

Tracking the truth: The effect of face familiarity on eye fixations during deception.

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Abstract

In forensic investigations, suspects sometimes conceal recognition of a familiar person to protect co-conspirators or hide knowledge of a victim. The current experiment sought to determine if eye fixations could be used to identify memory of known persons when lying about recognition of faces. Participants' eye movements were monitored whilst they lied and told the truth about recognition of faces that varied in familiarity (newly learned, famous celebrities, personally known). Memory detection by eye movements during recognition of personally familiar and famous celebrity faces was negligibly affected by lying, thereby demonstrating that detection of memory during lies is influenced by the prior learning of the face. By contrast, eye movements did not reveal lies robustly for newly learned faces. These findings support the use of eye movements as markers of memory during concealed recognition but also suggest caution when familiarity is only a consequence of one brief exposure.

Introduction

Forensic investigations routinely necessitate that investigators differentiate guilty and innocent suspects. Depending on the nature of the crime, a key task may be to determine when a suspect is lying about recognising a person believed to be linked to the investigation. Suspects might lie about a known person to protect a fellow co-conspirator or knowledge of a known victim. For instance, if shown photos of gang members already known to the police (and believed to be known to the suspect), a suspect might deny that they recognise any of the individuals presented. A crucial point is that denying person recognition will likely involve concealing the recognition of both well-known and lesser known persons. It is essential, then, that any method employed to detect concealed recognition can reliably detect knowledge of both strongly and weakly encoded memories. The aim of the present research was to determine whether eye fixations signified recognition when an individual lied about recognising a person known to them. Furthermore, the present experiment explored whether fixation patterns indicative of memory were robust across recognition of familiar faces types that differed in the way and degree that they were learned (newly learned, famous celebrities, personally known).

Unfamiliar faces become familiar in different ways and are, as a consequence, represented differently in the visual system. A face that is familiar because we have briefly encountered an individual in the street represents a single facial episode of that person based on visual familiarity (Klatzky & Forrest, 1984) and minimal associated information (Bruce & Young, 1986). Although human memory for faces is a highly specialised skill such that individuals can recognise a face at test following a brief study exposure, memory representations for newly learned faces are weak and thus recognition for such faces are highly fallible and prone to memory errors (Hancock, Bruce, & Burton, 2000). That different kinds of familiarity affect the nature of representations has been demonstrated in the

neuroimaging literature where different classes of familiar faces have been shown to activate distinct neural pathways in the brain (for review see Natu & O'Toole, 2011).

Cognitive-based models of face recognition explain these different representations in terms of different subcomponents of recognition. 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 access FRUs and personal identification nodes (PINs) facilitating fast and accurate recognition and recollection of information relating the person's identity (see also Yonelinas, 2002). Furthermore, the basis of familiarity for famous faces (photographic images and media-sourced information) is also quite distinct from the basis of personal familiarity encountered regularly on a day-to-day basis that include additional social and emotional experiences/associations (Gobbini & Haxby, 2007; Gobbini, Leibenluft, Santiago, & Haxby, 2004).

Neural network models of face recognition are based on the assumption that, during face learning, with each new exposure to a face, stronger and multiple memories are created that are represented more richly in neural networks for later access and retrieval (Schacter, Norman, & Koutstaal, 1998). Essentially, the processing of an unfamiliar face requires more effort for information processing in the initial viewing, whereas a familiar face is already represented in memory and, as a consequence, requires less effort for recognition on subsequent viewings (Bruce & Young, 1986; Burton, Jenkins, & Schweinberger, 2011). This decrease in cognitive effort for familiar face recognition has been documented via indirect tests of memory that report faster speed, higher accuracy and higher confidence recognition judgements for richly encoded memories (Balas, Cox, & Conwell, 2007; Ellis, Shepherd, & Davies, 1979; Osborne & Stevenage, 2013; Scapinello & Yarmey, 1970). More relevant to the present research, studies that measure eye movements document a gradual decrease in fixation quantity with increased familiarity and expertise for more familiar faces (Althoff,

1998; Althoff et al., 1999; Heisz & Shore, 2008). The aim of the present research is to explore how memory strength for different familiar face types directly impacts the quantity and distribution of eye fixations and if these fixation patterns can be used to detect memory for faces when individuals lie about recognition.

