FAMILAR FACES: THE EFFECTS OF EXPERIENCE ON CHANGE BLINDNESS

by

Gabriela Dinescu

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Abstract

Change blindness is influenced by factors such as: set size (the number of items in the scene), change size (the degree of change), and familiarity (whether or not the change occurs in a familiar stimulus). The objectives of this research were: (a) to investigate the role of familiarity in detecting changes in human faces and (b) to establish the temporal locus of the face familiarity effect within Tovey & Herdman's (2014) stage model for change blindness. Chinese and Caucasian participants detected changes in images of same-race (familiar) and other-race (unfamiliar) faces in a flicker paradigm. Familiarity, set size, and change size were jointly manipulated to determine the locus of the face familiarity effect using Sternberg's additive factors logic. Caucasian (but not Chinese) participants were faster and more accurate in detecting changes in Caucasian faces than in Chinese faces, and a 3-way interaction in the Caucasian participants' accuracy data was observed.

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Introduction

People are generally very good at detecting changes in their visual field when those changes are accompanied by motion. This competency has an adaptive value, insofar as it allowed our ancestors to avoid predators and other potentially threatening situations. However, when the motion signal acting as a cue for change gets interrupted (e.g., through blinking or brief occlusions), there is a surprising decrease in the ability to encode, store, and compare visual information from one glance to the next. Known as *change blindness*, this cognitive phenomenon can have serious practical implications. Driving a vehicle while briefly attending to a mobile telecommunication device provides an example of a routine activity in which change blindness can occur. While attending to the telecommunication device, any change in the driving conditions — for instance, a pedestrian beginning to cross the street — is at risk of going unnoticed. In addition, certain professions rely heavily on the ability to detect specific visual changes quickly and accurately, such as those involving the control and monitoring of military/commercial aircraft, or the monitoring of equipment in hospital operating rooms.

In an attempt to understand and potentially minimize the negative consequences of change blindness, scientists have been focusing on identifying those factors which influence its magnitude. The present research examined the role of familiarity in mitigating the effects of change blindness by evaluating the relationship between a participant's race and their ability to detect changes in same-race (familiar) or different-race (unfamiliar) faces. A second goal of the research was to establish the temporal locus of the familiarity effect within the visual processing stream.

Although the impact of familiarity on change blindness has been investigated (Pashler, 1988; Tovey & Herdman, 2014), these studies used digits and/or letters as visual stimuli. The current work differs by using human faces as stimuli. Human faces are known to be processed differently, both from a functional and anatomical perspective, compared to other objects. Accordingly, the study’s positioning within the change blindness framework will be complemented by a review of behavioural, neuropsychological, neuroimaging and neurophysiological research on visual face processing. The insights from these corroborative domains will be used to guide the prediction that, within the change blindness context, familiarity with faces influences an earlier processing stage than familiarity with other visual stimuli.

Change Blindness

Change blindness was discovered inadvertently by research into other areas of visual cognition. While studying visual memory, Phillips (1974) had participants perform a same/different discrimination task, in which a matrix partially filled with dots was followed by another matrix that was either identical or differed by a single dot. If the interval between the two matrices was short (less than 100 ms) performance was very good. However, if masking or movement of the pattern occurred during the interval, performance decreased dramatically. That is, participants were essentially “blind” to the change when the visual signal was briefly interrupted. In contrast, performance was not affected if the interval between the two matrices was long. Although this was likely the first laboratory-based demonstration of change blindness, Phillips used these results to make the important distinction between sensory memory and short-term visual memory. Similarly, McConkie and Zola (1979) used an eye tracking system to investigate the integration of visual information during eye movements (saccades). McConkie and Zola asked participants to read a text which was presented in alternating case on a computer monitor, and changed the case of every letter comprising the text during participants' saccades. Surprisingly, participants did not notice these case changes (upper-to-lower case, or vice versa). Having discovered another type of condition in which change blindness can occur, the authors concluded that certain visual features of letters (such as shape) are not integrated across fixations during reading.

Almost a decade later, Pashler (1988) used a more rigorous paradigm to highlight the change blindness effect. Ten alphanumeric characters were displayed in a 2 x 5 matrix, followed by a 67 ms display offset, followed by another 2 x 5 matrix that was either identical to the first or differed by one character. Participants who were asked to report whether or not a change was detected performed remarkably poorly (only slightly more than half of the changes were noticed), especially for brief (100 ms) exposure durations. Pashler also tested if participants' familiarity with letters facilitates change detection, by displaying a 2 x 5 matrix that contained either all familiar (upright orientation) or all unfamiliar (inverted orientation) letters. Participants were no more accurate at detecting changes in the upright than in the inverted letters, and these findings were not dependent on the display offset or exposure duration.

Using a more realistic setting, Grimes (1996) conducted a study in which participants were asked to memorize full-colour pictures displayed on a computer screen and to press a button if they noticed a change. The software used to display the images was also responsible for eye tracking, which allowed the altered image (the one incorporating the change) to be displayed immediately after a saccade was detected. Despite the fact that the changes were obvious and that participants were explicitly told what kind of changes to expect (e.g., change in colour, size, location), they missed 67% of the changes. Grimes used these results to propose that visual information from the environment interacts with one's internal visual representations formed on the basis of previous experience to create the current visual experience. It is important to point out that the meaning of the scenes did not change in Grime's experiment. As Simons & Levin (1997) argued, perhaps our visual system retains the *meaning* of a scene from one view to the next, while not preserving the *details* associated with the visual information. In this light, the phenomenon of change blindness can be explained by a human brain that has evolved to retain the gist of a visual scene — crucial to our experience of continuity — while discarding the less relevant details of that scene.

Paradigms

Change blindness can occur under a wide range of situations, not just during saccades or brief gaps in the presentation of the original and modified stimuli. Other conditions known to induce change blindness are: blinks (change introduced during an eye blink), mudsplashes (change accompanied by distractor shapes scattered over the image), occlusions (change taking place while target area is briefly obscured), movie cuts (change made during the cut from one camera position to another), and gradual changes (change happening over the course of several seconds).

Accordingly, various paradigms have been created for testing change blindness in empirical settings. In the *forced-choice detection paradigm*, observers are exposed to only one view of the original and altered scenes before responding. In the case of the *flicker paradigm* devised by Rensink, O'Regan, and Clark (1997), the original and modified images are presented in repeated succession, while separated by a brief blank screen, until a response is provided. This most commonly used procedure offers a more fine-tuned approach to the study of change blindness, allowing for the measurement of both accuracy and response time. Studies employing this paradigm consistently show that changes are rarely detected during the first cycle of alternation, and that it can take over a minute to notice a change under some conditions. Rensink et al. also noticed that attention is required to perceive change. Although necessary, attention does not appear to be sufficient for change detection. Even *intentional* approach studies, in which the main task is to detect changes, reveal surprisingly low change detection performance. As it would be expected, change blindness is even more pronounced in the case of *incidental* approach studies (where participants are not aware that changes may occur) or under *divided-attention* conditions (in which the primary task does not involve change detection).

Another method of inducing change blindness is the *mudsplash paradigm*, a variation of the flicker display. The original and altered images are presented in a cyclical fashion, but with visual distractors superimposed on the image at the time of the change instead of blank screens separating the two images (O'Regan, Rensink, & Clark, 1999).

Mediating Factors

As mentioned, change blindness can have alarming consequences in real-world applications. As such, there has been considerable effort to determine which factors influence the change blindness effect.

It has been consistently shown that set size (i.e., the number of items in the visual scene) affects the ability to detect change. For example, Zelinski (2001) systematically manipulated the number of objects in a visual display in a flicker paradigm study in which only one item changed between the original and altered stimuli. As the set size (hence the number of distractors) increased, participants made more errors and took longer to detect the change.

Smilek, Eastwood, and Merickle (2000) demonstrated that change size (i.e., the degree of change) also affects change blindness. Arrays of letters or digits were presented in a flicker paradigm, in which only one item changed. Change size was operationalized as the number of features in the changing letter/digit. For instance, an “E” changing into “L” represented a small change (two features removed), whereas an “F” changing into “L” represented a large change (two features removed and one feature added). Smilek et al. reported that large changes were detected faster and more accurately than small changes.

Another factor that appears to influence the ability to detect a change is whether or not the change occurs in a familiar stimulus/context. Jones, Jones, Smith, and Copley (2003) reported visual processing biases towards substance-related stimuli. The performance of low/heavy alcohol users and of cannabis non-users/users were compared in a flicker paradigm, with changes taking place in substance–neutral or substance-related components of full-colour photographs. The data revealed an interaction between participants’ level-of-use and change type: heavier alcohol users detected alcohol-related changes faster than lighter alcohol users, and cannabis users detected cannabis-related changes faster than non-users. It is, however, possible that Jones et al.’s findings are more reflective of substance dependence than they are of familiarity. Perhaps the heavier alcohol/cannabis users had their attention preferentially drawn to substance-specific items in the photographs, which gave them an advantage over the other participants when a change occurred in those items. A more precise investigation into the role of domain expertise in change blindness was conducted by Werner and Thies (2000). American football experts and novice participants were presented with football-related/unrelated scenes. The results were unequivocal: football experts were faster than novices in detecting changes in football-related scenes.

A Stage Model for Change Blindness

One common criticism of the reviewed research on the effects of familiarity on change detection concerns the feature composition/overall visual complexity associated with the areas of change, which were not kept constant between the familiar and unfamiliar conditions. A more explicit operationalization of observers' expertise with visual stimuli was performed by Tovey and Herdman (2014). In a series of experiments using the flicker paradigm, the researchers asked participants to detect changes in arrays of upright (familiar) and inverted (unfamiliar) letters. In addition to familiarity, Tovey and Herdman manipulated set size, change size, and stimulus quality (clear vs. degraded letters). Across all experiments, participants were faster in detecting changes in upright (familiar) letters than in inverted (unfamiliar) letters. Of particular importance here, stimulus quality interacted with set size and change size, set size interacted with change size, and change size interacted with familiarity. Tovey and Herdman used Sternberg's (1969) additive factors logic to interpret these interactions and drew from Sanders' (1990) visual information processing stages in order to develop a stage model for change blindness (see Figure 1).

The model espouses the stages of processing involved in detecting visual changes in letters and localizes the effect of familiarity (noted as "Orientation" in Figure 1). On the one hand, stimulus quality — known to have an effect at the early stages of processing (see Herdman, Chernecki, & Norris, 1999; Sternberg, 1969) — interacted with set size and change size. As a result, Tovey and Herdman proposed that set size and change size influence change-related visual processing during feature extraction. On the other hand, familiarity was additive with stimulus quality and with set size, which implies that familiarity affects a separate (and later) processing stage — namely, identification. Change size also interacted with familiarity, a finding that led the authors to argue for a gating mechanism (see Figure 1), in which large changes are detected at the feature extraction stage and the identification stage is bypassed. In contrast, for small changes, the identification stage is required for successful change detection.

