**Can gaze-contingent mirror-feedback from unfamiliar faces alter self-recognition?**

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**Abstract**

This study focuses on learning of the self, by examining how human observers update internal representations of their own face. For this purpose, we present a novel gaze-contingent paradigm, in which an onscreen face either mimics observers' own eye-gaze behaviour (in the congruent condition), moves its eyes in different directions to that of the observers (incongruent condition), or remains static and unresponsive (neutral condition). Across three experiments, the mimicry of the onscreen face did not affect observers' perceptual self-representations. However, this paradigm influenced observers' reports of their own face. This effect was such that observers felt the onscreen face to be their own and that, if the onscreen gaze had moved on its own accord, observers expected their own eyes to move too. The theoretical implications of these findings are discussed.

## Introduction

The face is one of our most distinctive physical features. It is considered the signature of the self (McNeill, 1998) and plays an important role in self-awareness (Morin, 2006). Therefore, it is not surprising that self-face recognition has attracted researchers' attention over the past two centuries (for a review, see Keenan, Gallup, & Falk, 2003). Most studies in this field have focused on the retrieval of the visual representation of the own face (e.g., Brady, Campbell, & Flathery, 2004, 2005; Brédart, 2003; Keenan, Wheeler, Gallup, & Pascual-Leone, 2000; Tong & Nakayama, 1999), the differences between the processes involved in the recognition of our own and other faces (e.g., Greenberg & Goshen-Gottstein, 2009), and the neural bases of self-face recognition (for a review, see Devue & Brédart, 2011). In this study, we want to explore one aspect of self-recognition that has received comparatively little attention, by examining how human observers might update visual representations of their own face.

Recognition requires that a seen face is matched to a stored, internal representation of that identity. Theories of face processing postulate that this internal representation is not tied to a specific instance of a seen face, but is activated by any image of this person (see, e.g., Burton, Bruce, & Johnston, 1990; Bruce & Young, 1986). Thus, this internal representation should be tolerant to some changes in the appearance of a face, such as variation in lighting direction (see, e.g., Bruce, 1982; Longmore, Liu, & Young, 2008). A question that arises is how this internal representation is created so that a previously unfamiliar face, of someone that we have not met before, becomes sufficiently familiar for recognition to occur.

Current theorising suggests one way to operationalize this process could be the creation of face *averages*, in which different instances of the same face are integrated into a single representation (Burton, Jenkins, Hancock, & White, 2005). In this process, information that is relevant to the identity of a person, and therefore present consistently across encounters, is combined to form a robust facial representation for recognition. By contrast, variable visual information that is irrelevant to identity, such as superficial changes in the appearance of a particular face, is eliminated naturally during averaging because their effect will be cancelled out across different instances.

This theoretical account can provide a robust method to simulate face recognition (Burton, Jenkins, & Schweinberger, 2011; Jenkins & Burton, 2008; Robertson, Kramer, & Burton, 2015). It also provides an account of face *learning* (see e.g., Burton, Kramer, Ritchie, & Jenkins, in press; Kramer, Ritchie, & Burton, 2015; Leib et al., 2014). Accordingly, the created internal representation of a face is tied in an additive manner to the experience of that identity, whereby every new exposure strengthens its average and leads to a stronger internal representation (Burton et al., 2005, 2011; Jenkins & Burton, 2008). Interestingly, this theoretical approach can also explain two interrelated aspects of self-recognition, namely how a visual representation of the own face is created and how this representation accommodates changes in physical appearance during the lifespan. According to this perspective, any new instance of the own face would be incorporated into the averaging process to naturally deal with changes in the appearance.

However, current theories stop short of explaining an important component of self-recognition, which is the self-referential process of knowing that a particular face is, in fact, one's own (e.g., Devue & Brédart, 2011; Morin, 2006). A potential answer to this question emerges from the domain of body perception, where research has shown the importance of *body-awareness* for self-recognition (e.g., Botvinick & Cohen, 1998; Tsakiris, 2010; Tsakiris & Haggard, 2005). Mental representations of our bodies are held to be created through the interaction and integration of different senses, such as visual, tactile and proprioceptive information (Blanke, Landis, Spinelli, & Seeck, 2004; Tsakiris & Haggard, 2005). This information appears to be used not only in the formation of a representation of our body, but also for updating and modifying that representation when necessary (Botvinick & Cohen, 1998; Lenggenhager, Tadi, Metzinger, & Blanke, 2007; Petkova et al., 2011; Tsakiris & Haggard, 2005).

Evidence for such accounts comes from the rubber hand illusion. In this paradigm, observers watch a rubber-hand being stroked while their own hand is stroked out of sight in synchrony. This simultaneous stimulation produces the feeling that the rubber hand is, in fact, one's own hand (Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005). This effect relies on the multi-sensory combination of touch (of one's own hand) and sight (of the rubber hand being stroked). However, a rubber-hand effect has also been obtained without touching, for example, when there is synchrony of movement between a rubber and one's own hand (e.g., Dummer, Picot-Annand, Neal, & Moore, 2009; Riemer et al., 2014). Similar effects have been reported with arms (Guterstam, Petkova, & Ehrsson, 2011) and even with the whole body (Lenggenhager et al., 2007; Petkova & Ehrsson, 2008; Petkova et al., 2011).

With respect to face learning, these findings are interesting in that they could provide a self-referential process to update internal representations, by accommodating physical changes in a person's appearance due to, for example, cosmetics, styling or aging. Accordingly, such updating could be supported if observers can *see* and, through proprioceptive feedback, *feel* their own face move at the same time. Outside of the laboratory, such feedback is available daily from mirrors, for example, during hygiene activities such as washing and grooming. In these conditions, a person's mirror reflection provides synchronous visual feedback for motor, proprioceptive and tactile information (Botvinick & Cohen, 1998; Tajadura-Jimenez, Grehl, & Tsakiris 2012a;

Tsakiris, 2008, 2010). This feedback provides direct evidence that a looked-at face is, in fact, one's own. The question arises of whether this also contributes to the updating of a person's face, by accommodating external changes in their physical appearance into existing internal representations.