A class of tests known as Concealed Information Tests (CITs) have been explicitly developed to identify deception about recognition (usually multiple choice answers to specific questions, for a recent volume reviewing CIT methodologies see Verschuere, Ben-Shakhar, & Meijer, 2011). Encoding of details relating mock crime studies have revealed memory strength to impact the discriminative ability of the test (Carmel et al., 2003; Gamer, Kossiol & Vossel, 2010; Peth, Kim & Gamer, 2013), yet no research has directly assessed familiarity strength on the ability to detect person recognition. Face recognition is complex, depending on kind and degree of familiarity, and so it is important to understand how these features will impact concealed recognition of known faces. The current experiment systematically manipulated the familiarity of concealed faces and required participants to lie about different groups of faces (newly learned, famous celebrities, personally known) during a modified Concealed Information Test (*mCIT*) whilst eye fixations were recorded to assess recognition. This study is novel in combining eye movement monitoring with a *mCIT* to investigate whether eye movement patterns might facilitate memory detection of known faces that varied in familiarity.

To date, studies of concealed person recognition have not exploited what basic research has shown about different processing of different kinds of familiar faces. The majority of CIT research has used experimental exposure to faces to establish familiarity (Bhatt et al., 2009; Schumacher, Seymour, & Schwarb, 2010; Schwedes & Wentura, 2012; Seymour & Kerlin, 2008; Lefebvre, Marchand, Smith, & Connolly, 2009). Other work has used images of famous celebrities to represent familiarity (Ganis & Patnaik, 2009). Finally, a

relatively small number of studies have used faces that are more representative of real-world familiarity, such as university professors, friends and siblings (Meijer, Smulders, Merckelbach, & Wolf, 2007; Meijer, Smulders, & Wolf, 2009). Considering extant face research that document activation of different neural network pathways during recognition of different types of familiar faces, it is pertinent to explore how these different types of memory representations manifest in eye movement fixation patterns.

Comparing CIT studies that have used different kinds of familiar faces highlights the importance of further research considering familiarity type. In a study by Meijer and colleagues (2007), for highly familiar faces (i.e., siblings and best friends) and under instructions to actively conceal recognition, 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), highly familiar faces were probed without instructions to conceal recognition, and detection was successful. The results of these two studies indicate that photographs of personally known and highly familiar faces elicit stronger markers of recognition and, as a result, increase the likelihood of correct discrimination in CIT methodologies.

Research on concealed recognition has used a variety of measures including the skin conductance response, reaction times, event related potentials (ERPs) and neuroimaging fMRI to detect recognition (Verschuere, Ben-Shakhar, & Meijer, 2011). The current experiment presents a modified eye movement-based concealed information test (EM-*m*CIT). Eye movement monitoring was selected as a novel methodology for concealed memory detection because eye movements during non-deceptive face-recognition tasks consistently reflect memory (for review see Hannula et al., 2010). Specifically, there are fewer fixations during processing of familiar compared to unfamiliar faces. Previous experience with a

person's face results in distinct changes in the quantity and distribution of fixations during face recognition (Althoff & Cohen, 1999). Althoff and colleagues 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. Importantly, the effect of memory on eye movements, or the Eye Movement-based Memory Effect (EMME), has been observed for familiar faces that differ in type and degree of familiarity that include experimentally induced familiarity (Althoff, 1998; Heisz & Shore, 2008), famous celebrities (Althoff & Cohen, 1999; Ryan, Hannula, & Cohen, 2007), and personally known faces (van Belle, Ramon, Lefèvre, & Rossion, 2010).

In the EMME, there are fewer fixations as a face is viewed more often (i.e. becomes more familiar). The differences in fixation patterns, therefore, not only discriminate processing of familiar and unfamiliar faces but also index recognition strength. Experiments using multiple face displays have observed memory effects for newly familiar faces after a single five second exposure (Ryan et al, 2007) whereas experiments using single face displays observed memory effects after three (Althoff et al., 1999; Althoff, 1998) to five (Heisz & Shore, 2008) exposures.

Gaze behaviour is multifaceted, and the EMME has been observed in a wide range of different fixation measures including number of fixations, number of regions of the face viewed, number of return fixations to previously viewed regions of the face, number of fixations directed to the inner regions of the face and fixation durations (for review see (Hannula et al., 2010)). Each eye movement measure taps into subtly different aspects of visual processing. For example, the number of fixations reflects cognitive effort in general, such that recognition of less familiar faces receives more fixations before a judgement is made (Althoff, 1998; Althoff et al., 1999; Heisz & Shore, 2008). The number of face regions viewed demonstrate the spatial distribution of face processing whereas the number of times

gaze returns to specific areas of interest on faces is thought to reflect featural ambiguity during processing (Barton, Radcliffe, Cherkasova, Edelman, & Intriligator, 2006). Finally, the information rich inner regions of the face (eyes, nose and mouth) are particularly important for person recognition (Bruce et al., 1999; O'Donnell and Bruce, 2001) and eye movement records reveal that the majority of fixations during recognition are directed to these key face features (Althoff & Cohen, 1999; Heisz & Shore, 2008; Stacey, Walker and Underwood, 2005; Walker-Smith et al, 1977). Furthermore, when responses are honest, there is more extensive viewing of inner face regions for unfamiliar than for familiar faces (Althoff, 1998; Althoff & Cohen, 1999). This viewing pattern during correct rejection of unfamiliar faces is thought to reflect a sampling without replacement strategy, to optimise extraction of information from unknown faces (Stark & Ellis, 1981). For this reason the present research considered multiple fixation measures.