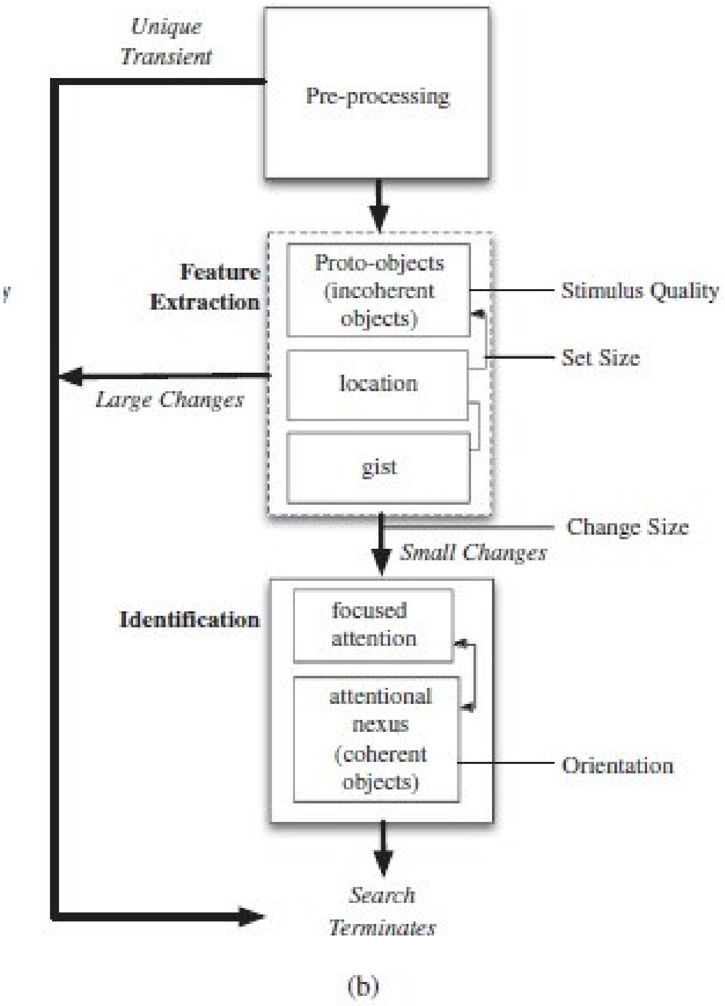

Figure 1. A stage model for change blindness. From "Seeing changes: How familiarity alters our perception of change" by M. Tovey and C. M. Herdman, 2014, Visual Cognition, 22 (2), p. 233.

The visual information processing stream in Tovey and Herdman's (2014) model can be integrated with Rensink's (2000, 2002, 2005) triadic architecture concerning the structures involved in the selection, binding, and identification of visual objects. Rensink's (2005) early, low-level system (generating simple visual elements, or proto-objects) and the setting system (determining the gist of a scene and the location of its items) correspond to the feature extraction stage, while the object system (responsible for forming a coherent representation of the scene by resolving collections of features as objects) corresponds to the identification stage.

Summary

Change blindness is an intriguing cognitive phenomenon, which can be induced in a variety of situations and tested/demonstrated in various laboratory-based paradigms and real-world contexts. Attention is necessary for detecting change, although certainly not sufficient. In addition, set size, change size, and familiarity influence the ability to detect a change. Patterns of interactions and additivity between these factors have led to the development of a theoretical model that specifies the stages (and the factors exerting an influence at those stage) of visual information processing involved in detecting changes.

Human Face Processing

From the moment we are born, we are exposed more to the faces of our conspecifics than we are to any other visual stimuli. Our success in social interactions depends on our ability to follow other people's eye gaze and to understand their intentions and emotions from facial expressions. Converging evidence from three distinct research domains – cognitive psychology, neuropsychology, and neuroscience – supports the idea that human faces belong to a special class of visual stimuli.

Behavioural Studies

Cognitive psychology research indicates that human face processing may be qualitatively different from the processing of other visual stimuli. For example, Yin (1969) tested participants in a forced-choice recognition memory task using upright and inverted pictures of faces and other mono-oriented objects. When the orientation of the visual stimuli was the same between the memorizing and recognition phases, all mono-oriented stimuli were more difficult to recognize when presented upside-down, however faces were the most affected. Similarly, the recognition memory performance suffered for all stimuli when the orientation of the visual stimuli differed between the memorizing and recognition phases, but again faces were disproportionately affected. Yin concluded that the difficulty in recognizing upside-down faces was more than simply a reflection of a general impairment associated with the processing of inverted mono-oriented visual stimuli. This larger decrease in recognition memory performance as a result of inversion for faces compared to other mono-oriented objects was labeled the “face inversion effect”. However, in a later study, Ashworth, Vuong, Rossion, & Tarr (2008) did not find a larger inversion effect for faces than for Greebles (novel, non-face visual stimuli matched to faces along various dimensions). Their results suggest that the inversion effect is, at least in part, due to properties of faces *as a stimulus category* rather than to faces *per se*.

More recently, Young, Hellawell, and Hay (1987) discovered a different phenomenon associated with the visual processing of faces, which they labeled the “composite face effect”. Participants viewed pictures containing only the top or bottom halves of famous people’s faces, and were subsequently asked to identify each half under two test conditions: composite condition (a top and bottom half previously inspected and belonging to different identities were fused to form a new face), and non-composite condition (same as the composite condition, except that the top and bottom halves were misaligned horizontally). Young et al. found that participants took longer to identify the two halves in the composite than in the non-composite condition, and concluded that the perception of a complete, novel face interferes with the identification of its constituent parts. Interestingly, this interference was completely eliminated by inversion: no differences in response times were observed between the composite and non-composite conditions when the face parts were presented upside-down.

Young at al.’s (1987) research showed that upright faces are processed in a holistic fashion, and that changing the orientation of faces (i.e., turning them upside-down) interferes with this holistic processing. Furthermore, Tanaka and Farah (1993) investigated if upright faces are processed in a more holistic fashion than other non-face objects. According to Tanaka and Farah, a *holistic* representation of a visual stimulus is one in which the parts/features that comprise the stimulus are not explicitly represented as structural units per se; in contrast, stimuli perceived in terms of their component parts are characterized by a *featural* representation. The authors tested their hypothesis by asking participants to memorize human faces and several contrasting stimuli (e.g., houses). Participants were then tested using a forced-choice recognition memory task in which a component of a previously memorized stimulus was presented either in isolation (e.g., a nose that belonged to a memorized face, a window that belonged to a memorized house) or as part of the whole image (e.g., the entire face/ house). Tanaka and Farah reported that recognition memory performance for facial features (but not for non-facial features) was worse when they were presented in isolation than when presented as part of the entire stimulus. The authors concluded that face recognition is *relatively* more dependent on holistic representations than the recognition of other visual stimuli.

Farah, Wilson, Drain, and Tanaka (1998) extended Tanaka and Farah’s (1993) findings by showing that faces are not only remembered holistically, but are also *perceived* holistically. Farah et al. (1998) compared the relative contributions of partial and whole representations of a face to the perception of faces in a same/different matching task. Pairs of faces that were identical, differed in only the probed part, or completely different were briefly presented as both upright or both inverted. The task was to indicate whether or not a given facial feature (e.g., eyes, nose) was shared by the two faces. Response accuracy was higher when the probed and non-probed face parts between the two faces were compatible (both same or both different) than when they were not. Further, this compatibility effect was larger for upright faces than for inverted faces. Given participants' difficulty in comparing facial parts independent of the whole face, the authors concluded that the perception of faces relies on holistic representations.

Neuropsychology Findings

Many advances in neuropsychology rely on studying different patterns of behavioural breakdowns in people with brain injuries/dysfunctions in order to make inferences about the structure and function of the cognitive mechanisms underlying basic perceptual and cognitive abilities. In the neuropsychological literature, an impairment of the capacity to recognize visual stimuli — not due to a malfunction of perceptual processes or to a loss of intellectual ability — is known as *visual agnosia*. More specifically, *prosopagnosia* is defined as the inability to recognize familiar faces. Farah (1996) showed that prosopagnosia was selective for faces in a study comparing neurologically-normal participants with a highly prosopagnosic individual in their ability to recognize recently studied photos of faces and other objects. The controls performed equally well with faces and objects, while the prosopagnosic's memory for objects was significantly better than it was for faces. Farah concluded that human face recognition is "special", insofar as it relies on specialized systems which are not necessary for the recognition of other classes of visual stimuli.

Farah, Wilson, Drain, and Tanaka (1995) studied the "face inversion effect" in a prosopagnosic participant in a same/different matching task. Two faces were presented in sequence, both upright or both inverted, and separated by a brief interval. Farah et al. found the prosopagnosic performed better at matching inverted faces than upright faces, and interpreted this as evidence for a neurologically localized module for *upright* face processing. In an unpublished study, Farah, Drain, and Tanaka tested Farah et al.'s prosopagnosic participant using a same/different short-term memory paradigm, in which the first face was presented either as a whole or as "exploded" into four different frames (or quadrants), with the second face being presented as a whole. While the controls performed better in the whole-to-whole condition than in the exploded-to-whole condition, the prosopagnosic participant showed no statistical differences between the two conditions. Taken together, neuropsychological research converges on the idea that prosopagnosia is a neurological deficit that relates specifically to the holistic processing of upright faces.

In addition, neuropsychologists have encountered other forms of visual agnosia, whereby the reverse pattern of deficits is observed. That is, individuals cannot recognize non-face objects, while having preserved the ability to recognize faces (Feinberg, Schindler, Ochoa, Kwan, & Farah, 1994). This double dissociation between prosopagnosics (impaired face recognition, but spared object recognition) and visual agnosics (impaired object recognition, but spared face recognition) suggests that the neural systems responsible for recognizing faces and objects are functionally independent, anatomically distinct (i.e., they can be damaged independently), and different with respect to the degree of feature decomposition, with the face-specific system relying more on holistic representations.

Neuroscience Research

Neural correlates of behaviour offer biological plausibility to proposed theoretical cognitive models, allowing scientists to move from a descriptive to a mechanistic level of explanation. Functional magnetic resonance imaging (fMRI) allows scientists to explore *where* in the brain a task-specific activity takes places, by measuring hemoglobin oxygenation/de oxygenation ratios — the basic premise being that neural activity and local oxygenation extraction are coupled. A complementary brain measurement technique is event-related potentials (ERPs). Measured by means of electroencephalography, ERPs detect transient changes in the electrical activity of the brain occurring in response to a stimulus presentation and can inform us about the *timing* of cognitive processes.

fMRI studies. Kanwisher, McDermott, and Chun (1997) discovered an area within the ventral occipito-temporal pathway (i.e., the lateral fusiform gyrus) which responded more strongly when participants viewed faces compared to non-face stimuli. The authors labeled this as the "fusiform face area" (FFA). Face-selective brain activity was also reported, to a lesser degree, in the superior temporal sulcus (or STS) and in the inferior occipital gyrus (termed the "occipital face area", or OFA). In a later study, Hoffman and Haxby (2000) showed that the FFA and OFA are involved in the recognition of invariant facial aspects, such as identity.

In another study examining the role of FFA in face recognition, Agguire, Singh, and D'Esposito (1999) found that face inversion did not alter the levels of activity in the FFA compared to upright faces, but created an increase in activity in the regions associated with non-face object processing. These findings led Agguire et al. to conclude that inverted faces are processed as non-face objects and that the FFA is automatically engaged when an inverted face is displayed.