Studies of multi-sensory integration already provide some evidence to support this idea. For example, when observers' faces are stroked in synchrony with a target that consists of a 50:50 morph of their own face and that of another person, they subsequently tend to see more of their own features in the other person's face (Tsakiris, 2008). This perceptual effect is accompanied by a subjective illusion that the other face *belongs* to the observer. This bias in self-recognition or "enfacement effect" (Sforza, Bufalari, Haggard, & Aglioti, 2010) has been shown with totally unfamiliar (Tajadura-Jiménez et al., 2012a), familiar (Sforza et al., 2010), and other-race faces (Bufalari, Lenggenhager, Porciello, Serra-Holmes, & Aglioti, 2014; Fini, Cardini, Tajadura-Jiménez, Serino, & Tsakiris, 2013).

While these findings point to a remarkably robust effect, multi-sensory paradigms rely on observing the tactile stimulation of another agent. This presents a scenario that is not encountered outside of the laboratory. In this study, we therefore wish to examine whether a similar updating of observers' facial representations occurs with a stimulation method that is more similar to the experience of studying one's own reflection in a mirror. For this purpose, we present a gaze-contingent paradigm, in which the eye movements of a face on a computer screen directly mimic the looking behaviour of an observer.

To measure the effect of this manipulation on self-recognition, we compared several conditions. In Experiment 1, the gaze behaviour of the onscreen target face provided a direct "mirror-reflection" of observers' gaze behaviour, by mimicking their eye movements in the *congruent* condition. This was contrasted with an *incongruent* condition in which the eyes of the onscreen face responded to observers eye-gaze but moved in a different direction. If mirror-reflection is used to update facial representations of the own face, then it should be possible to induce an enfacement-type effect in this paradigm, whereby the onscreen face should be perceived as more similar to the own face. In line with studies of multi-sensory stimulation (e.g., Fini et al., 2013; Sforza et al., 2010; Tajadura-Jiménez et al., 2012a; Tsakiris, 2008), this effect should be found in the *congruent* gaze condition in comparison with *incongruent* displays.

To assess this possibility, we adopted established measures of the enfacement illusion from multi-sensory stimulation paradigms (see, e.g., Keenan et al., 1999; Maister, Tsiakkas, & Tsakiris, 2013; Tajadura-Jiménez et al., 2012a; Tsakiris, 2008). This comprised a self-other discrimination task, in which observers were shown a morphing sequence between the onscreen face viewed in the stimulation stage and observers' own face. In this task, observers were asked to determine at which point they could perceive their own face in the sequence. This measure was complemented with an enfacement questionnaire, which assessed different aspects of observers' phenomenological experience of identifying with the onscreen face of the stimulation stage.

## Experiment 1

In this experiment, observers watched an onscreen face in a gaze-contingent paradigm, which was comprised of two conditions. In the congruent condition, the eyes of this face mimicked observers' eye-gaze direction to imitate, in this particular aspect, the experience of looking in a mirror. Observers triggered the eye-gaze of the onscreen face by moving their own eyes, which were tracked concurrently, around the display screen. To encourage such eye movements, the onscreen face was surrounded by eight boxes, which, upon being fixated, revealed a visual icon. Performance in this task was contrasted with an incongruent condition, in which the eyes of the onscreen face moved in temporal synchrony with an observer eye-gaze but in a different direction.

Before and after this task, observers performed a self-other discrimination task. This consisted of a morphing sequence between the onscreen face from the stimulation stage and observers' own faces. This sequence always began with the onscreen face, which was gradually morphed into the observer's face. Observers had to stop this sequence as soon as they felt that the face resembled their own face more than that of the stimulation face. In addition, observers' phenomenological experience of the gaze-contingent task was assessed with an established enfacement questionnaire.

If this gaze-contingent mirror-reflection paradigm can be used to update observers' representations of their own face, then the onscreen face should become integrated into this representation in the congruent condition. As a consequence, observers should detect their own face earlier in the morphing sequence in the congruent than the incongruent condition. This effect should also be evident from the questionnaire, with observers reporting a greater resemblance with the stimulation face in the congruent condition.

## Method

### Participants

Twenty Caucasian students (13 females) from the University of Kent, with a mean age of 22 years (SD = 4.2), participated in this study. All provided informed consent prior to taking part and received course credits or a small fee for participation. All reported normal or corrected-to-normal vision.

## Stimuli

*Gaze-contingent stimulation displays*

For the stimuli of the gaze-contingent task, a male and a female frontal face were taken from the Glasgow Face Database (Burton, White & McNeill, 2010). These faces were digitized with FaceGen Modeller software (Singular inversions Inc., Toronto). The resulting faces provided artificial representations of the original stimuli, in which gaze direction can be controlled with the same software. This was used to create nine images of each face, in which the eye-gaze systematically varied across three horizontal (left, middle, right) and three vertical positions (up, middle, down). To enhance the salience of these gaze directions, the brightness of the sclera was increased by 25% using Adobe Photoshop.

In the experiment, each of these faces was presented at a width and height of 325 x 420 pixels at a resolution of 72 ppi in the centre of a white display. These faces were surrounded by eight boxes, which measured 220 x 220 pixels. When fixated, these boxes were replaced by images of objects (e.g., a radio, cd, glove), which measured maximally 200 x 200 pixels. These displays are illustrated in Figure 1.