A further key feature of the EMME is that some researchers suggest it might be involuntary in nature, and occurring irrespective of the nature of the task (Althoff et al, 1999; Ryan et al, 2007). The proposed involuntary nature of memory on eye fixations has been documented in non-recognition based tasks (judgements based on emotions) and during false rejection of familiar faces in both typical (basic memory errors) and clinical populations (e.g., prosopagnosia; Bate, Haslam, Tree & Hodgson, 2008). For a measure to be useful in a CIT, it is important that liars are not able to easily alter the behaviour. Thus, the involuntary nature of the EMME promotes gaze behaviour as a prime candidate for a CIT measure, as it might be more resistant to deceptive strategies than other simple CITs, such as those based on the monitoring of reaction-time based data, which some researchers suggest might be particularly vulnerable to countermeasures (Farwell & Donchin, 1991; Rosenfeld, Soskins, Bosh & Ryan, 2004). Recent research has shown that even technically complex and expensive CIT measures such as ERPs or fMRI are not resistant to simple countermeasures (Ganis,

Rosenfeld, Meixener, Kieviet & Schendan, 2011; Rosenfeld et al., 2004). Combined, the proposed involuntary nature of the EMME and its relative practical ease of administration make fixation-based CITs appealing for potential field use. From a theoretical perspective, eye movements are thought to track online cognitive processes (Just and Carpenter, 1976) and thus also fit with contemporary, cognitive models of deception and memory detection (Walczyk, Igou, Dixon, Tcholakian, 2013).

Cognitive effort also plays a role in both face recognition generally and lying about recognition. Tasks that are cognitively effortful tend to result in increased reaction time which generally increases fixation behaviour. The longer the fixation 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 both during honest behaviour (Griffin & Bock, 2000; Griffin, 2001; Meyer, Sleiderink, & Levelt, 1998; Meyer & van der Meulen, 2000) and dishonest behaviour, with some evidence that the effect is amplified in deception (Baker, Stern, & Goldstein, 1992; Cook, Hacker, Webb, Osher, Kristjansson, Woltz, Kircher, et al., 2012; Griffin & Oppenheimer, 2006).

The finding that deceptive responses produce more fixations compared to telling the truth is consistent with the Cognitive Load Theory of Deception (CLT: Vrij, Fisher, et al., 2008). CLT is based on the assumption that lying involves additional cognitive operations that make lying harder than truth telling, a concept that defines most contemporary and well-accepted approaches to lie detection (Vrij, Hope, & Fisher, 2014). Cognitive accounts 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 present research further assessed the effect of cognitive demands during lies about recognition, which may potentially impact recognition-based eye movement patterns. No research to date has assessed the effect of cognitive load during lying on the EMME.

One recent publication has attempted to combine a CIT with eye movements to detect concealed recognition. Schwedes and Wentura (2012) used a modification of a standard CIT design in which participants lied about recognition of some familiar faces (probes) whilst correctly classifying the other familiar faces (targets) and correctly rejecting unknown unfamiliar faces (irrelevants). The photographic face stimuli in the Schwedes and Wentura (2012) study were presented in circular arrays of six-face displays (not typical in a standard CIT). Face stimuli were all pre-experimentally unfamiliar. During a study phase, participants were requested to learn one set of faces as their 'friends' and another set as 'foes'. Participants viewed each face during a learning task at least three times as required for a memory effect documented by Althoff (1998). Participants were presented 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. In the neutral display all photographs were of unfamiliar faces but participants were instructed to select one arbitrarily. The main result of the study supported an effect of memory: Fixations on concealed faces (known but not selected) were longer than fixations on unfamiliar faces that were not selected in the neutral display.

The current research 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 (familiarised by repeated exposures during a single study phase) by asking them to select an unknown face in a six-face display. Our research explored 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. For the test to have wider ecological validity it is important to establish whether eye fixations can index concealed recognition when prior learning of the face differs in type and degree. Crucially, the present experiment tested the boundaries of eye fixations as an index of recognition for newly familiar faces after only one brief exposure. The present research also used single face presentation mode that is typical of a standard CIT (see Osugi, 2011). Also, Schwedes and Wentura's primary aim was to dissociate the effect of the cognitive effort of responding from memory, thus they did not explore the effect of deceptive load (such as response conflict) on existing memory effects. We considered it important to explore the effect of cognitive load during the act of memory concealment. A recent memory-based model account of the 'guilty knowledge effect' explained it by a number of parallel processes required for concealed recognition such as memory, response selection, response preparation and motor execution (Seymour, 2001). Such comprehensive accounts of guilty knowledge behaviour are becoming more evident in the CIT literature (e.g., Ambach, Stark, Peper & Vaitl, 2008; Vershuere, Crombez, Smolders & De Clerq, 2009) and offer a fuller account of sub-processes pertaining to concealed recognition than the original Orienting Response (OR) Theory (Sokolov, 1963) that discount the relevance of emotional-motivational factors in the guilty knowledge response (Lykken, 1974). Finally, Schwedes and Wentura only explored one fixation measure. The present experiment examined the effect of deception on a range of different fixations measures.

