim of the final experiment, Experiment 4, was to examine if fixations could reveal memory for face-scene associations and the effort of false identifications on fixation duration. In the first fixation longer fixations revealed memory for faces that matched previously viewed face-scene pairs. The last fixation further showed longer durations when liars selected the incorrect face that did not match the scene compared to the truth teller selection of the face that matched the scene. Given the applied importance of linking suspects with specific crimes, this finding is an exciting and novel contribution to the memory detection literature.

6.4. Contribution to Theoretical Understanding

The general consensus in the literature on face processing is that familiar and unfamiliar faces are processed in a qualitatively different way, and also that there are important differences in the way that we process different classes of familiar faces (Natu & Toole, 2011). Often, experimental research uses previously unfamiliar faces that are learned during a study phase to represent familiar faces. However, previous research (Natu & Toole, 2011) and the findings presented in Experiments 1 and 2 in the present thesis, emphasise that newly familiar faces are not the same as those for which we have multiple real world experiences. Experiment 3 also confirms that this issue also extends to newly familiar objects and scenes compared to those that have real-world familiarity. It is most common that liars will be lying about a person, place or object that has distinct personal significance to them and thus memory detection researchers should bear this in mind in their research.

Experiments 1-3 support and extend basic research (Althoff & Cohen, 1999; Althoff, 1998; Heisz & Shore, 2008; Ryan et al., 2007) indicating that various fixation measures reveal memory for well-known faces (fewer fixations, longer durations), scenes and objects (personally familiar) and that this finding is generally reliable (and produces large effect sizes) when participants make honest identifications or lie about recognition. The findings for memory detection of newly learned items via fixations is not so clear cut.

In Experiment 1, recognition of newly learned faces produced small effects of memory in the number of fixations made during honest identification and lies about newly learned faces (although results for lies were not significant after Bonferroni correction). This finding was encouraging given that participants in Experiment 1 were only briefly exposed to newly learned faces before the concealed information test. Previous researchers who also used single face displays of newly learned faces in standard recognition tests found that participants required at least three separate exposures to new faces before memory effects were reliably observed (Althoff, 1998; Heisz & Shore, 2008). In Experiments 2 and 3 the learning procedure was changed to encourage a deeper processing of newly learned faces (Experiment 2), and objects and scenes (Experiment 3). In lie trials, the resulting fixations were fewer in quantity (number of fixations, run counts, number of interest areas visited) and longer in duration, as predicted by the effect of memory on visual reprocessing. However, the fixation data during honest recognition of the same newly learned items did not produce significant memory effects. The results suggest that liars might have been intentionally controlling their fixations to conceal their deception consistent with explicit task instruction at the start of the experiment stating that they should try to conceal their deceit and that the experimenter would be monitoring their eye movements to detect deception. This is an interesting finding considering that previous research proposes that memory effects in fixations are an obligatory consequence of previous exposure and that they occur whether participants make judgements based on the identity or emotional expression of a face (Althoff & Cohen, 1999), view the face freely (Ryan et al., 2007), make face misidentifications (Hannula et al., 2012) or have no conscious memory of a face such as in prosopagnosia (Bate et al., 2008).

6.4.1. Are memory effects involuntary?

The present results support that recognition of personally familiar items is fast and relatively automatic (Stacey et al., 2005; Yonelinas, 2002) and this makes it less vulnerable to cognitive interference as a result from conflicting recognition processes during lies (Seymour, 2001). The same is not true however, for newly learned faces that are relatively unfamiliar compared to those that are personally known. Memories for newly familiar items tend to be weaker (Hancock et al., 2000) and thus require more effortful recollection. The findings of Experiments 2 and 3 suggest this makes them more vulnerable to cognitive efforts required to execute the response consistent with the lie as well as to maintain strategies to evade lie detection. Thus, the main contribution that Experiment 2 and 3 makes to the existing literature on memory is that fixation based markers of memory appear to be involuntary during automatic recognition of well-known faces, scenes and objects, but that recollection of newly learned items are consciously more effortful and thus are more likely to be vulnerable to cognitive interference as a result of lying. Furthermore, In Experiment 4, the durations of first fixations also revealed memory for face-scene relations despite effort to deceive. This finding provides further support for memory effects that were unable to be concealed.

6.4.2. Effect of Cognitive Load on Memory Effects

Some support was found in Experiment 1 to suggest that memory effects for newly learned faces was diminished by an increase in fixation durations during lies about newly learned faces compared to honest identification of newly learned faces. However, this made little difference to the small effect sizes observed in both truths and lies. It is also possible that the lack of a memory effect during honest identification of newly learned faces, objects and scenes in Experiment 2 and 3 was a result of overall efforts to strategically control fixations during lies. Furthermore, analyses of fixation durations directly before deceptive responses were made (button press and verbal response) always revealed the longest fixation durations which would also suggest that most cognitive effort was experienced during lies. Finally, in Experiment 4, fixations durations in the last fixation before dishonest response selections were longer than those during honest identification of matching faces.

6.5. Limitations and Methodological Considerations

Experiments 2 and 3 revealed particularly interesting results that suggested that participants were strategically attempting to control their eye movements compared to Experiment 1, where no indication of gaze control was observed. The findings suggest that this result occurred, at least partly, as a consequence of a change in task instructions. The aim of Experiment 2 was to emphasise monitoring of memory and eye movements to explore if patterns of confidence (and associated eye movements during decision making) would reveal lies about confidence in relation to recognition judgements. This instructional change had an obvious impact on eye movements during recognition of newly learned faces. To draw stronger conclusions about the effect of strategies and the monitoring of eye movements during deception, future studies should consider deploying a between subjects factor to isolate the effect of instructions for specific gaze strategies on actual characteristics of fixations.