*Self-other discrimination task*

For the self-other discrimination task, a digital photograph of each observer was taken prior the experiment. For consistency with the model's face, these pictures were also modelled with FaceGen. The resulting images were morphed with the stimulation face that matched the observer's sex in 1% steps using Fantamorph (Abrasoft) software. This resulted in a sequence of 100 images, which provided a smooth continuum between the stimulation face and an observer's own face. Each of these images was presented at a size of 254 x 313 pixels at a resolution of 96 ppi.

*Enfacement questionnaire*

A questionnaire was administered to assess observers' subjective experience of the gaze-contingent paradigm. This questionnaire was adapted from studies of the "enfacement" effect (Tajadura-Jiménez et al., 2012a; see also Maister et al., 2013) and consisted of 11 items (see Table 1). The first seven questions assessed observers' enfacement experience and included items such as "I felt like the onscreen face was my face" and "I felt like I was looking at my own face in the mirror". A high score in these items indicates that observers felt that the stimulation face had become integrated with the internal presentation of their own face during the experiment (see Tajadura-Jiménez, Longo, Coleman, & Tsakiris, 2012b). The four remaining items assessed whether observers perceived the eye-gaze of the stimulation face, with statements such as "I felt like the onscreen face's eyes followed my eyes", to provide a manipulation check. Responses to all items were recorded on 7-point Likert scales, which ranged from *"strongly disagree"* to "*strongly agree"*.

**Procedure**

In the experiment, observers participated in the self-other discrimination task first to obtain a baseline measure of self-recognition (the pre-test), which was conducted using E-prime on a computer with a 21" screen. In this task, observers viewed the sequence of the morphed faces. This sequence always began with the stimulation face (100% stimulation face, 0% observer), which was gradually morphed, in 1% segments, into an observer's own face. This sequence was presented at a rate of one segment per second. While watching this sequence, observers were asked to press the space bar as soon as they felt that the displayed face resembled their own face more than that of the stimulation phase. Prior to this pre-test, observers were trained on this discrimination task by watching a sequence that morphed the face of David Cameron (British Prime Minister) into Barack Obama (American President).

The pre-test was followed by the gaze-contingent stimulation task. For this task, observers' eye movements were tracked using the SR-Research Eyelink 1000 desk-mounted eye tracking system. Observers sat at a distance of 50 cm from a 21" screen, which was held constant by a chinrest. Although viewing was binocular, only the left eye was tracked. To calibrate eye-gaze, the standard nine-point Eyelink procedure was used. Thus, observers fixated a set of nine fixations targets, which was followed by a second sequence of nine targets to validate calibration. If this procedure indicated poor measurement accuracy (i.e., a measurement error of > 1° of visual angle), calibration was repeated.

At the beginning of the stimulation task, observers fixated a central dot so that an automatic drift correction could be performed. The stimulation face was then displayed in the centre of the screen. The sex of this face was always kept congruent with that of the observer. The stimulation face was surrounded by eight boxes, which were depicted in different colours (see Figure 1). Each of these boxes hid an object, which was revealed when it was fixated by the observers, to provide a task demand that would encourage eye movements around these displays. Observers were asked to look at these boxes and to memorize their contents. Crucially, the onscreen location of these boxes served as trigger regions to manipulate the eye-gaze direction of the stimulation face, which changed only 150 msec after a trigger region was fixated. This task lasted for two minutes and, to assess any effects of this stimulation on self-recognition, was followed by a repetition of the self-other discrimination task and the enfacement questionnaire. Observers were then presented with a second block of the stimulation task, which was followed by a further repetition of the discrimination task and the questionnaire.

One of the stimulation blocks comprised congruent stimulation (i.e., the gaze of the stimulation face was always congruent with observers' own eye-gaze direction) and the other block incongruent stimulation (i.e., the gaze of the stimulation face was always incongruent with observers' own eye-gaze direction). This spatial incongruence was created by randomly assigning a different gaze direction to the stimulation face for each of the observer's possible gaze directions. Over the course of the experiment, the presentation order of the congruent and incongruent conditions was counterbalanced across observers.

## Results

*Self-other discrimination task*

Performance in the discrimination task was assessed first. Figure 2 shows the mean percentage of frames that were perceived as the stimulation face and as observers' own face in the morphing sequence. This data is given for the initial baseline measure and after the gaze-congruent and incongruent stimulation conditions were administered. A one-factor ANOVA (baseline, congruent, incongruent condition) of this data showed a main effect of condition, $F(1,19) = 7.13$, $p < .01$, $\eta_p^2 = .27$. Paired sample t-tests (Bonferroni-corrected) revealed that observers perceived their own face earlier in the morphing sequence after the application of the gaze-congruent condition in comparison with the baseline, $t(19) = 2.80$, $p < .05$. However, a similar effect was observed also in the incongruent condition in comparison to baseline, $t(19) = 3.44$, $p < .01$, and the congruent and incongruent condition did not differ from each other, $t(19) = 0.50$, $p = .98$. Taken together, these results suggest a practice effect as observers perceived their own face earlier in both the congruent and incongruent condition compared with the baseline. However, the equivalent performance in the congruent and incongruent condition also indicates that gaze-contingent stimulation did not affect observers' perceptual self-representations.