To summarise, the current experiment tested whether eye-movement behaviour differed when observers falsely stated that they did not recognise familiar faces, where familiarity type was systematically manipulated. A range of eye movement parameters were recorded in this study: 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 fixations made to informative inner regions of the face (Stacey et al., 2005). To assess the effect of cognitive load during deceptive and honest responses to familiar faces, we made the following predictions: (i) recognition of familiar faces would produce a memory effect via a decrease in fixation quantity and corresponding differences in other eye-movement measures; (ii) the effect of memory on eye fixations would be stronger for more familiar faces (personally known) than for less familiar faces (famous faces or newly-learned faces); and (iii) lying would require more cognitive effort than truth telling which potentially would increase fixation quantity and diminish the EMME.

Method

Design

The research used a *mCIT* method during which participants lied and told the truth about recognising different types of familiar faces. A 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

59 undergraduate students (46 females; Age $M = 19.60$ years, $SD = 3.60$; range 18-55 years) participated in the experiment. All participants reported having normal or corrected-to-normal vision and were awarded course credit for their participation. Participants were recruited from pre-existing tutorial groups so that photographs of tutorial group members could be used as personally familiar stimuli in the experiment.

Apparatus and Materials

Participants' eye movements were tracked using the Eyelink II head mounted eye tracker (SR Research, Canada). 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. A programme presenting the images was written using Experiment Builder (Version 1.6.121, SR Research) on a desktop computer linked to a 19-inch CRT Monitor (model ViewSonic G90FB; resolution, 1280 x 1024 pixels; refresh rate 89Hz). Manual button press responses were collected by a Microsoft Sidewinder Plug-and-Play game pad.

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. Each 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).

Personally known faces for each participant were faces of fellow tutorial group members photographed against a blue background screen using a SONY Cybershot digital

still camera (model, DSC-W55), a tripod stand, and spot lamps for studio lighting. At the time of the first experimental trials, participants had been in these tutor groups for at least five months, which meets the criteria for reasonably close familiarity (Wegner, Erber, & Raymond, 1991). In addition, a team-building activity conducted during the photo-shoot asked each participant to share five pieces of personal information with their fellow group members; full name, age, place of birth, a personality characteristic and favourite pastime. Participants then recalled, as a group, each person's details. In the current study the participants were not necessarily groups of friends and so may have had varying degrees of personal interaction. Recent models of person recognition emphasise distinct differences between real-world familiarity and other types of face familiarity (newly learned, famous celebrities) on a number of factors that include social and emotional knowledge (Gobbini & Haxby, 2007; Gobbini, Leibenluft, Santiago, & Haxby, 2004). The purpose of the team building task was to ensure that all participants had a common social experience and associated biographical knowledge with each member.

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. Familiarity ratings were recorded just prior to the concealed recognition test primarily to ensure that tutor group members had maintained familiarity and had not forgotten their peers between the time of photographic stimuli preparation and the test date. A RM ANOVA 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 ($M = 3.42, SD = 0.92$) increased after the familiarisation process ($M = 4.30, SD = 1.12; t(43) = 5.91, p < 0.001$) and again by the time of the *mCIT* ($M = 5.16, SD = 0.68; t(43) = 4.88, p < 0.001$).

For each block of memory testing, a new set of photos were used. For famous and personally familiar faces, different photos of the same persons were used in each different condition block. For newly-learned faces, new faces were learned before each block.

Famous faces were contemporary celebrities faces sourced on the internet. During the team-building task, participants each identified a celebrity that matched their own face in terms of hair, eye and skin colour. The experimenter sourced one photo of the celebrity for each individual student (10 students in each group) for each block (5 condition blocks), equalling 10 unique famous celebrity photographs in total for each block of trials for each group.

Newly learned faces were unfamiliar faces that became familiar during a study phase within the experiment. 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. The same images were used at study and at test.

The appearance of all photographs was standardised using Adobe Photoshop Elements (Version 2.0) for the removal of red-eye, accessories and jewellery and for making the background a standardised blue (HEX: 91BE87) measuring 666 x 500 pixels. The mean image size was approximately 4.03° of visual angle ($SD = 1.32$), and was centred either 1/3

or 2/3 of screen width from the left edge of the screen (i.e., to the left or right of fixation). The choice of image location was random to minimise anticipatory eye movements.