It is also pertinent to raise the issue here that the photographs of newly learned items in Experiments 1-3 were the same at study as they were at test. The decision to use the same photographs for newly learned items at study and test was partly a practical limitation in sourcing enough quality images of the same face, place or object for multiple condition blocks but also because we did not want to make identification of new items further difficult to recognise. Realistically, the items that people lie about are likely personally significant to them. However, in future researchers might wish to determine the presence of memory effects for recognition of different images of newly encoded items (faces, objects and scenes). Memory detection researchers that have examined memory effects during viewing of photographs of objects viewed during mock crime have been unsuccessful in identifying memory effects for photographs of crime objects that were not central to the mock crime (Peth et al., 2013; Twyman et al., 2010). The problem with identifying a person with whom you have only had brief and limited visually exposed of is a common limitation in eyewitness identification of suspects. Genuine eyewitnesses are prone to identification errors especially if they have only witnessed a crime in passing and the information is only incidentally encoded (Hope & Sauer, 2014). When contemplating concealed recognition the problem is more commonly the opposite; the suspect is concealing recognition of a person whom they have a personal association thus consequently should identify quite easily.

6.6. Potential Field Application.

The current research suggests that fixation-based measures of memory have potential for field use. However more research is required to establish the reliability of fixation-based memory effects for newly familiar items. Even more importantly, research into possible efforts to countermeasure memory effects require more thorough investigation. In Experiments 2 and 3 the experimental briefing emphasised eye movement monitoring as a means for memory detection in liars and observed different slightly different patterns of results than in Experiment 1, where no explicit emphasis was put on evading lie detection. Possible countermeasures strategies might include using visual imagery to disrupt visual processing patterns when viewing familiar faces (Ganis et al., 2011; Ganis & Schendan, 2008), scenes or objects, or employing a deterministic pattern of viewing behaviour (such as looking at each feature of a face in turn; Althoff, 1998), so that viewing behaviour was consistent when viewing familiar and unfamiliar items.

Furthermore, before fixations are considered for potential memory detection in the field, laboratory studies should examine which Concealed Information Test protocol is best for fixation-based memory detection. There are two main versions of The Concealed Information Test, one presents a single probe in each test block and the other presents multiple probes of different familiar items in the same tests block. The 1-probe block presents only a single probe (familiar item that is lied about), a single target (familiar item that is honestly identified) and at least four irrelevant (unfamiliar) items. Each item is repeated at least four times. The multiple probe block (e.g., Allen, Iacono, & Danielson, 1992; Farwell & Donchin, 1991), however, presents multiple probes, targets and irrelevants within each single block. Each probe is usually from a different category (such as a weapon, or a person) and matched across targets and irrelevants. Farwell and Donchin (1991) typically used six probes within each block, mixed randomly among 6 targets and 24 irrelevants. Each protocol has both advantages and disadvantages. The multiple probe block is a more efficient way to gather data but puts the examinee under more task demand. The detection efficiencies of the two tests were recently examined using an ERP300-based CIT (Rosenfeld et al., 2007). The results suggested that task demands for the multiple probe block was greater than the single probe block and that a trend in the data favoured ERP300 sensitivity in the single probe block.

The experiments presented in the current thesis were variations of a multiple probe block test. Experiments 1-3 each presented 10 probes of the same (faces) or similar category (objects and scenes) which may have made the task particularly difficult and thus impacted the strength of memory effects manifested in eye movement patterns. Furthermore, the ratio of targets and probes to irrelevants also differed to the single and multiple probe protocols outline above. To address this methodological issue, an additional study has been developed to assess the discriminative power of the two tests using fixations as markers of memory. Pilot data has now been collected and refinements are being made to the design before re-commencement of data collection during 2015. Although this additional study falls outside the remit of current thesis, it represents the onward trajectory of this research.

In addition to identifying the optimal method, another important empirical direction before considering real world applications would be to test how fixation-based memory detection compares to the discriminative ability of ANS-based concealed information tests. Skin conductance rate was the first successful measure of concealed or guilty knowledge with high detection rates (Lykken, 1959, 1960) and is the main procedure utilised by practitioners in the field, although only consistently in Japan (Matsuda, Nittono, & Allen, 2012; Osugi, 2011). In fact, it is reasonable to suggest that all new methods should be compared to autonomic measures of detecting concealed information (Gamer, 2011).

6.7. Conclusion

Achieving its key aim, this thesis has empirically examined the effect of deception on fixation-based memory effects across four different experiments. Memory effects have been shown to reliably expose lies about personally familiar faces, scenes and objects in Experiments 1-3. Memory effects for familiar items were robust to cognitive efforts required for lying. Experiment 4 also showed that memory effects reveal associations for specific face-scene relations. The effect of deception on memory effects was less clear, however, during truths and lies about recognition of newly familiar items. Fixation-based measures of memory during recognition of newly learned items appeared somewhat vulnerable to both cognitive load and gaze strategies. Future research should further examine the effect of cognitive load and deceptive strategies on fixation-based memory effects and to determine if fixation measures are reliable in the face of countermeasures. Should fixation-based measures of memory detection prove robust in the face of cognitive efforts and deceptive strategies then further assessment should compare its efficacy or incremental validity alongside ANS-based CITs.

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