*Enfacement questionnaire*

We also assessed observers' questionnaire responses to determine if this paradigm affected how they felt regarding the stimulation face. These data are provided in Figure 3 as mean Likert responses to each of the enfacement items, for the congruent and incongruent conditions. Four of the questionnaire items are verification items, which assess whether observers were sensitive to the gaze-contingent task. The differences in ratings for these verification items show that observers were aware that the stimulation face followed their own eye-gaze in the congruent compared to the incongruent condition (items 8 and 9), both $ts(19) \geq 4.00$, $ps < .001$. The ratings also show a clear difference between conditions in terms of the directionality of the eye-gaze (items 10 and 11), whereby observers were more likely to report that the eyes of the stimulation face moved in the same direction as their own eyes in the congruent condition, $t(19) = 7.28$, $p < .001$. In contrast, observers noted that the eyes of the stimulation face moved in a different direction to their own in incongruent displays, $t(19) = 5.98$, $p < .001$. However, when the ratings for items 10 (eyes moved in the same direction) and 11 (eyes moved in a different direction) are compared directly, it emerges that these are more similar in the incongruent condition, $t(19) = 1.60$, $p = .12$, than the congruent condition, $t(19) \geq 15.79$, $p < .001$. This suggests that observers always perceived movement of the stimulation face's eyes, but were less sensitive to the direction of these movements in the incongruent condition.

A comparison of the congruent and incongruent condition also shows that the gaze contingent paradigm did not affect observers' feelings about the onscreen face, which were comparable across these conditions in all enfacement questions (items 1-7), all $ts(19) \leq 1.65$, $ps > .07$. An overall enfacement score, which was calculated by averaging across items 1 to 7 also shows that the congruent (M = 20.4, SD = 8.2) and incongruent (M = 17.9, SD = 9.1) conditions did not differ, $t(19) = 1.14$, $p = .14$.

## Discussion

Experiment 1 explored whether it would be possible to update the internal representation of one's own face with a gaze-contingent paradigm that simulates the mirror-reflection experience. This was investigated by comparing a congruent condition, in which the eye-gaze of an onscreen face follows that of the observer, with an incongruent condition, in which the gaze of the onscreen face was spatially incongruent. To assess whether this stimulation affected observers' self-representation, they were asked to detect their face in an image sequence that began with the onscreen face and gradually morphed into their own face. In comparison with a baseline measure, which was obtained prior to the administration of the stimulation task, a shift in self-recognition was found in the congruent condition, whereby observers recognized their own face at an earlier stage of the morphing sequence. However, the same effect was also observed after the administration of the incongruent condition. Taken together, these results suggest that the gaze-congruent condition did not affect observers' self-recognition *per* se. Instead, these findings hint at a practice effect whereby observers perceived their own face earlier in the morphing sequence of the congruent and incongruent conditions in comparison to the initial baseline measure. In line with these findings, the results indicate also that the gaze-contingent paradigm did not affect how observers feel about the onscreen face and their own face.

A possible explanation for these findings is that the difference in eye-gaze between the congruent and incongruent conditions was insufficient to elicit a mirror effect that can alter self-recognition. The verification items of the questionnaire reveal that observers were sensitive to the eye movements of the stimulation face in the congruent condition. However, this effect was considerably smaller with incongruent displays. Here, observers showed some false agreement that the stimulation face followed their eyes (see item 8 in Figure 3), and a direct comparison of items 10 and 11 indicates limited insight into whether the onscreen gaze was moving in the same or a different direction to observers' own eyes.

This situation might arise because eye-gaze direction cannot be perceived easily outside the focus of attention (Burton, Bindemann, Langton, Schweinberger, & Jenkins, 2009; Hermens, Bindemann, & Burton, in press). In the current paradigm, observers have to explore the boxes surrounding the stimulation face to trigger its eye movements. As a result of this, however, this face is unattended when any changes in its gaze direction occur. If observers have limited awareness of these changes, then this might not produce the mirror-type effects that are required to affect self-recognition. To explore this possibility, we conducted a further experiment in which the incongruent condition was replaced with a neutral display, in which the eyes of the onscreen face looked straight ahead regardless of the observers' gaze behaviour. Such direct gaze is more salient than averted gaze outside the focus of attention (Yokoyama, Sakai, Noguchi, & Kita, 2014) and should therefore produce a stronger contrast to the congruent eye-gaze condition.

## Experiment 2

In contrast to Experiment 1, which compared congruent gaze-contingent displays with an incongruent condition, this experiment compared congruent with neutral displays, in which the gaze of the onscreen face remained static and unresponsive. Based on previous research, we predicted that this condition should provide a stronger contrast to the moving eye-gaze of the congruent condition, particularly when the stimulation face is not attended (see Burton et al., 2009; Hermens et al., in press; Yokoyama, et al., 2014). If it is possible to update the representation of the own face using a gaze-contingent paradigm, then such an effect might now be observed here, by comparing observers' self-representations after the congruent and neutral displays.

## Method

### Participants

Twenty new Caucasian students (10 female) from the University of Kent, with a mean age of 21 years (SD = 5.1), participated in this study. All provided informed consent prior to taking part, received course credits or a small fee for participation, and reported normal or corrected-to-normal vision.

### Stimuli and procedure

The stimuli and procedure were identical to Experiment 1, except that the incongruent condition was replaced with neutral gaze displays. In this condition, the eye-gaze of the onscreen was always directed straight at the observers and unresponsive. As in Experiment 1, the self-other discrimination task was administered initially to obtain a baseline measure of self-recognition. Observers then performed two blocks, one for the congruent condition and one for the neutral condition, which comprised the stimulation phase, the self-other discrimination task, and the enfacement questionnaire. The order of these blocks was counterbalanced across observers.

## Results

*Self-other discrimination task*

Figure 4 illustrates performance in the self-other discrimination task for the baseline condition and after the administration of the congruent and neutral displays. A one-factor ANOVA (baseline, congruent, neutral condition) showed a main effect of condition, $F(1,19) = 20.37$, $p < .001$, $\eta_p^2 = .51$. Paired sample t-tests (Bonferroni-corrected) show that observers perceived their own face earlier in the morphing sequence after the application of both the congruent and neutral conditions in comparison with the baseline, $t(19) = 6.68$, $p < .001$ and $t(19) = 4.51$, $p < .001$, respectively. Discrimination performance in the congruent and neutral conditions did not differ, $t(19) = 0.75$, $p = 1.00$.