Newly familiar and unfamiliar faces were resourced from the unfamiliar face data bases of Glasgow University (GUFDB; Burton, White, & McNeill, 2010); the Psychological Image Collection at Stirling (PICS; <http://pics.stir.ac.uk>) and The CBCL face database (<http://www.ai.mit.edu/projects/cbcl>). Staff and students from local colleges also volunteered to have their photographs taken to create an extended database for the present experiment.

Procedure

Participants were seated in a 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 and were asked to rate each of them for familiarity, attractiveness, distinctiveness and using seven-point Likert scales. The personally familiar faces were rated for familiarity before the concealed recognition test to ensure that group members were still familiar with their peers before the experimental phase. Attractiveness and distinctiveness ratings were further requested so that the procedure for rating personally familiar faces was similar to the processing of newly learned faces at study. The ratings were also collected should the researchers wish to further explore the relationship between eye movements, familiarity, attractiveness and distinctiveness as post hoc analyses. There was no time limit for the rating 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 Eyelink II headband was comfortably secured to the participant's head, and 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. 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. Where

necessary, the calibration was repeated between condition blocks. In addition, calibration was checked and drift-corrections made before each face was presented during the experiment. Following calibration, and prior to the test phase, participants “learned” the faces subsequently labelled as newly-learned.

During each block of the CIT, participants were presented with a sequence of 40 full face colour photographs in random order. Within each condition block unfamiliar (10), newly learned (10), famous celebrities (10) and personally known (10) faces were displayed. 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. 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 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 (Leal & Vrij, 2008, Hannula et al., 2012). These data were intended for separate analyses but for clarity we do not report them here.

(Figure 1 about here)

Instructions were different in each of the blocks of trials. In the first block, which was treated as a practice block, participants were required to respond honestly to all trials. Three lying blocks were then presented in a fully counterbalanced order across participants. In the lying blocks 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 that they lie about personally known faces whilst telling the truth about all other face types. Note that participants were always truthful about unfamiliar faces.

When all 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.

Measures

Data Viewer (Version 1.6.121, SR Research) was used for distilling eye-movement measures for analyses. Interest areas marked included each eye individually, the nose, and the mouth. The rest of the face, including hair, ears, cheeks and chin were labelled the outer face area. Measures analysed included 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, defined as fixations on the eyes, nose, and mouth).

Analysis Strategy

First, probes (lies about familiar faces) were compared to the irrelevant (truths about unknown faces) to assess the presence of memory effects when participants lied about recognition. Second, targets (truths about familiar faces) were compared to the same irrelevant (truths about unknown faces) to assess memory effects in fixations during honest

recognition. Each analysis was performed using separate Repeated Measures Analyses of Variance (RM ANOVA) for each fixation measure: number of fixations, run counts, IAs visited, proportion fixations inner (fixation quantity and distributions as analysed in Althoff & Cohen, 1999). The parameter threshold used to define fixations was set at 100ms. No upper threshold was defined. Note that the analyses conducted in the present experiment (false rejection of known ‘probes’ to correct rejection of unknown irrelevants) are consistent with the original Guilty Knowledge Test (Lykken, 1959; 1960). The addition of target item (in this experiment correct identification of familiar faces) is a relatively new addition to the original GKT (see Farewell & Donchin, 1991; Rosenfeld et al., 2004) to encourage attention toward the stimuli so that the participant does not respond “unfamiliar” for every trial without properly engaging in the test. The target also presents a benchmark by which responses to probes are sometimes compared. The CIT is the most reliable and valid tool for the study of memory detection during lies about recognition (Ben-Shakhar, Bar-Hillel & Kremnizet, 2002; Ben-Shakhar & Elaad, 2003; Lykken, 1998).

Where Mauchley’s Test of Sphericity were violated, RM ANOVAs were calculated using Greenhouse Geisser adjustments to degrees of freedom. The corrected p value and Greenhouse Geisser epsilon (ϵ) are reported for F tests. Post hoc tests were performed using paired sample t-tests. P values were adjusted for the number of post hoc tests conducted ($\alpha=0.017$). Bonferroni corrections were made, since there were multiple tests on multiple fixations measures.

Results

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 or 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: unknown faces (truths 8%), newly learned (truths 8%, lies 13%) famous celebrities (truths, 3%, lies, 1%), and personally familiar (truths, 3%, lies, 10%). These exclusion criteria resulted in removal of 6.7% of the data in the Lie-Learned condition, 4.49% in the Lie-Famous and 6.65 % Lie-Personal condition. This left 4966 trials out of the original 5280. Outliers in the reaction time data were removed if they were faster than 300 ms or slower than 5000 ms. This removed a further 54 trials (1.09%) leaving a total of 4912 trials out of the original 5280.