ERP studies. Bentin, Allison, Puce, Perez, and McCarthy (1996) discovered a negative deflection in the EEG that occurred selectively in response to the presentation of human faces (primarily over the right hemisphere's temporal scalp areas), at about 170 ms after stimulus onset. Labeled "N170", this ERP component was initially considered a marker for face processing. However, subsequent studies (Eimer, 1998) showed that a smaller amplitude N170 was also elicited in response to viewing non-face objects. Importantly, Rossion et al. (2000) found an increase in both latency and amplitude for N170 when faces, but not non-face objects, were presented upside-down. This N170 *delay for inverted faces* came to be regarded as the electrophysiological correlate for face specificity.

Temporal Loci for Face Detection and Identification

An interpretation of the N170's increase in amplitude in response to inverted faces that was observed by Rossion et al. (2000) is that the signal is associated with simply the *detection* of a face, and not its *identification*. However, Campanella et al. (2000) showed an identity-priming effect involving N170 during ERP recordings in a delayed same/different matching task. Pairs of faces created through a morphing technique were presented in sequence (separated by a black screen) under three conditions: same (two identical faces), within (different morphed faces obtained from the same individual), and between (two morphed faces corresponding to different identities). Participants performed better in discriminating two faces in the between pairs than in the within pairs, despite the fact that the physical difference inside each pair was kept constant. Consistent with the behavioural results, the amplitude of N170 was reduced upon the presentation of the second face in the pair only for the same or within conditions (i.e., when the second face belonged to the same identity as the first face), thus suggesting that N170 is involved in face identification.

One way to reconcile these competing results is that, in the case of human faces, detection and identification occur simultaneously. Support for this theory comes from Tanaka's (2001) experiments, in which participants viewed photographs of famous personalities and various other objects. While faces were more often identified at the subordinate level (e.g., Bill

Clinton) than at the basic level (e.g., human) and were verified as quickly and accurately at the subordinate level as they were at the basic level, with exposure duration having no impact on subordinate-level face identification, the opposite pattern of results was true for all non-face stimuli. Tanaka used the results to propose that the entry points of face and object recognition differ as a result of heightened expertise with faces.

Summary

Research from the fields of cognitive psychology, neuropsychology, and neuroscience consistently show that human faces represent a special class of stimuli that are perceived and recognized holistically. By comparison, non-face objects appear to be processed by mentally assembling their component parts, or geons (Biederman, 1987). Faces, in this regard, are like templates — what matters most when perceiving or recognizing a face is the overall fit between a given stimulus and a template representation, not the summation of the fits of its constituent features. Evidence from neuroimaging studies revealing the existence of anatomically distinct and functionally independent face and object recognition systems is consistent with the view that faces and non-face objects are processed as separate entities. Finally, electrophysiological correlates indicate that, unlike non-face objects, faces are detected and identified at the same time, which is substantiated by an enhanced expertise with human faces.

Present Research

The main goal of this study was to investigate the effects of familiarity on change blindness when human faces are used as stimuli. Previous studies (Pashler, 1988; Tovey & Herdman, 2014) have manipulated familiarity by changing the orientation of the stimuli, whereby upside-down stimuli were regarded as unfamiliar. However, faces appear to be disproportionately affected by inversion (Yin, 1969) and fMRI research shows that, while upright faces are processed by specific brain areas (Kanwisher, McDermott, & Chun, 1997), inverted faces are treated by the visual system more like objects (Agguire, Singh, & D'Esposito, 1999). To avoid this problem, familiarity was operationalized here by leveraging the own-race bias observed in recognition memory studies, whereby faces from one's own race are remembered better than faces from another race. Research has shown this phenomenon is generally consistent across racial and ethnic groups (Bothwell, Brigham, & Malpass, 1989; Luce, 1974) and across memory tasks (Megreya, White, & Burton, 2011; Platz & Hosch, 1988). In addition, there is evidence for an own-race bias at the encoding stage of face processing (Walker & Tanaka, 2003). The current research therefore investigated the relationship between participants' race (Chinese or Caucasian) and their ability to detect changes in own-race (familiar) and other-race (unfamiliar) faces in a flicker paradigm. It was hypothesized that participants would be faster and more accurate at detecting changes in own-race (familiar) faces than in other-race (unfamiliar) faces.

The second goal of the study was to establish the temporal locus of the face familiarity effect within Tovey and Herdman's (2014) stage model for change blindness. For this purpose, the study manipulated two additional factors known to affect change blindness: set size and change size. Set size was defined as the number of faces that were simultaneously displayed (6 or 12), with one changing (target) face and 5 or 11 non-changing (distractor) faces. Change size is typically operationalized in change blindness research by varying the number of features that change in the target stimulus. However, since the visual processing of human faces relies to a relatively high degree on holistic representations, the current study manipulated change size at the global level rather than at the featural level, through the use of morphing software. Thus, an original face changed into a completely different identity (large change), or into a morphed image of two different identities (small change). For both small and large changes, the original and altered faces belonged to the same race and gender.

Patterns of interaction (or lack thereof) between the three factors (set size, change size, and familiarity) were interpreted using Sternberg's (1969) additive factors logic, which assumes that factors with an additive effect on the measured response influence different stages of processing, and that interacting factors influence a common processing stage. Tovey and Herdman (2014) showed that familiarity with letters had an impact at the identification stage, while set size and change size affected the feature extraction stage. In contrast, it is hypothesized here that, due to the holistic nature of face processing, the familiarity effect will influence an earlier processing stage (i.e., feature extraction).

To briefly preview the results, Caucasian (but not Chinese) participants were faster and more accurate in detecting changes in same-race faces than in other-race faces. In addition, there was a three-way interaction between set size, change size, and familiarity, which is consistent with the claim that the face familiarity effect has an early temporal locus in the visual recognition system.

Method

Participants

Forty-seven undergraduate students from Carleton University (22 native Chinese, 25 Caucasian) participated in the study. They were recruited using Carleton's online experiment sign-up system or through flyers posted on campus, and received course credit or $15 for their participation. Nine graduate students (four native Chinese) volunteered for the pilot study. All participants had normal or corrected-to-normal vision.

Stimuli and Apparatus

Face databases. Photographs of 24 Chinese and 24 Caucasian individuals were used as visual stimuli. The photographs of the Chinese individuals were downloaded from the University of Beijing’s and Hong Kong University’s face databases, once permission had been granted. The photographs of the Caucasian individuals were collected from a variety of online face databases, including the National Institute of Standards and Technology’s database. The photographs were selected such that there was an equal number of males and females (within each race), a frontal view of the entire face was shown, the face had a neutral expression, there was no facial hair or adornments (e.g., sunglasses, earrings), and nothing was visible in the background.

Image editing/morphing software. All 48 photographs were converted to black-and-white images and cropped to hold the face:background ratio as constant as possible, using Picasa image editing software (version 3.9) for Windows 7. After processing, all photographs measured 180 pixels in width and 250 pixels in height. Six face pairings were selected for each of the four subgroups created by crossing race (Chinese vs. Caucasian) and gender (female vs. male), with the constraint that a face could only appear in one pairing.

The 24 face pairings were imported into FaceMorpher version 2.51 software, which automatically detects patterns in the two faces to be morphed in order to create a clean transition. The software also provides a manual enhancement mode, which allows the user to monitor and adjust the reference points on the two faces, if need be. Multiple frames were created on a continuum as one face was morphed into another. The number of intermediate frames was configurable, thus providing an easy and objective method for manipulating the degree of change between the two faces. Figure 2 provides an example of a Caucasian male face (A) morphing into another Caucasian male face (B) in 5 frames. As face A changed into face B, the degree of change was manipulated in an ordinal fashion. Based on pilot work, a large change was defined as face A changing into face B, whereas a small change was defined as face A changing into a 50%-50% morph image of the two identities. The use of other morphing ratios would have increased the difficulty of the change detection task.

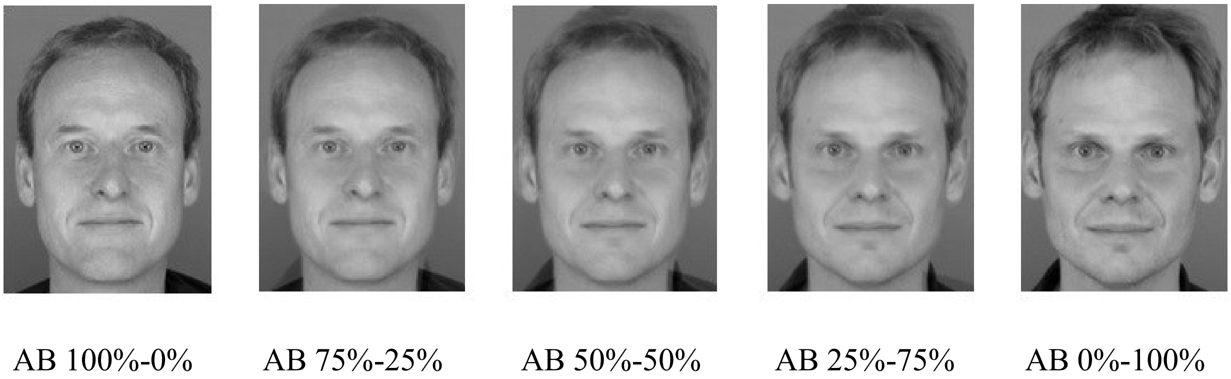

Figure 2. Caucasian male face (A) morphing into Caucasian male face (B) with the relative percent contributions of faces A and B, respectively.

Equipment and presentation software. The experiment was implemented on an Apple iMac 2 GHz Intel Core 2 Duo running the Mac OS X 10.7.5, featuring a 20-inch LCD monitor. The stimulus presentation software was developed using Python version 2.7.5 with pygame module, version 1.9.1.

Design

A 2 (set size: 6 vs. 12) x 2 (change size: small vs. large) x 2 (familiarity: familiar vs. unfamiliar) repeated-measures design was used. All three factors were mixed. Set size was defined as the number of faces that were displayed in a 6 x 6 matrix. Change size referred to the degree to which the target face changed across two displays. A small change occurred when face

A changed to a 50:50 ratio of face A and face B (Figure 3). A large change occurred when face A completely changed to face B (Figure 4). Familiarity was defined as the relationship between the participant's race and the race of the faces shown in the matrix. On a given trial, the faces in the matrix were either all Caucasian or all Chinese. Thus, the familiar condition consisted of Caucasian participants being shown Caucasian faces or Chinese participants being shown Chinese faces. Similarly, the unfamiliar condition consisted of Caucasian participants being shown Chinese faces or Chinese participants being shown Caucasian faces.

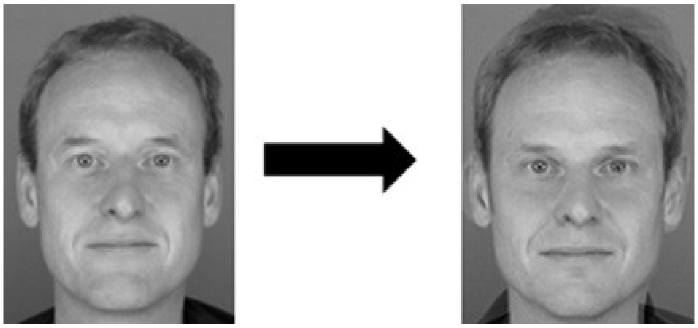

Figure 3. Example of a small change: Face A (left) changes to a 50:50 ratio of face A and face B (face B not shown).