*Enfacement questionnaire*

Observers' questionnaire responses are summarized in Figure 5. The difference in mean ratings for the verification items between the congruent and neutral condition demonstrates that observers were aware that the onscreen face followed their own eye-gaze (see items 8-10 in Figure 5), all $ts(19) \geq 6.55$, $ps < .001$. In addition, when asked whether the onscreen face's eyes moved in a different direction to observers' own (item 11), ratings were low in both conditions and no difference was found, $t(19) = 0.92$, $p = .36$.

A comparison of the congruent and neutral condition also shows that the gaze-contingent paradigm affected how observers felt about the stimulation face. Observers were more likely to report that this face looked like their own in the congruent than the neutral condition (items 1 and 2), both $ts(19) \geq 2.87$, $ps < .01$, and also reported a closer resemblance between their own face and that of the onscreen face in the congruent than the neutral condition (items 5 and 6), both $ts(19) \geq 2.44$, $ps < .05$. This effect was such that, if the eyes of the onscreen face had moved, they expected their own eyes to move too in the congruent condition (item 7), $t(19) = 2.72$, $p < .05$. However, an effect of condition was not universally found. Observers did not report that their own face felt out of control (item 4), $t(19) = 0.19$, $p = .84$, or, despite the clear convergence in felt resemblance between their own and the onscreen face, that they were looking at their own face in a mirror (item 3,) $t(19) = 0.98$, $p = .33$.

Finally, an overall enfacement score was also calculated for each observer, by averaging across items 1 to 7. This enfacement score was higher in the congruent (M = 22.8, SD = 10.6) than the neutral condition (M = 16.9, SD = 8.4), $t(19) = 3.24$, $p < .01$.

## Discussion

This experiment investigated whether it is possible to update the representation of one's own face with a gaze-contingent paradigm by comparing a congruent condition, in which the eye-gaze of an onscreen face followed that of the observer, with a neutral condition, in which the onscreen face was static and unresponsive. As in Experiment 1, observers were sensitive to the eye movements of the onscreen faces and their directionality in the congruent condition. However, a clearer contrast between conditions was now found, by replacing incongruent with neutral gaze displays (c.f., items 8-10 in Figures 3 and 5). Once again, however, this did not affect observers' self-recognition in the discrimination task, which revealed identical effects after congruent and neutral stimulation.

Despite the absence of an effect on self-recognition in the visual discrimination task, the gaze-contingent paradigm affected observers' reports of how they felt about the onscreen and their own face. These reports revealed that observers felt that the onscreen face 'was' their own face and 'belonged' to them, and also that both faces began to resemble each other. This effect was such that, if the eyes of the onscreen face had moved, observers expected their own eyes to move too.

These results indicate that this mirror-like gaze-contingent paradigm can affect how observers feel about their own faces. This finding converges with recent enfacement experiments, in which similar effects are found when observers view the tactile stimulation of another agent while their own face is also stimulated (e.g., Maister et al., 2013; Tajadura-Jiménez et al., 2012a, 2012b; Tsakiris, 2008). However, in these studies a concurrent effect in the self-other discrimination task is typically also found (e.g., Tajadura-Jiménez et al., 2012a; Tsakiris, 2008).

A possible explanation for the absence of such an effect here might relate to the objects surrounding the onscreen face, which acted as trigger-regions to change its gaze-direction and were required to elicit mirror-like responses. As a result of this manipulation, observers were actually drawn away from the onscreen face during stimulation. If this limits the encoding of the stimulation faces in our visual displays, by presenting these outside of foveal vision (see, e.g., Rousselet, Thorpe, & Fabre-Thorpe, 2004; Rousselet, Husk, Bennett, & Sekuler, 2005), then this could limit the integration of the stimulation face into observers' self-representations. To explore this possibility, we conducted a third experiment in which the eight boxes surrounding the onscreen face were replaced with the same face. The aim of this manipulation was to maximize encoding of this identity even when observers were not viewing the central stimulation face directly.

## Experiment 3

In this experiment, we sought to maximise the encoding of the face identity in the stimulation task. As in the preceding experiments, an unfamiliar face was placed in the centre of the screen and responded to observer's eye-gaze. However, to increase the encoding of this identity, the eight surrounding boxes were replaced with copies of the same face. In contrast to Experiments 1 and 2, observers were therefore able to view the stimulation face directly, in the centre of the screen or one of the surrounding locations, throughout this task. These surrounding faces also responded to observer's eye-gaze by copying the actions of the central face. This manipulation overcomes the potential limitations of Experiment 1, in which eye-gaze direction could be perceived only from the unattended central face. In the current experiment, this allowed us to revert to incongruent gaze displays, in which the onscreen gaze moves in temporal synchrony but a different direction to observers' own eye-gaze. To introduce a task demand, one of the surrounding faces would close its eyes after the two-minute stimulation period and observers were asked to detect this change. If it is possible to update self-representations with this gaze-contingent paradigm, then such an effect should be more likely under these conditions, which maximise encoding of the stimulation face, than the preceding experiments.

## Method

### Participants

Twenty new Caucasian students (17 female) from the University of Kent, with a mean age of 22 years (SD = 8.5), participated in this study. All provided informed consent prior to taking part, received course credits or a small fee for participation, and reported normal or corrected-to-normal vision.