Lies: Comparing “Unknown” Responses (Irrelevants and Probes)

Figure 2 shows eye-movement measures for targets, irrelevants and probes. RM-ANOVAs were performed on four different ways in which participants responded that a face was unfamiliar: truth about unknown faces (Irrelevants), lies about personally known faces (Probes), lies about famous faces (Probes), and lies about newly learned faces (Probes). Analyses reveal significant differences in fixation behaviour in all four parameters measured; Num. Fixations, $F(2.3, 88.18) = 13.16, p < 0.001, \eta^2 = 0.26, \eta^2 = 0.11$, Run Count, $F(2.34, 12.67) = 12.67, p < 0.001, \eta^2 = 0.25$, IAs Visited, $F(3, 114) = 19.23, p < 0.001, \eta^2 = 0.34$, Prop. Fixations Inner, $F(2.49, 94.43) = 4.51, p = 0.01, \eta^2 = 0.11$, with medium to large effects across measures. Post hoc tests are reported in the order of responses to newly learned faces, famous celebrities and personally known faces.

When participants concealed recognition of newly learned faces, a trend in the data suggested that fixations were fewer during concealed recognition compared to honest rejection of unfamiliar faces for Num. Fixations, $t(43) = 2.22, p = 0.03, d = 0.23$. No significant effects of memory emerged for the remaining three measures, Run Count, $t(43) = 1.737, p = 0.09, d = 0.16$, IAs Visited, $t(43) = 1.87, p = 0.07, d = 0.21$, Prop. Fixations Inner, $t(43) = 0.21, p = 0.83, d = 0.03$.

When participants concealed recognition of famous celebrity faces, fixation behaviour was significantly less compared to honest rejection of 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, $t(43) = 3.28, p = 0.002, d = 0.40$. No significant effect of memory was found for Prop. Fixations Inner $t(43) = 1.99, p = 0.05, d = 0.20$.

When participants lied and reported that they did not recognise a personally familiar face compared to honest rejection of 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, $t(43) = 3.60, p = 0.001, d = 0.45$. Post hoc tests are reported below.

(Figure 2 about here)

Truth trials

Repeated Measures ANOVAs were performed on truth data with four independent levels of face familiarity: unfamiliar faces (irrelevant), newly learned faces (target), famous celebrity faces (target), and personally known faces (target). There was a main effect of familiarity type in all four eye movement parameters; Num. Fixations, $F(2.50, 94.92) =$

33.35, $p < 0.001$, $\eta p2 = 0.47$, Run Count, $F(3, 114) = 31.25$, $p < 0.001$, $\eta p2 = 0.45$, IAs Visited, $F(3, 114) = 22.44$, $p < 0.001$, $\eta p2 = 0.37$, Prop. Fixations Inner, $F(3,114) = 3.24$, $p = 0.025$, $\eta p2 = 0.08$, showing substantial medium-large effect sizes across measures (see Figure 2). When participants truthfully identified newly familiar, famous celebrities and personally known faces all four eye movement parameters significantly differed from the quantity of these four measures when correctly rejecting recognition of unknown faces.

As shown in Figure 2 above, when participants honestly identified newly learned faces, significantly fewer fixations were made compared to the correct rejection of unknown faces in Num. Fixations only, $t(43) = 2.72$, $p = 0.009$, $d = 0.28$. Trends were observed that suggested fewer IAs Visited during recognition of newly familiar faces, $t(43) = 2.12$, $p = 0.04$, $d = 0.25$, as well as fewer Run Counts, $t(43) = 2.22$, $p = 0.03$, $d = 0.22$. No significant effect of memory emerged for the measure Prop. Fixations Inner, $t(43) = 1.92$, $p = 0.06$, $d = 0.21$.

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, $t(43) = 7.22$, $p < 0.001$, $d = 0.82$, 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, $t(43) = 3.69$, $p < 0.001$, $d = 0.33$.

When participants revealed recognition of personally known faces they made significantly fewer 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 Prop. Fixations Inner, $t(43) = 2.28$, $p = 0.027$, $d = 0.25$.

Thus, when observers were telling the truth, this study provided converging evidence for the effect of recognition strength of the EMME (Althoff & Cohen, 1999).

Discussion

The current experiment aimed to determine whether concealed recognition could be detected in liars' eye fixations when they lied about three different types of familiar faces: newly familiar, famous and personally known faces. The main findings supported predictions that fixation quantities would reveal lies about recognition of personally known and famous celebrity faces.

The effect of recognition (fewer fixations) were clearest and most reliable during lies about personally known faces where effects of memory were observed across all four fixation measures. The largest effect sizes were observed in the number of fixations, which produced fewer fixations when participants deceptively denied recognition of personally known faces compared to correct rejection of unknown faces. The smallest effect sizes were observed for proportion of fixations directed to the inner regions of the face.