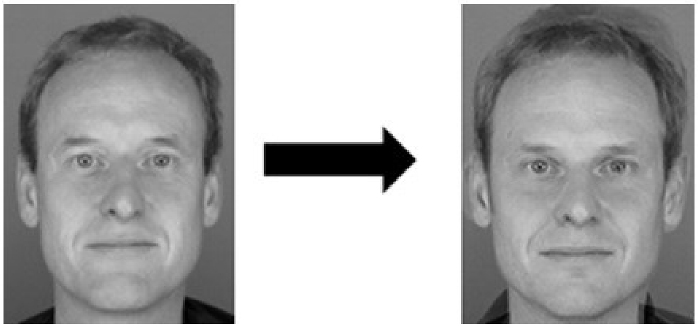

Figure 4. Example of a large change: Face A (left) changes entirely to face B (right).

Procedure

Participants completed the change detection task, followed by a similarity rating task, and then a questionnaire. Once informed consent was obtained and the experimenter ensured that the instructions were understood, participants were tested individually in a quiet room and were debriefed following completion of the experiment. The study took approximately one hour to complete.

Change detection task. Participants were seated comfortably approximately 60 cm from the computer monitor, and were instructed to respond as quickly and as accurately as possible using a standard keyboard and mouse. Participants familiarized themselves with the experimental procedure by completing sixteen practice trials. Performance during the practice trails was not logged. The practice block was followed by 160 experimental trials presented in four blocks of 40 trials each, and included three self-paced rest breaks between blocks. The eight conditions created by crossing set size, change size, and familiarity were randomly sampled for both the practice and experimental blocks, with the constraint that each condition was presented an equal number of times.

On each trial, a standard flicker paradigm was used in which a 6 x 6 matrix (A), populated with either 6 or 12 Chinese or Caucasian faces (depending on set size), was displayed for 200 ms. A blank screen was then presented for 80 ms, followed by a second 6 x 6 matrix (A’) that was identical to matrix A, except that one face (i.e., the target) had changed. Matrix A’ was then followed by another 80 ms blank screen, after which matrix A was displayed again (see Figure 5). This presentation cycle was repeated until the participant pressed the spacebar to indicate that the change was detected or until 15s had elapsed (timeout).

Each matrix measured 18 cm x 18 cm onscreen and subtended a visual angle of 17° vertically and 17° horizontally. Each face in the matrix measured 3 cm (height) x 2 cm (width) and subtended a visual angle of 3° vertically and 2° horizontally.

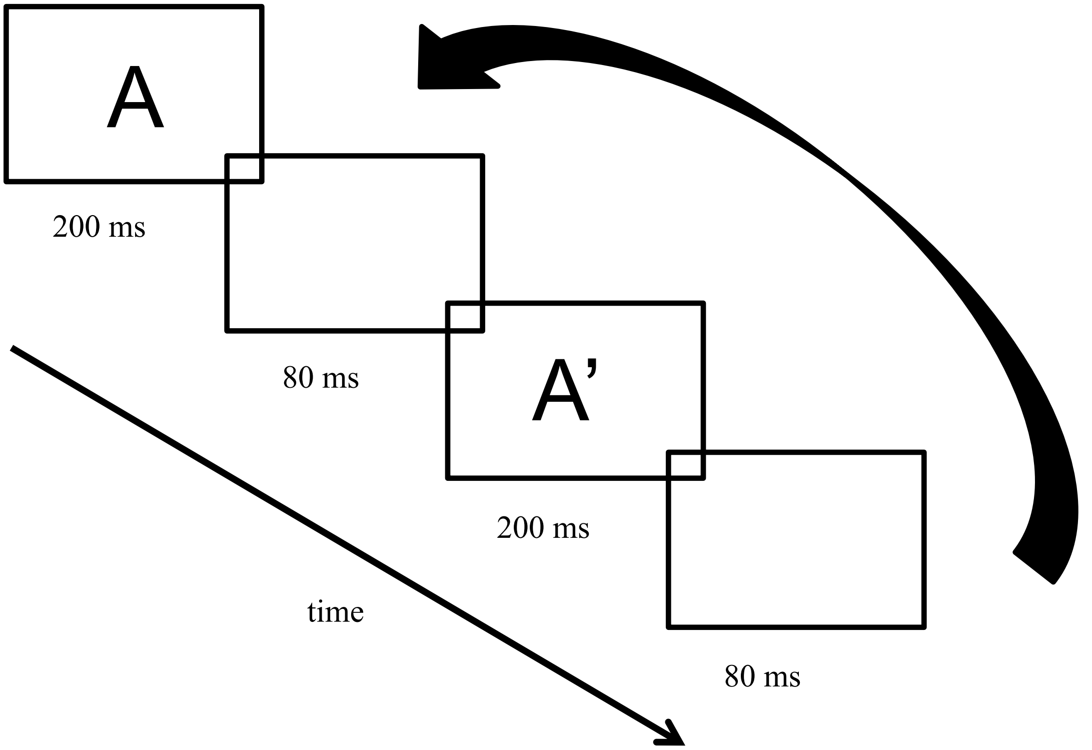

Figure 5. Trial sequence in the flicker paradigm task.

Matrix A was generated by randomly selecting 6 or 12 face images from the original pool of 24 face pairings and randomly placing them in the 6 x 6 grid with the following restrictions: 1) faces were either all Chinese or all Caucasian and 2) there was an equal number of males and females. Matrix A’ was generated by reproducing matrix A, except that one face was replaced with another face (large change condition) or with its morphed image (small change condition). An example of trial matrices A and A’ is shown in Figure 6.

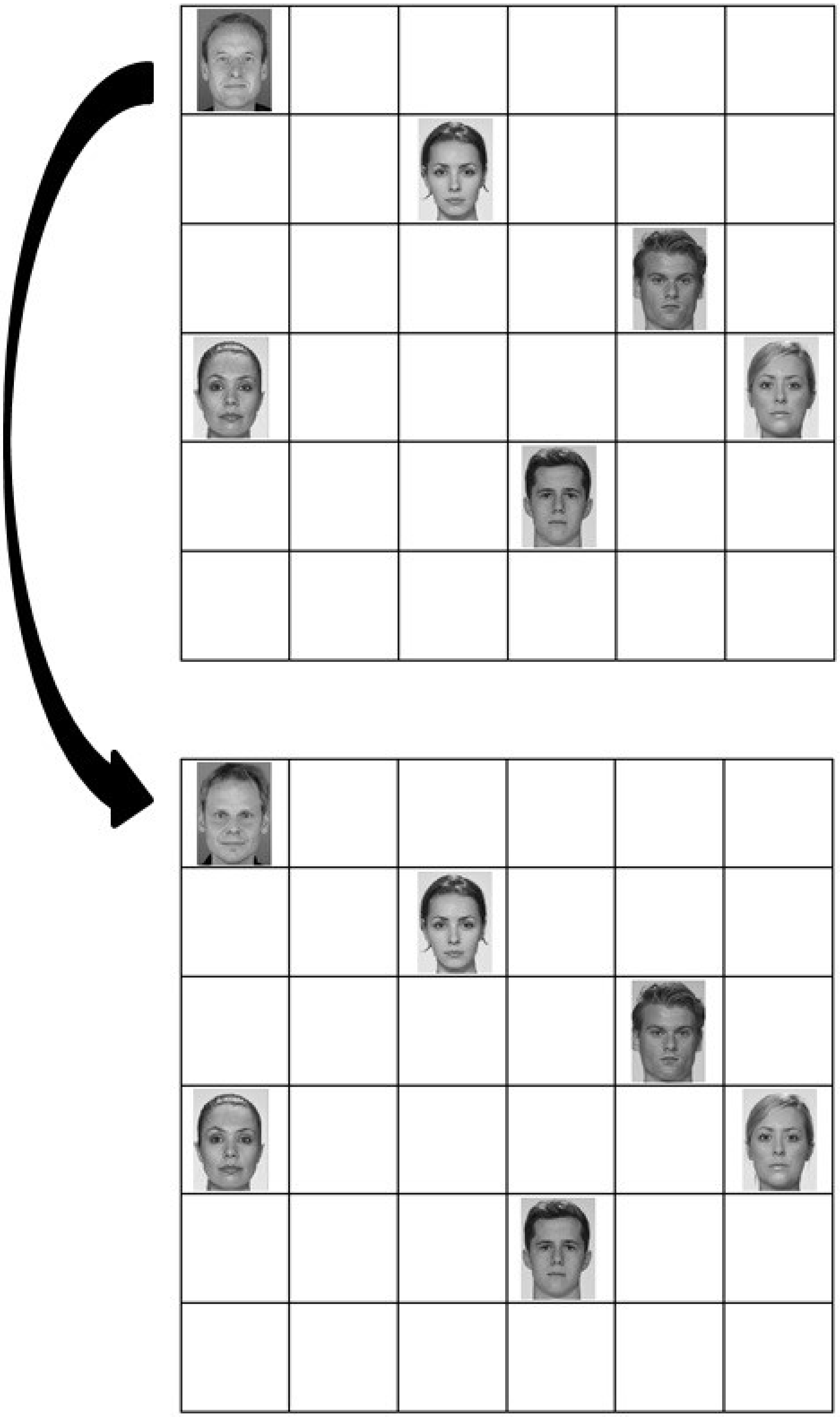

Figure 6. Example of matrices A (top) and A’ (bottom) for a set size of 6, large change size, Caucasian face trial. The top left face changes.

The matrix that was visible when the spacebar was pressed (or when the timeout occurred) remained on the screen until the participant used the mouse to ‘click’ on the face they thought had changed. Feedback regarding the accuracy of the participant’s response was provided on the screen after each trial. Performance was measured in terms of response time and accuracy. Response time was defined as the time (in ms) between the onset of matrix A and the participant’s spacebar response. Accuracy was a binary measure in which participants either clicked on the face that changed (correct) or clicked on another face in the matrix (incorrect).

Similarity rating task. The second task required participants to provide similarity ratings for the 24 pairs of faces used in the change detection task of the experiment. The pairs were presented sequentially on a computer screen and remained visible until participants responded. Participants were instructed to rate the similarity of the two visible faces using a 5-point Likert rating scale (1 = very dissimilar; 2 = dissimilar; 3 = neither similar nor dissimilar; 4 = similar; 5 = very similar). Responses were recorded manually by the experimenter.

Social Experience Questionnaire (SEQ). The final task was to complete a questionnaire that evaluated the participant’s exposure to the other race (i.e., a Caucasian participant’s exposure to the Chinese population, or a Chinese participant’s exposure to the Caucasian population). Two questionnaires were developed—one for Chinese participants (Appendix A) and one for Caucasian participants (Appendix B)—based on a modified version of Brigham’s (1993) SEQ. Each questionnaire was comprised of 11 questions measuring the participant’s quantity and quality of Chinese–Caucasian cross-race contact. There was no time limit to complete the questionnaire.

Results

Of the 47 participants tested, seven were excluded from the analysis for the following reasons: one participant did not fully complete the SEQ; one participant did not follow instructions on the change detection task; one Chinese participant lived in China for only one year; one Chinese participant was born in Canada; and three participants were from Qatar, Egypt, or Jamaica. The remaining 40 participants included 20 native Chinese and 20 Caucasians.