**Stimuli and procedure**

The stimuli and procedure were identical to Experiment 1, except for the following changes. In the stimulation task, the eight boxes surrounding the central face, and the objects within, were now replaced by copies of the stimulation face (see Figure 6). Each of these peripheral faces measured 160 by 210 pixels at a resolution of 72 ppi. In the congruent condition, the central face and each of these peripheral copies mirror-mimicked observers' eye-gaze direction. In the incongruent condition, the eye-gaze direction of the central face and the peripheral copies was spatially incongruent with observers' gaze. After a two-minute stimulation period, one of the surrounding faces closed it eyes. Observers were asked to scan the surrounding faces and to press the spacebar as soon as they detected this change.

## Results

*Self-other discrimination task*

Figure 7 summarizes performance in the self-other discrimination task for the baseline condition and after the administration of the congruent and incongruent stimulation displays. A one-factor ANOVA (baseline, congruent, incongruent) showed a main effect of condition, $F(1,19) = 11.57$, $p < .001$, $\eta_p^2 = .38$. Paired sample t-tests (Bonferroni-corrected) show that observers perceived their own face earlier in the discrimination sequence in the congruent condition compared to the baseline, $t(19) =$

3.12, $p < .05$. However, a similar effect was observed in the incongruent condition, $t(19) = 3.40$, $p < .05$, and performance was indistinguishable when the congruent and incongruent conditions were compared directly, $t(19) = 0.95$, $p = 1.00$.

*Enfacement questionnaire*

The questionnaire responses indicate that observers were aware of the onscreen face following their own eye-gaze in the congruent compared to the incongruent condition (see items 8 and 9 in Figure 8), both $ts(19) \geq 2.19$, $ps < .05$. Observers were also more likely to report that the target's eyes moved in the same direction as their own in the congruent condition (item 10), $t(19) = 7.13$, $p < .001$, and in a different direction in the incongruent condition (item 11), $t(19) = 6.66$, $p < .001$. In addition, a direct comparison of the ratings for items 10 (eyes moved in the same direction) and 11 (eyes moved in a different direction) confirmed that observers discriminated the directionality of the onscreen eye movements in both the congruent, $t(19) = 12.15$, $p < .001$, and incongruent condition, $t(19) = 3.10$, $p < .001$.

The gaze contingent paradigm also influenced how observers felt about the onscreen face. In the congruent compared to the incongruent condition, observers were more likely to report that the onscreen face looked like their own face (item 1), that it belonged to them (item 2), and that they felt they were looking at their own face in a mirror (item 3), all $ts(19) \geq 2.06$, $ps < .05$. This effect was such that observers expected their own eyes to move too if the eyes of the target face had moved (item 7), $t(19) = 2.96$, $p < .01$.

However, an effect of condition was not universally found. Despite the clear convergence in felt resemblance between observers' own and the onscreen face, they did not report that these faces actually began to resemble each other (items 5 and 6), both *ts*(19) ≤ 1.65, *ps* >.07. In addition, observers also did not report that their own face felt out of control (item 4), *t*(19) = .19, *p* = 1.67). Despite these similarities across conditions, observers' overall ratings, which combine items 1 to 7, also revealed a higher enfacement score in the congruent (M = 25.5, SD = 9.1) than the incongruent condition (M = 19.7, SD = 8.8), *t*(19) = 3.42, *p* < .01.

## Discussion

In this experiment, the objects surrounding the onscreen face during the stimulation phase were replaced with further images of this identity to maximize its encoding. In this context, observers were clearly sensitive to the onscreen face's eye movements in the congruent and incongruent conditions. As in Experiment 2, the gaze-contingent stimulation paradigm also influenced how observers felt about the onscreen face, such that they were more likely to report that the onscreen face looked like their own face and that it belonged to them in the congruent than in the incongruent condition. This effect was sufficiently strong for observers to be more likely to report that they felt as if they were looking at their own face in a mirror in the congruent condition, and that their own eyes might move to mimic the actions of the onscreen face. Despite this impact on observers' reports, the gaze-contingent task did not produce separable effects for the congruent and incongruent conditions in the perceptual self-other discrimination task. This converges with the findings of Experiments 1 and 2 to suggest that the gaze-contingent paradigm does not influence observers' facial self-representations.

## General discussion

In this paper, we have presented a new paradigm to study how human observers might update mental representations of their own face. This paradigm simulates the mirror reflection experience by mimicking observers' eye-gaze behaviour with an onscreen face. In Experiment 1, observers were exposed to congruent stimulation, in which the movement of the onscreen face was synchronized with their own gaze behaviour, and an incongruent condition, in which the eyes of the onscreen face moved in a different direction to observers' eye-gaze. This experiment did not reveal an effect of gaze stimulation in the self-other discrimination task or on observers' subjective reports. The verification items of the questionnaire suggest that observers were sensitive to onscreen eye-gaze in the congruent condition. By contrast, however, observers did not report a clear directionality effect for the onscreen face's eye movements in the incongruent condition. This suggests that they misperceived the direction of the onscreen face's eye movements, which might have undermined any stimulation effects of the gaze-contingent task.

Subsequent experiments explored whether the gaze-contingent paradigm can be modified to elicit such effects. Experiment 2 replaced the incongruent condition with neutral displays, in which the onscreen eye-gaze was static and unresponsive, to provide a stronger contrast with congruent displays (see Burton et al., 2009; Hermens et al., in press; Yokoyama et al., 2014). Observers' self-reports showed that they were sensitive to the difference in the eye movements between conditions, and also the mimicry that these eye-movements exerted in the congruent condition. This was accompanied by a feeling that the onscreen face 'was' their own face and 'belonged' to them, and that both faces began to resemble each other. This effect was such that, if the eyes of the onscreen face had moved, observers would have expected their own eyes to move too. Once again, however, these changes were not accompanied by a corresponding effect in the self-other discrimination task, which indicates that the gaze-contingent task did not modify observers' perceptual representations of their own face.