Lying about recognition of famous celebrities also revealed memory effects, with fewer fixations, fewer returns to previous viewed regions of interest and fewer interest areas of the face visited. As with personally known faces, effect sizes were largest for the number of fixations made to the face. No effects of memory were observed in the proportion of fixations directed to the inner regions of the face, suggesting that the effect of memory was less reliably detected during lies about lesser known faces. This result may be a consequence of cognitive effort during lies, however we acknowledge that famous celebrity photographs were less consistent in pose, lighting and expression than the other categories of test images, and this might have exerted some influence on fixation patterns during recognition. Previous research suggests that face recognition is disrupted by physical properties of the image such as facial expression (Bruce, 1982; Bruce et al, 1999, Patterson & Baddeley, 1977), viewpoint (Bruce, 1982; Bruce et al., 1999; Hill & Bruce, 1996; O'Toole, Edelman, & Bulthoff, 1998;

Roberts & Bruce, 1989) and lighting (Hill & Bruce, 1996) when images are relatively unknown. Famous celebrity photographs in the present experiment were selected based on known celebrities reported by participants, however future deception research may wish to address this issue more directly.

Lies about newly learned faces did not produce any reliable memory effects in any of the fixation measures with the exception of a trend suggesting an effect of memory in fewer fixations when participants lied about recognising newly familiar faces. It should be noted that the present data might be considered conservative given Bonferroni corrections for multiple comparisons. On the other hand, the use of identical images during learning and test in this condition should have strengthened memory. Hence the weakness of the memory effects is even more notable. Future research should present unique images at study and test to further assess the limitation of fixations to detect memory during lies about recognition of newly familiar faces after one brief exposure.

Compared to the equivalent honest recognition judgements of the same classes of familiar faces, the patterns of fixation data were similar with two exceptions. Overall, effects sizes of memory were larger during honest recognition judgements suggesting a small effect of cognitive load that tended to increase fixation quantities during lies compared to truthful responses. Most notable was the finding that an effect of memory was observed in the number of fixations during honest recognition of newly familiar faces but only a trend approaching significance was observed during lies about the same face type. The results are consistent with previous research using single face displays in that effects of memory are weak after only a brief exposure and only become robust after three (Althoff et al., 1999; Althoff, 1998) or five face exposures (Heisz & Shore, 2008). They are not consistent, however, with previous research using multiple face displays that reveal effects of memory after only 5 second exposure to a previously unfamiliar face (Ryan et al., 2007). It is unclear

why effects of memory might be exposed more easily in multiple face displays compared to single face displays. The study by Ryan and colleagues, however, did not involve deception and it is possible the effect of deception increased fixation quantity overall such that weaker memory traces for less familiar faces are not as robust during tests of concealed recognition compared to more basic research. Future research should further explore the relationship between the sensitivity of fixations to detect concealed recognition and presentation display type.

Another explanation of the lack of memory effects for newly familiar faces is that it is possible that weaker certainty of recognition of newly learned faces during lie trials was compounded by the difficulty of concealing recognition, resulting in guessing behaviour. Guessing behaviour could most certainly explain the lack of memory effects for newly learned faces, although it should also be noted that the statistics reported here are extremely conservative due to the number of analyses conducted. In light of the current finding, future studies could use fewer measures from the outset, and so a more liberal criterion would be employed for any one measure.

An unexpected finding was observed in the proportion of fixations made to inner face regions during lies about personally familiar faces. This decrease in proportion of fixations resulted in a larger difference between unfamiliar faces and familiar probes which suggests a larger effect of memory. The decrease was contrary to predictions that lying would be harder and thus increase fixation quantity. This exception in fixation behaviour was also 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 irrelevant and probes, compared to effect sizes observed between irrelevant 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. 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. Future research should seek to disentangle the mechanisms underpinning these results. The present findings on proportion of fixations, however, suggest that this measure should not be relied upon for detection of deceit.

In sum, this research supports the notion that a number of different fixation measures present markers of memory during lies about recognition. The nature of prior learning of faces affected the ability to detect memory: Results were most clear and reliable for personally familiar faces where memory effects decreased all four fixation measures. One particular eye movement measure, number of fixations, most consistently displayed effects of memory (fewer fixations) for all face types, with large effect sizes for personally known faces and 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). 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 might not be a particularly reliable measure for the purpose of

memory detection. Future research should further investigate the robustness of different fixations measures during lies where the stakes are high as in real world situations.