Change Detection Task

Response time and accuracy were analyzed using a 2 (set size: 6 vs. 12) x 2 (change size: small vs. large) x 2 (familiarity: familiar vs. unfamiliar) repeated-measures analysis of variance (ANOVA). Given that only the Caucasian participants showed a familiarity effect, the results will first be presented as a combined analysis (n=40) and then as separate analyses for the Caucasian (n=20) and Chinese (n=20) participants. In the following graphs, error bars represent 95% confidence intervals calculated according to Jarmasz and Hollands (2009).

Combined response times. Only those trials in which participants responded correctly and did not time out were included in the response time analysis. These data were submitted to a recursive outlier procedure, in which scores falling three or more standard deviations above or below the mean score for a given experimental condition were eliminated from further analysis (Van Selst & Jolicoeur, 1994). This resulted in the elimination of 0.07% of the data. The remaining data were submitted to the aforementioned ANOVA.

As predicted, there was a significant effect of familiarity, $F(1,39) = 13.19$, $MSE = 477061$, $p < .005$, $\eta_p^2 = .253$. Overall, changes in familiar faces (i.e., when the target face and the participant were from the same race) were detected faster ($M = 4960$ ms, $SD = 84$ ms) than changes in unfamiliar faces ($M = 5240$ ms, $SD = 101$ ms). There was a significant main effect of set size, *F*(1,39) = 568.47, *MSE* = 655691, $p < .001$, $\eta_p^2 = .936$. Participants were slower to detect changes in the target face when 12 faces were displayed (*M* = 6179 ms, *SD* = 116 ms) than when only 6 faces were displayed (*M* = 4021 ms, *SD* = 71 ms). The effect of change size was also significant, *F*(1,39) = 158.28, *MSE* = 745617, $p < .001$, $\eta_p^2 = .802$. Large changes were detected faster (*M* = 4493 ms, *SD* = 83 ms) than small changes (*M* = 5707 ms, *SD* = 111 ms).

The interaction between set size and change size was significant, *F*(1,39) = 6.27, *MSE* = 297982, $p < .05$, $\eta_p^2 = .138$. The difference in response times between small and large changes was significantly greater for a set size of 12 than for a set size of 6. No other interactions were significant.

Combined accuracy. There was a significant main effect of set size, *F*(1,39) = 140.41, *MSE* = .010, $p < .001$, $\eta_p^2 = .783$. The proportion of correct responses was higher when 6 faces were displayed (*M* = .938, *SD* = .009) than when 12 faces were displayed (*M* = .804, *SD* = .015). There was also a main effect of change size, *F*(1,39) = 124.22, *MSE* = .011, $p < .001$, $\eta_p^2 = .761$. The proportion of correct responses was lower for small changes (*M* = .807, *SD* = .016) than for large changes (*M* = .935, *SD* = .008). The main effect of familiarity was not significant.

The interaction between set size and change size was significant, *F*(1,39) = 90.66, *MSE* = .005, $p < .001$, $\eta_p^2 = .699$. This interaction took the same form as in the response time data. That is, the difference in accuracy between small and large changes was significantly greater for a set size of 12 than for a set size of 6. No other interactions were significant.

The reaction time and accuracy data were also analyzed using a Participant Race (Chinese vs. Caucasian) x Stimulus Race (Chinese vs. Caucasian) mixed-factors ANOVA. This analysis revealed that only the Caucasian participants showed an effect of familiarity. Specifically, Caucasian participants were faster and more accurate in detecting changes in

Caucasian faces than in Chinese faces (see Figure 7). In contrast, the Chinese participants were neither faster nor more accurate in detecting changes in Chinese faces than in Caucasian faces (see Figure 8).

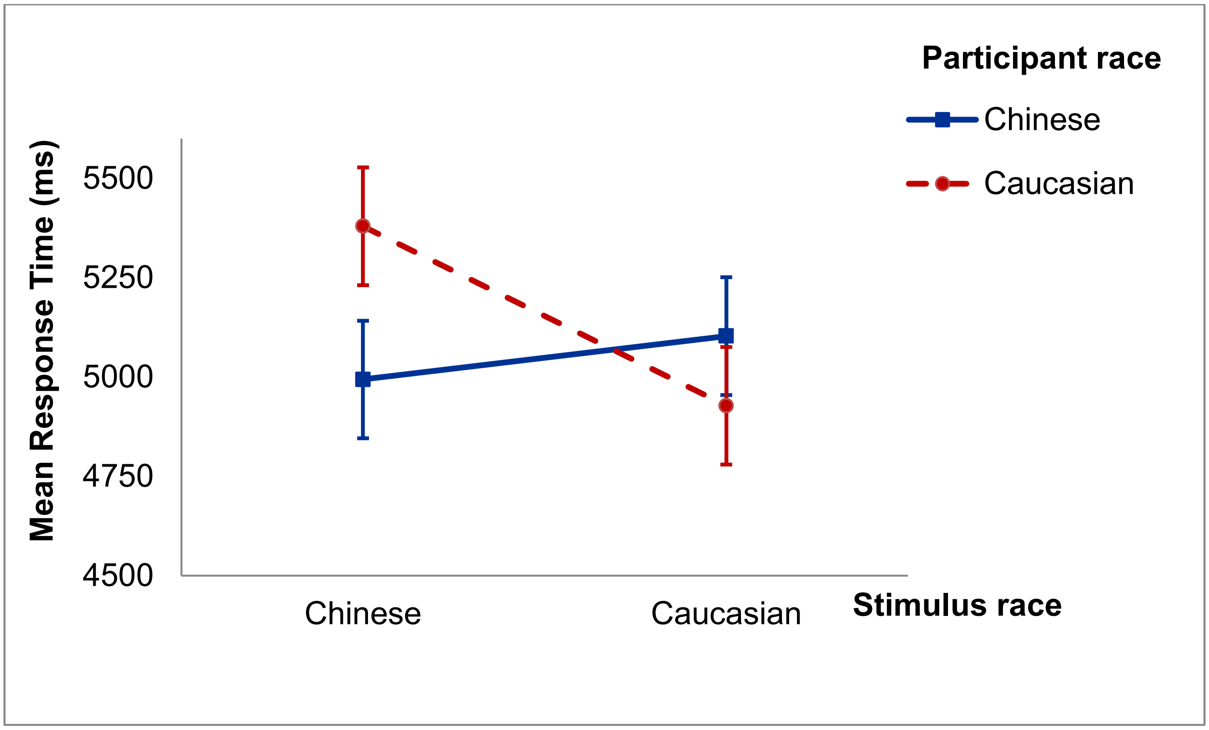

Figure 7. Mean response time (in ms) as a function of stimulus race and participant race.

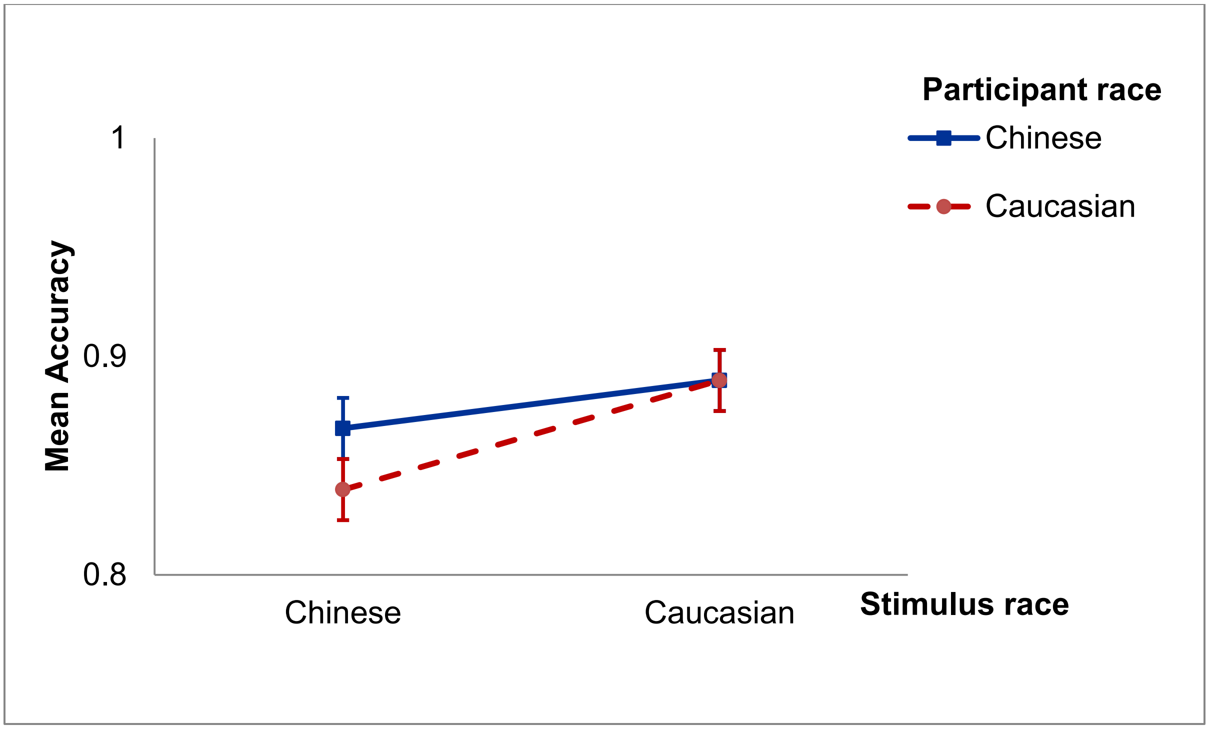

Figure 8. Mean accuracy (proportion correct) as a function of stimulus race and participant race.

Caucasian response times. The same trials used in the combined response time analysis were analyzed here, except only the data from the Caucasian participants were included. The same ANOVA used for the combined analysis revealed a significant main effect of familiarity, $F(1,19) = 16.15$, $MSE = 505503$, $p < .005$, $\eta_p^2 = .459$. Participants were faster in detecting changes in Caucasian faces ($M = 4927$ ms, $SD = 92$ ms) than in Chinese faces ($M = 5379$ ms, $SD = 131$ ms). The main effect of set size was also significant, $F(1,19) = 285.34$, $MSE = 644304$, $p < .001$, $\eta_p^2 = .938$. Changes were detected faster when 6 faces were displayed ($M = 4081$ ms, $SD = 84$ ms) than when 12 faces were displayed ($M = 6225$ ms, $SD = 142$ ms). The effect of change size was also significant, $F(1,19) = 133.84$, $MSE = 419234$, $p < .001$, $\eta_p^2 = .876$. Large changes were detected more quickly ($M = 4561$ ms, $SD = 110$ ms) than small changes ($M = 5745$ ms, $SD = 111$ ms).

There was a significant interaction between set size and change size, *F*(1,19) = 4.79, *MSE* = 255151, $p < .05$, $\eta_p^2 = .201$. As in the combined analysis, the effect of change size was significantly greater for a set size of 12 than for a set size of 6 (see Figure 9).