It is possible that the encoding of the onscreen face was limited in these experiments because observers were drawn from its location to the peripheral object-triggers during the stimulation phase. We therefore conducted a third experiment in which these peripheral objects were replaced with further photos of the onscreen face to promote further encoding of this identity. These additional face images also responded to observers' gaze in an attempt to further enhance this manipulation. In contrast to Experiment 1, observers were now clearly sensitive to gaze direction in both the congruent and incongruent condition. As in Experiment 2, this was accompanied by stronger reports in the congruent condition that the onscreen face was observers' own face than with incongruent displays, and that observers felt like they were looking at their own face in a mirror. Once again, however, the stimulation conditions did not affect the perceptual discrimination task.

Taken together, these results indicate that our gaze-contingent mirror-experience paradigm can alter observers' subjective reports about their own face, by creating a 'felt' resemblance between their own face and an onscreen target. This effect is remarkable considering it followed a short stimulation period of only two minutes. At the same time, this stimulation was not effective in altering observers' perceptual self-representations, as measured with the self-other discrimination task. A possible explanation for these differences between observers' subjective reports and their perceptual performance could be that these reflect partially independent pathways in the cognitive face recognition system. One of these is responsible for the perceptual recognition of a face, whereas the other might provide an accompanying affective familiarity response, which can be expressed through changes in electrodermal activity (i.e., skin conductance responses, see Ellis & Young, 1990; Schweinberger & Burton, 2003). This idea derives from the study of Capgras delusion and prosopagnosia. In the former, observers can identify familiar faces but do not exhibit the appropriate corresponding feelings of familiarity and related skin conductance responses. As a consequence, people with Capgras delusion believe that familiar persons have been replaced by impostors or aliens (Ellis, 1997). Prosopagnosic observers, on the other hand, are impaired in overt recognition but can still exhibit arousal responses to familiar faces (see, e.g., Ellis, Quayle, & Young, 1999). It is possible that our findings also tap into these dissociable processes, by manipulating affective evaluations of the own face but not perceptual representations.

This idea receives some support from explorations of the enfacement effect, where visuotactile stimulation mediates arousal responses to target faces (e.g., Bufalari et al., 2014; Fini et al., 2013; Maister et al., 2013; Paladino, Mazzurega, Pavani, & Schubert, 2010; Tajadura-Jiménez et al., 2012a). These physiological changes are similar to skin conductance responses during familiar face recognition (Ellis, Young, & Koenken, 1993; Tranel & Damasio, 1985, 1988) and have been observed after synchronous, but not asynchronous, tactile stimulation with an unfamiliar face (see Tajadura-Jiménez et al., 2012a). However, in contrast to the current experiments, this enfacement effect is also accompanied by changes in the perceptual processing of faces.

It remains unresolved why perceptual processing was not affected as well in the current experiments, but one possibility is that a stimulation phase of only two minutes is insufficient to manipulate self-representations that have been build-up over twenty years in our participants. This explanation would be consistent with theories of face recognition, such as average-based accounts, in which different instances of the same face are integrated into a single representation (Burton, et al., 2005). Such averages appear to be remarkably resistant to contamination by other identities. For example, changes to the average of a person's face appear to be imperceptible even when 20% of the source images are photographs of the wrong person (Jenkins & Burton, 2011). If this approach corresponds to the cognitive system for face recognition, then one would also expect internal facial representations to be immune to the brief perceptual stimulation that is applied in the experiments here.

In future studies, this could be explored further by extending the stimulation phase or by applying this paradigm to developmental populations, in which self-representations have been established for fewer years and facial appearance is undergoing more pronounced age-related changes. Future studies could also examine whether the effect of mirror-feedback might be enhanced by mimicking more than observers' eye-gaze, such as facial expression and speech. By encompassing further facial information in this way, the mirror-mimicry may exert more direct effects on visual encoding and the updating of representations of the own face.

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TABLE 1. The enfacement questionnaire.

| Type of Item | Enfacement Item |
| --- | --- |
| Enfacement | **1.** I felt like the onscreen face was my face |
| | **2.** I felt like the onscreen face belonged to me |
| | **3.** I felt like I was looking at my own face reflected in a mirror |
| | **4.** I felt like my own face was out of my control |
| | **5.** I felt like my face began to resemble the onscreen face |
| | **6.** I felt like the onscreen face began to resemble my face |
| | **7.** I felt like if the onscreen face's eyes had moved, my eyes would have moved too |
| Verification | **8.** I felt like the onscreen face's eyes followed my eyes |
| | **9.** I felt like if I had moved my eyes, the onscreen face's eyes would have moved too |
| | **10.** The onscreen face's eyes moved in the same direction as my eyes |
| | **11.** The onscreen face's eyes moved in a different direction as my eyes |

FIGURE 1. Example stimuli of the congruent condition for Experiment 1 and 2, showing direct eye-gaze (left panel) and the eyes pointing up (centre) or down (right). In the neutral condition, the eye-gaze remained direct and static throughout. In the incongruent condition, the eyes of the onscreen face pointed in a different direction to observers' own eye-gaze and therefore did not point at the revealed object.

FIGURE 2. Performance in the self-other discrimination task in Experiment 1, expressed as the percentage of frames that observers judged to show their own face or that of the onscreen face, for the baseline measure and after congruent and incongruent stimulation.