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Figure 1: Sequence order of display screen presentation in test trials. Participants made familiar/unfamiliar (button press) responses to each face. The face remained on the screen for 2 secs post response followed by a blank screen for two seconds. Each trial was preceded by the fixation dot to ensure accuracy of eye movement data. The white dot seen in the figure when the face was presented was not displayed. It indicates for the reader the position of the fixation dot that began the trial.

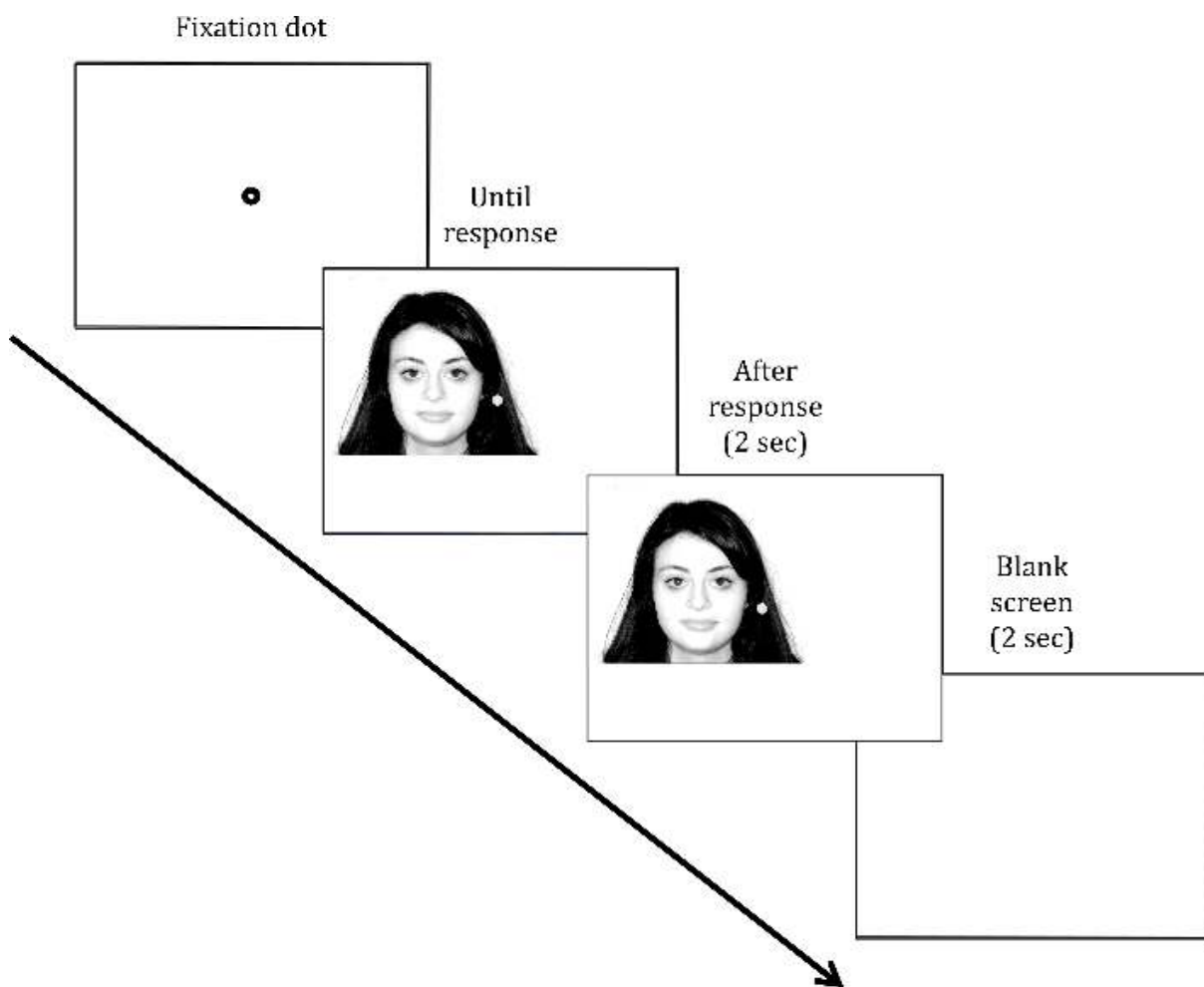


Figure 2: RM ANOVAS for fixation measures, Number of Fixations, Run Counts, Interest Areas Visited, Proportion of Fixations on Inner face regions ($df = 43$ in each case, no effect of condition order) with Bonferroni corrections for multiple paired post hoc tests ($\alpha = 0.017$). The y axis shows data for unfamiliar faces (UF), newly learned faces (F-L) famous celebrity faces (F-F), and personal familiar faces (F-P). In each graph, the unfamiliar (UF) irrelevant (hatched bars) are the comparison baseline for all lie (white bars) and truth (black bars) data. $p < 0.001$ ***, $p < 0.01$ ** . Error bars represent $M \pm SEM$.