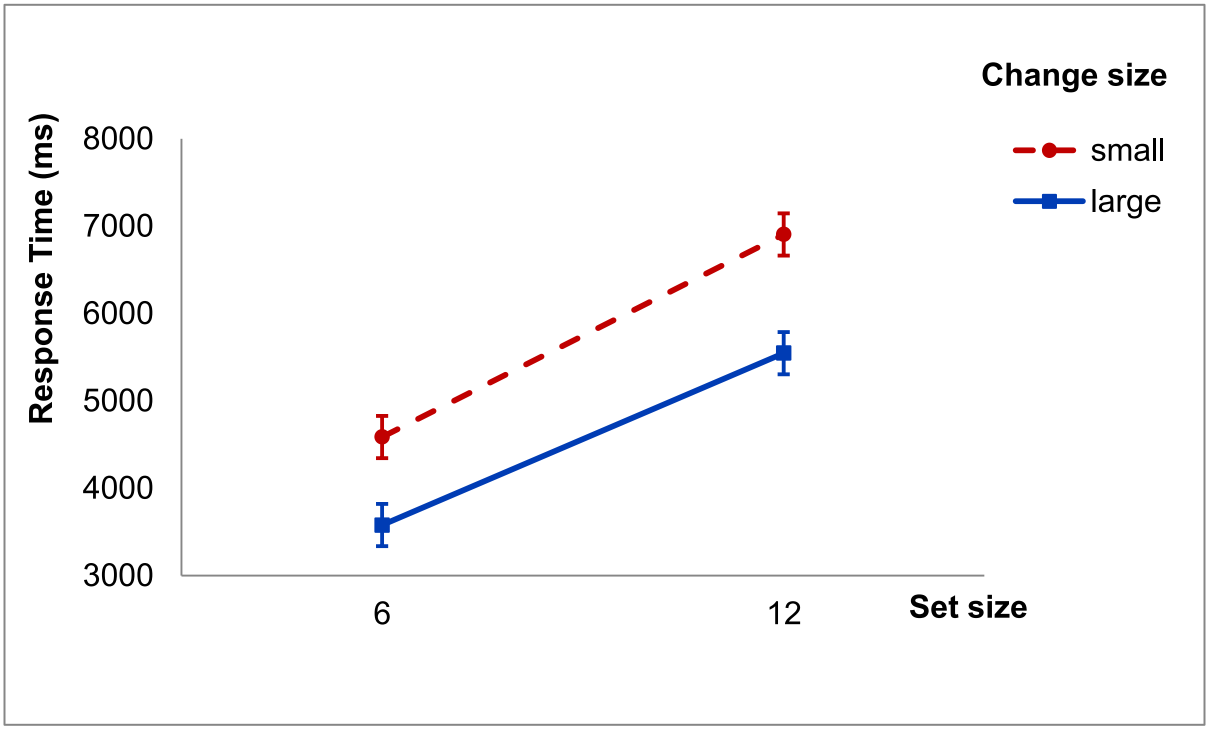

Figure 9. Mean response time (in ms) as a function of set size and change size.

A significant interaction between change size and familiarity was also observed, *F*(1,19) = 4.32, *MSE* = 517712, $p < .05$, $\eta_p^2 = .185$. As can be seen in Figure 10, there was a significant effect of familiarity for small changes, but not for large changes.

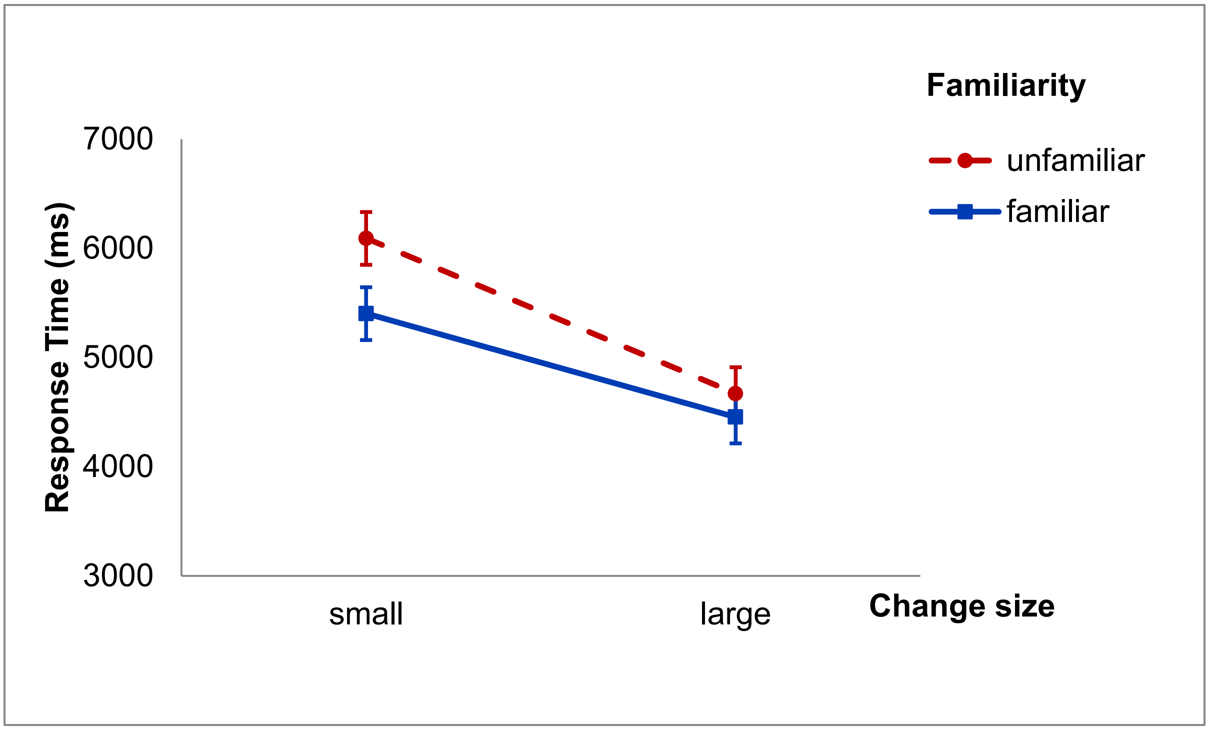

Figure 10. Mean response time (in ms) as a function of change size and familiarity.

Caucasian accuracy. The same data from the combined accuracy analysis were analyzed here, except that only the data from Caucasian participants were included in the analysis. The ANOVA revealed a significant main effect of familiarity, $F(1,19) = 14.59$, $MSE = .007$, $p < .005$, $\eta_p^2 = .435$. Participants were less accurate in detecting changes in Chinese faces ($M = .839$, $SD = .022$) than in Caucasian faces ($M = .889$, $SD = .014$). The main effect of set size was also significant, $F(1,19) = 78.40$, $MSE = .007$, $p < .001$, $\eta_p^2 = .805$. Participants were less accurate at detecting changes when 12 faces were displayed ($M = .808$, $SD = .022$) than when only 6 faces were displayed ($M = .921$, $SD = .014$). The main effect of change size was significant, $F(1,19) = 57.86$, $MSE = .013$, $p < .001$, $\eta_p^2 = .753$. As expected, participants were less accurate at detecting small changes ($M = .794$, $SD = .025$) than large changes ($M = .934$, $SD = .012$).

The interaction between set size and change size was significant, $F(1,19) = 45.99$, $MSE =$

.004, $p < .001$, $\eta_p^2 = .708$, as was the interaction between change size and familiarity, $F(1,19) = 9.12$, $MSE = .002$, $p < .01$, $\eta_p^2 = .324$. These interactions mirrored the patterns of data observed in the response time analysis. That is, the change size effect was significantly larger for a set size of 12 than for a set size of 6 (see Figure 11). Further, the familiarity effect was significantly larger for small changes than for large changes (see Figure 12). The interaction between set size and familiarity approached significance, $F(1,19) = 3.62$, $MSE = .005$, $p < .075$, $\eta_p^2 = .160$.

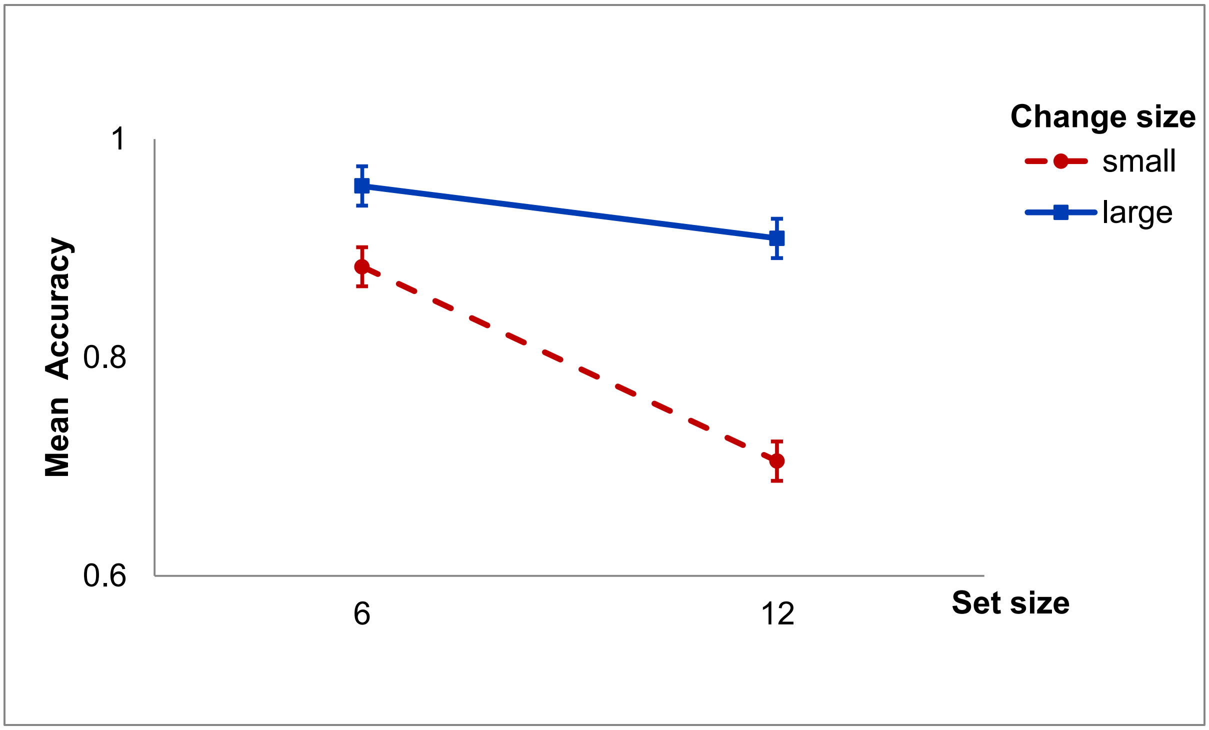

Figure 11. Mean accuracy (proportion correct) as a function of set size and change size.

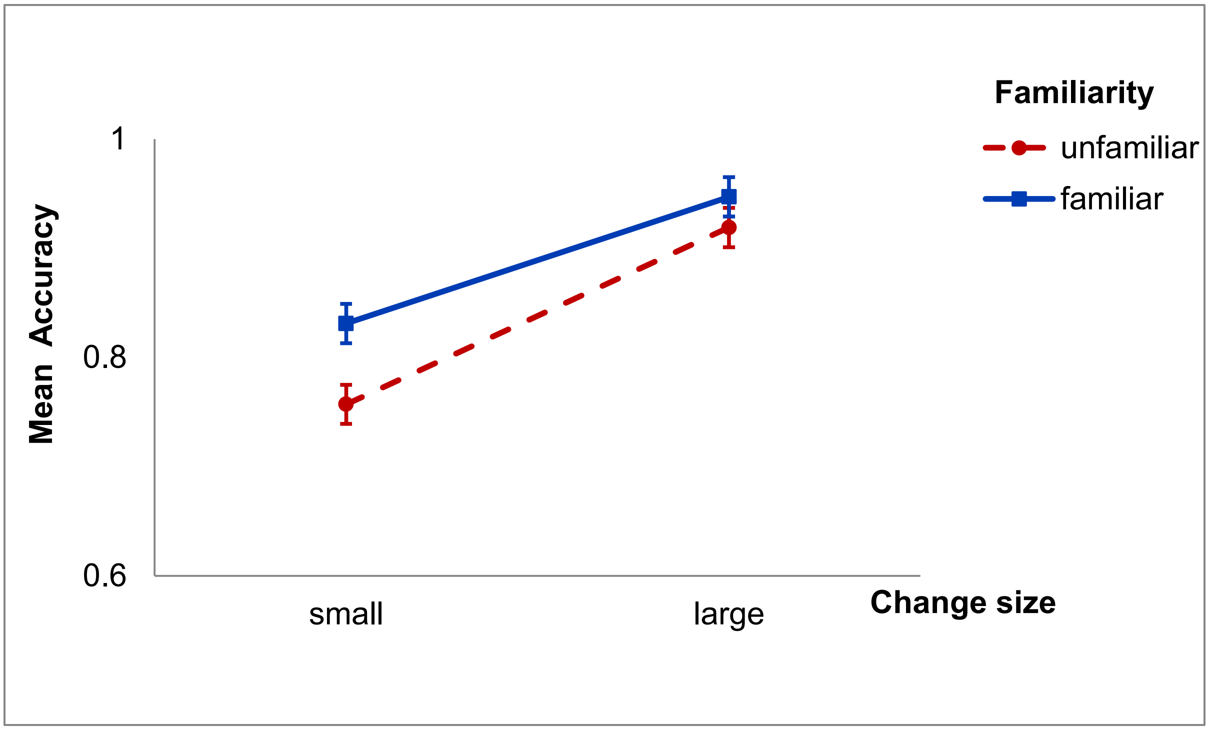

Figure 12. Mean accuracy (proportion correct) as a function of change size and familiarity.

Finally, there was a significant three-way interaction between set size, change size, and familiarity, *F*(1,19) = 8.45, *MSE* = .003, $p < .01$, $\eta_p^2 = .308$. As shown in Figures 13 and 14, the magnitude of set size by change size interaction appears to be modulated by familiarity. Specifically, the set size x change size interaction is significantly larger for unfamiliar faces (Figure 13) than for familiar faces (Figure 14).

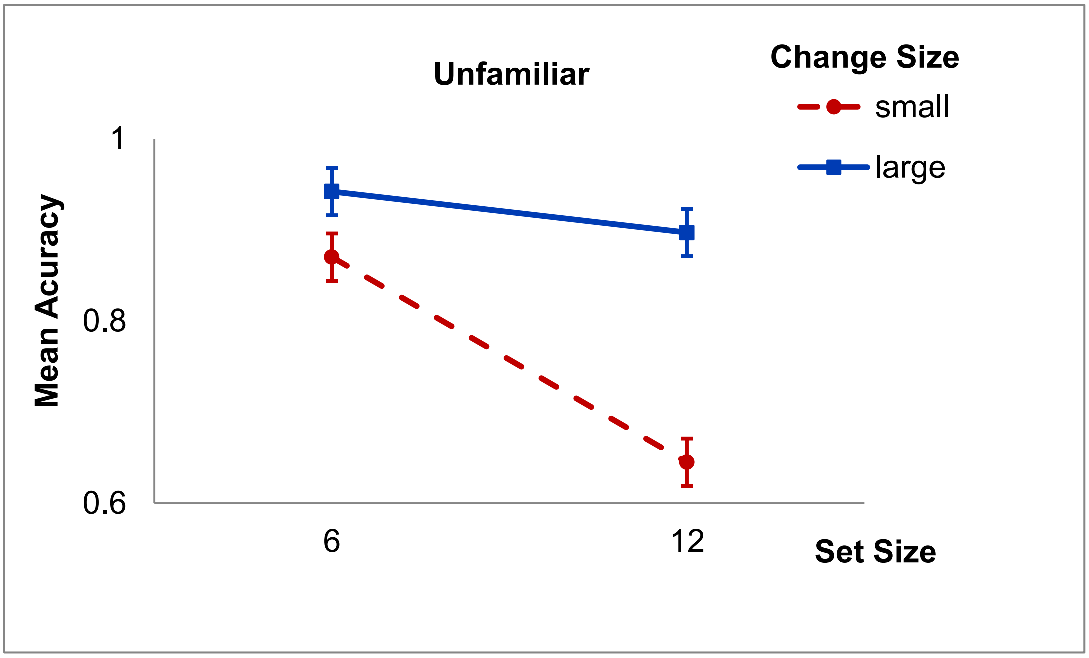

Figure 13. Mean accuracy (proportion correct) as a function of set size and change size for *unfamiliar* faces.

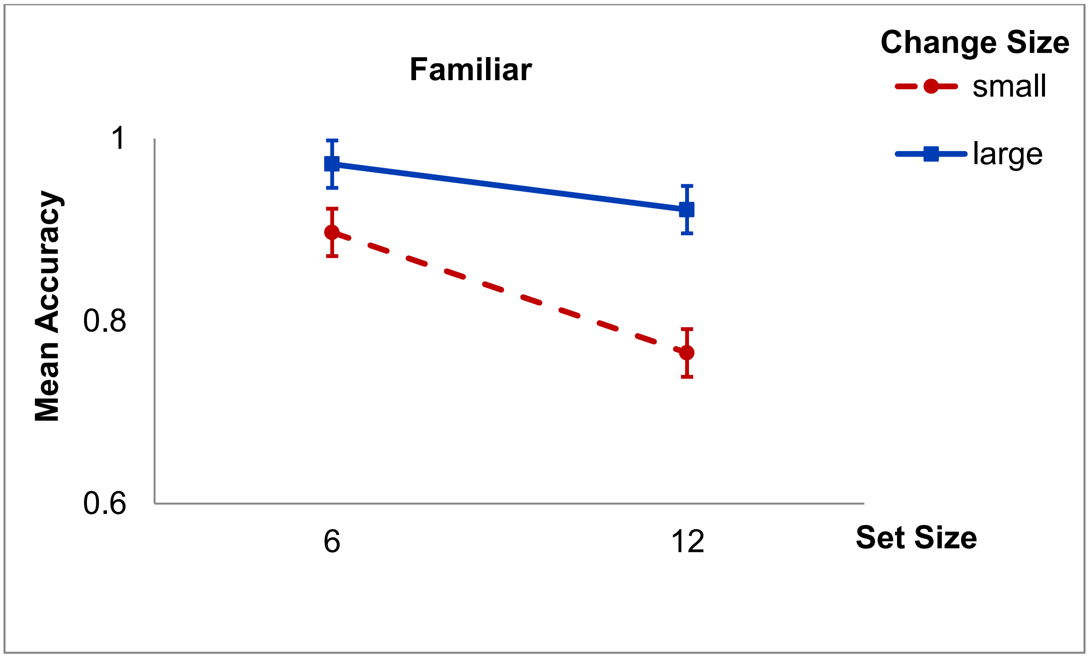

Figure 14. Mean accuracy (proportion correct) as a function of set size and change size for *familiar* faces.

Chinese response time. The same trials used in the combined response time analysis were analyzed here, except only data corresponding to Chinese participants were included. In contrast to the combined and Caucasian analyses, there was no main effect of familiarity, $F(1,19) = 1.36$, $MSE = 350182$, $p > .25$, $\eta_p^2 = .067$.

There was a significant main effect of set size, $F(1,19) = 269.61$, $MSE = 700682$, $p < .001$, $\eta_p^2 = .934$, with responses being faster for a set size of 6 ($M = 3961$ ms, $SD = 115$ ms) than for a set size of 12 ($M = 6134$ ms, $SD = 188$ ms). There was also a significant main effect of change size, $F(1,19) = 55.97$, $MSE = 1107406$, $p < .001$, $\eta_p^2 = .747$. Participants detected large changes faster ($M = 4425$ ms, $SD = 125$ ms) than small changes ($M = 5670$ ms, $SD = 195$ ms). None of the interactions were significant.

Chinese accuracy. The same data from the combined accuracy analysis were analyzed here, except that only the data from Chinese participants were included. The effect of familiarity approached significance, $F(1,19) = 4.19$, $MSE = .004$, $p < .06$, $\eta_p^2 = .181$. Interestingly, the Chinese participants were more accurate in detecting changes in *Caucasian* faces ($M = .889$, $SD = .014$) than in Chinese faces ($M = .867$, $SD = .015$).

There was a significant main effect of set size, $F(1,19) = 76.00$, $MSE = .013$, $p < .001$, $\eta_p^2 = .800$. Participants were less accurate in detecting changes when 12 faces were displayed ($M = .801$, $SD = .022$) than when 6 faces were displayed ($M = .956$, $SD = .008$). The effect of change size was also significant, $F(1,19) = 71.11$, $MSE = .008$, $p < .001$, $\eta_p^2 = .789$. Large changes were detected more accurately ($M = .936$, $SD = .012$) than small changes ($M = .820$, $SD = .018$).

The set size by change size interaction was the only significant interaction, $F(1,19) = 44.64$, $MSE = .005$, $p < .001$, $\eta_p^2 = .701$. The form of this interaction was identical to the other set size by change size interactions in that the change size effect was significantly larger for a set size of 12 than for a set size of 6.

Similarity Rating Task

The similarity rating data were first analyzed to determine whether there were any systematic differences in the similarities of the "familiar" faces. To this end, the Caucasian participants' similarity ratings of the Caucasian face parings were compared to the Chinese participants' similarity ratings of the Chinese face pairings. An independent t-test revealed that there was no difference between these ratings ($t < 1$).

The similarity rating data were then submitted to a Participant Race (Chinese vs. Caucasian) x Stimulus Race (Chinese vs. Caucasian) mixed-factors ANOVA to determine whether there was an overall similarity effect of Stimulus Race. There was a significant main effect of Stimulus Race, with Chinese face parings being rated more similar than Caucasian face pairings, $F(1,39) = 10.54$, $MSE = .119$, $p < .005$, $\eta_p^2 = .213$. A simple effects analysis revealed that while the Caucasian participants rated the Chinese face pairings as being significantly more similar than the Caucasian face pairings, $F(1,19) = 13.95$, $MSE = .084$, $p < .001$, $\eta_p^2 = .423$, the Chinese participants rated the Caucasian and Chinese face parings as being equally similar, $F(1,19) = 1.66$, $MSE = .151$, $p > .20$, $\eta_p^2 = .080$.

Discussion

The present research had two main objectives: (1) to examine the role of familiarity in detecting changes in human faces, by evaluating how a participant's race (Chinese or Caucasian) affects their ability to detect changes in same-race (familiar) or other-race (unfamiliar) faces and (2) to establish the temporal locus of the familiarity effect within the Tovey and Herdman's (2014) stage model for change blindness. These objectives were addressed by measuring Chinese and Caucasian participants' performance on a change detection task in which photographs of

Chinese and Caucasian faces were displayed using a flicker paradigm. Familiarity was operationalized as a function of the own-race bias where same-race photographs were familiar and other-race photographs were unfamiliar. In addition to familiarity, two other factors known to influence change blindness (set size and change size) were jointly manipulated, so that their interactive and additive effects could be interpreted using Sternberg's (1969) additive factors logic to establish the processing stage(s) at which familiarity with faces exerts its influence. Set size was defined as the number of faces presented in a matrix, while change size was represented by the degree to which the target face changed.

Careful consideration was given to the selection and presentation of visual stimuli, in order to reduce the possibility that attentional and/or cultural variables interfered with the experimental results. That is, only photographs of faces displaying a neutral expression were selected from the databases and were modified such that all images were in black and white and had a similar face:background ratio. Similarly, the faces presented on any give trial always belonged to the same race (to avoid a same-race bias within a trial), and always had an equal gender representation (to avoid a gender bias).

As predicted, there was an overall effect of familiarity, with participants being faster at detecting changes in same-race faces than in other-race faces. However, a more in-depth analysis revealed that only the Caucasian participants were exhibiting a familiarity effect, in that they were faster and more accurate at detecting changes in Caucasian faces than in Chinese faces. In contrast, the Chinese participants did not demonstrate a familiarity effect. In fact, the Chinese participants were more accurate (one-tailed) at detecting changes in *Caucasian* faces than in Chinese faces.

The finding that the Chinese participants did not exhibit a familiarity effect is somewhat surprising, given that the Caucasian participants did produce a robust familiarity effect in the same experimental paradigm. One explanation for this unexpected finding is that the Chinese and Caucasian participants were not equally exposed to the other race. Data collected on the SEQ showed that Chinese participants lived, on average, 2.75 years in a country with a population that was predominantly Caucasian, whereas none of the Caucasian participants lived in a country with a predominantly Chinese population. Indeed, one of the main theories attempting to explain the own-race bias is the *contact hypothesis*, whereby the more exposure an individual has to a certain race/ethnicity, the better they become at remembering faces from that group. For example, Chiroro and Valentine (1995) tested the recognition memory of four groups of participants (black Africans with low/high exposure to white faces, and Caucasians with low/high exposure to black faces) and found that the high-contact participants showed a significantly reduced own-race bias, compared to the low-contact participants. The current finding that Chinese participants did not demonstrate a familiarity effect might therefore not hold up, should a sample of Chinese participants who never lived in a predominantly Caucasian country be tested.

Another plausible interpretation for null effect of familiarity observed in the Chinese participants is offered by the *physiognomic variability hypothesis* (Sporer, 2001), which states that certain ethnic groups have higher phenotypic similarities than others. More specifically, it is possible that the Chinese face pairings used here were physically more similar than the Caucasian face pairings simply because there is less variability in Chinese faces than in Caucasian faces. As such, changes in Caucasian faces would be easier to detect than changes in Chinese faces, independent of participants' other-race exposure. This possibility can be addressed by examining the similarity rating data. Specifically, the similarity ratings of Chinese faces by Chinese participants can be compared to the similarity ratings of Caucasian faces by Caucasian participants. If the Chinese face pairings used in this study are physically more similar to each other than the Caucasian face pairings are to each other, than an “expert” at recognizing Chinese faces (i.e., a Chinese participant) should report higher similarity ratings for Chinese faces than a Caucasian does for Caucasian faces. This was not the case. The similarity ratings by Chinese participants for Chinese face pairings was statistically equivalent to the similarity ratings by Caucasian participants for Caucasian face pairings. The physiognomic variability hypothesis therefore does not appear to mediate the familiarity effect – at least for the stimulus set used in the current experiment.

An additional interpretation for the presence/absence of a familiarity effect in Caucasian/Chinese participants is that there is an ethnicity-based difference in the degree to which visual information is processed holistically (see Nisbett & Masuda, 2003). Given the aforementioned evidence that human faces are candidates for holistic processing, this interpretation appears to be appropriate. Of particular relevance to this explanation are the cultural differences in change blindness reported by Masuda and Nisbett (2006). The authors used a flicker paradigm to present visual scenes in which changes happened either in focal object information or in contextual information. While Westerners detected changes in focal objects faster than changes in contextual information, East Asians (including Chinese participants) detected context changes as rapidly as focal changes. Importantly, East Asians were faster than Westerners in detecting context changes. Masuda and Nisbett interpreted the results as evidence for cultural variations at the level of basic visual information processing, whereby East Asians view the world holistically while Westerners view the world analytically.

Considering that only the Caucasian participants showed a familiarity effect, the second purpose of this study (i.e., to establish the stage at which familiarity with faces impacts change detection) was tested by drawing exclusively from data belonging to this sub-sample of participants. Overall, the results are consistent with and extend Tovey and Herdman's (2014) stage model for change blindness. Response time and accuracy data revealed that set size interacted with change size, and change size interacted with familiarity, thus mirroring the interaction effects observed in Tovey and Herdman's research using familiar (upright) and unfamiliar (inverted) letters.

In terms of extending Tovey and Herdman's model, the key finding reported in this study is that there was a three-way interaction between set size, change size, and familiarity in the accuracy data. Importantly, Tovey and Herdman did not find this interaction. This three-way interaction indicates that the familiarity effect associated with detecting changes in human faces affects the same visual information processing stage that is influenced by set size and change size. In particular, and as predicted, familiarity influences the ability to detect changes in faces at an early visual processing stage — most likely the feature extraction stage. By comparison, Tovey and Herdman showed that familiarity with letters affected a later processing stage — the identification stage. In support of the claim that familiarity with faces affects an early processing stage, Tanaka (2001) showed an early entry point for face recognition. Faces and non-face visual stimuli were presented for either a short (75 ms) or a long (950 ms) exposure duration. Participants' accuracy of face identification at the subordinate level (i.e., unique identity of faces) was just as good for short and long exposure durations. This was in contrast with other visual stimuli, for which the accuracy in subordinate-level identification suffered in response to shorter exposure durations.

In conclusion, the current research is consistent with Tovey and Herdman's model for change blindness, insofar as Caucasian participants' familiarity with faces, as with letters, influences the ability to detect change. It also extends the model, by proposing that familiarity with faces is distinct from familiarity with letters with regard to the temporal locus of their effects. That is, familiarity with letters impacts change blindness at a later stage of visual information processing (identification), whereas familiarity with faces affects an earlier processing stage (feature extraction). One explanation for this difference is that our high level of expertise with human faces — owing to our predominant exposure to this class of stimuli — facilitates the early perception of faces, thus enabling a fast and efficient analysis of the visual information associated with a face.

The theoretical implications of this line of research encourage a rethinking of the own-race bias, originally interpreted in the context of recognition memory studies. That is, faces belonging to one's own ethnic group may be better remembered *because* they are better recognized and differentiated at an early encoding stage. Practical applications of change blindness research, at a general level, focus on mitigating the tendency to miss changes in one's visual field under certain viewing conditions. In particular, the current findings could be employed to design training tailored to the specific visual demands of professionals working in areas where failure to respond to rapid visual changes in human faces is of key importance.

Appendix A

Social Experience Questionnaire (Chinese participants)

1. In which country were you born?
2. How many years have you lived in a country where the majority of the population is Caucasian?
3. Approximately what percentage of the students in the elementary school you attended were Caucasian?

   0 = 0-9%

   1 = 10-19%

   2 = 20-29%

   3 = 30-39%

   4 = 40-49%

   5 = 50-59%

   6 = 60-69%

   7 = 70-79%

   8 = 80-89%

   9 = 90-99%
4. How many Caucasian friends did you have in elementary school?

   (9 = 9 or more)

   0 1 2 3 4 5 6 7 8 9
5. Approximately what percentage of the students in the high school you attended were Caucasian?

   0 = 0-9%

   1 = 10-19%

   2 = 20-29%

   3 = 30-39%

   4 = 40-49%

   5 = 50-59%

   6 = 60-69%

   7 = 70-79%

   8 = 80-89%

   9 = 90-99%
6. How many Caucasian friends did you have in high school?

   (9 = 9 or more)

0 1 2 3 4 5 6 7 8 9

7. Approximately what percentage of the people in the neighbourhood in which you grew up were Caucasian?

0 = 0-9%
1 = 10-19%
2 = 20-29%
3 = 30-39%
4 = 40-49%
5 = 50-59%
6 = 60-69%
7 = 70-79%
8 = 80-89%
9 = 90-99%

8. In an average week, approximately how many Caucasian do you have conversations with on campus?

(9 = 9 or more)

0 1 2 3 4 5 6 7 8 9

9. In an average week, approximately how many Caucasian do you have conversations with in recreational activities (sports, parties, etc.)?

(9 = 9 or more)

0 1 2 3 4 5 6 7 8 9

10. Of your nine closest friends, how many are Caucasian?

(9 = 9 or more)

0 1 2 3 4 5 6 7 8 9

11. How many times have you dated a Caucasian person?

(9 = 9 or more)

0 1 2 3 4 5 6 7 8 9

Appendix B

Social Experience Questionnaire (Caucasian participants)

1. In which country were you born?
2. How many years have you lived in a country where the majority of the population is Chinese?
3. Approximately what percentage of the students in the elementary school you attended were Chinese?

   0 = 0-9%

   1 = 10-19%

   2 = 20-29%

   3 = 30-39%

   4 = 40-49%

   5 = 50-59%

   6 = 60-69%

   7 = 70-79%

   8 = 80-89%

   9 = 90-99%
4. How many Chinese friends did you have in elementary school?

   (9 = 9 or more)

   0 1 2 3 4 5 6 7 8 9
5. Approximately what percentage of the students in the high school you attended were Chinese?

   0 = 0-9%

   1 = 10-19%

   2 = 20-29%

   3 = 30-39%

   4 = 40-49%

   5 = 50-59%

   6 = 60-69%

   7 = 70-79%

   8 = 80-89%

   9 = 90-99%
6. How many Chinese friends did you have in high school?

   (9 = 9 or more)

0 1 2 3 4 5 6 7 8 9

7. Approximately what percentage of the people in the neighbourhood in which you grew up were Chinese?

0 = 0-9%
1 = 10-19%
2 = 20-29%
3 = 30-39%
4 = 40-49%
5 = 50-59%
6 = 60-69%
7 = 70-79%
8 = 80-89%
9 = 90-99%

8. In an average week, approximately how many Chinese do you have conversations with on campus?

(9 = 9 or more)

0 1 2 3 4 5 6 7 8 9

9. In an average week, approximately how many Chinese do you have conversations with in recreational activities (sports, parties, etc.)?

(9 = 9 or more)

0 1 2 3 4 5 6 7 8 9

10. Of your nine closest friends, how many are Chinese?

(9 = 9 or more)

0 1 2 3 4 5 6 7 8 9

11. How many times have you dated a Chinese person?

(9 = 9 or more)

0 1 2 3 4 5 6 7 8 9

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