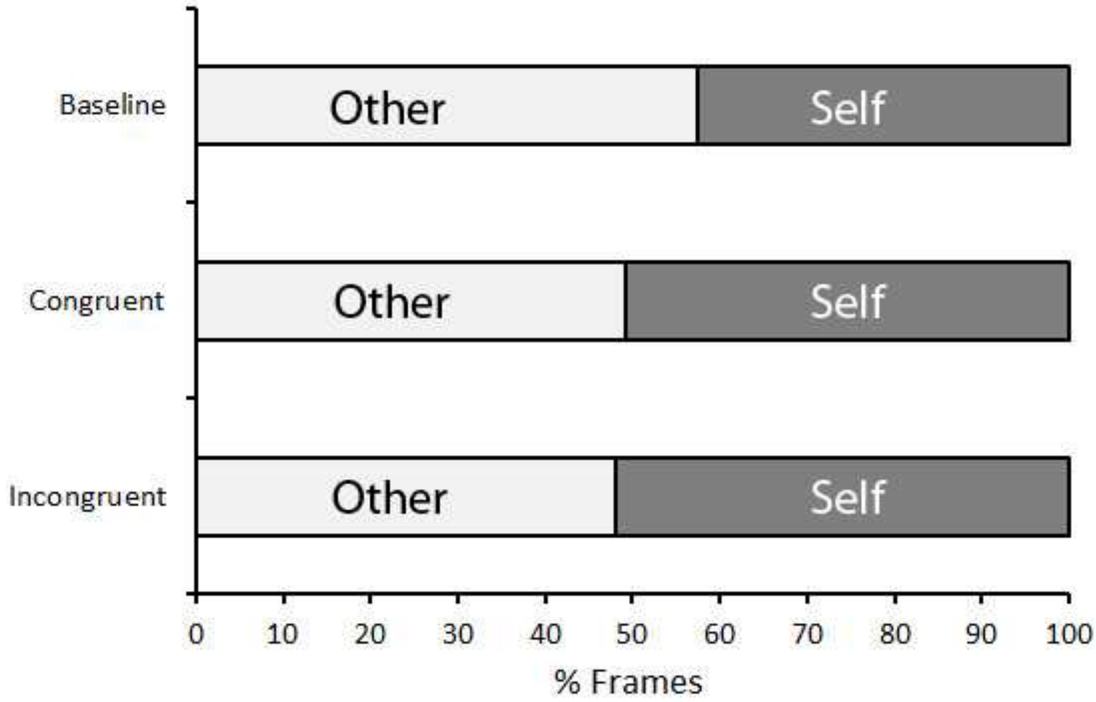

FIGURE 3. Mean Likert responses to each enfacement item for the congruent (black bars) and the incongruent (grey bars) conditions in Experiment 1. * $p < .05$; ** $p < .01$; *** $p < .001$.

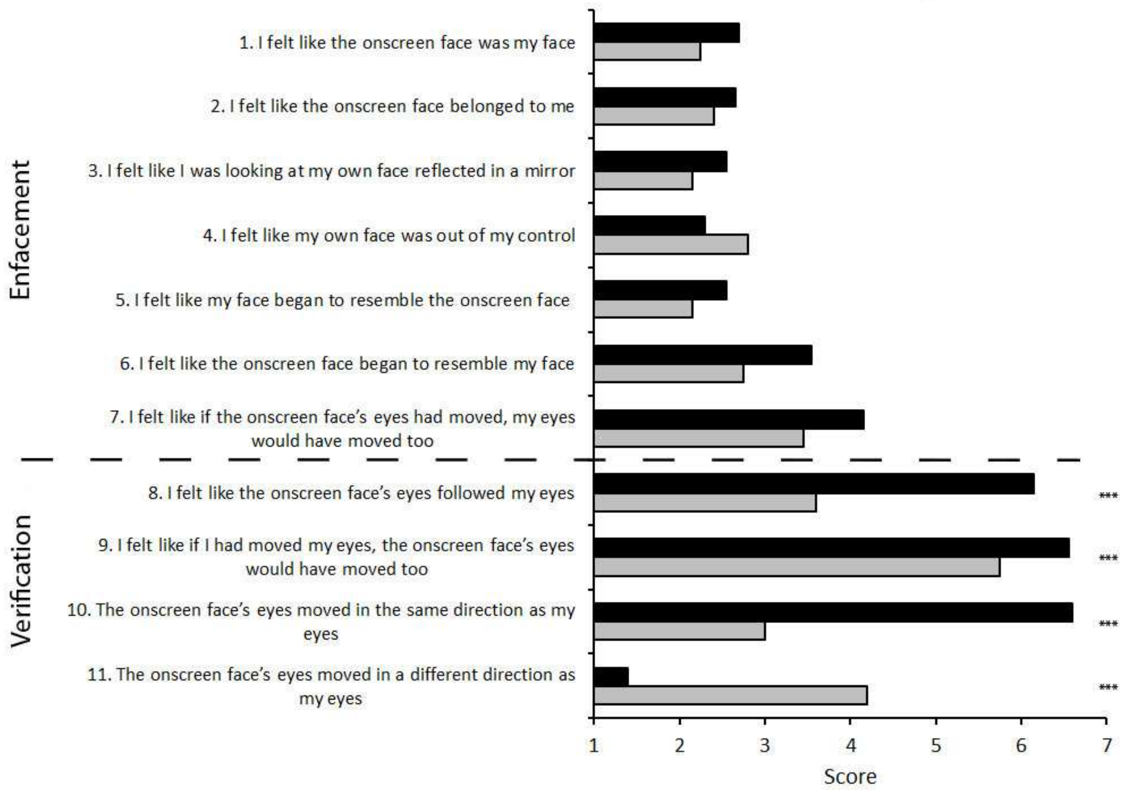

FIGURE 4. Performance in the self-other discrimination task in Experiment 2, expressed as the percentage of frames that observers judged to show their own face or that of the onscreen face, for the baseline measure and after congruent and neutral stimulation.

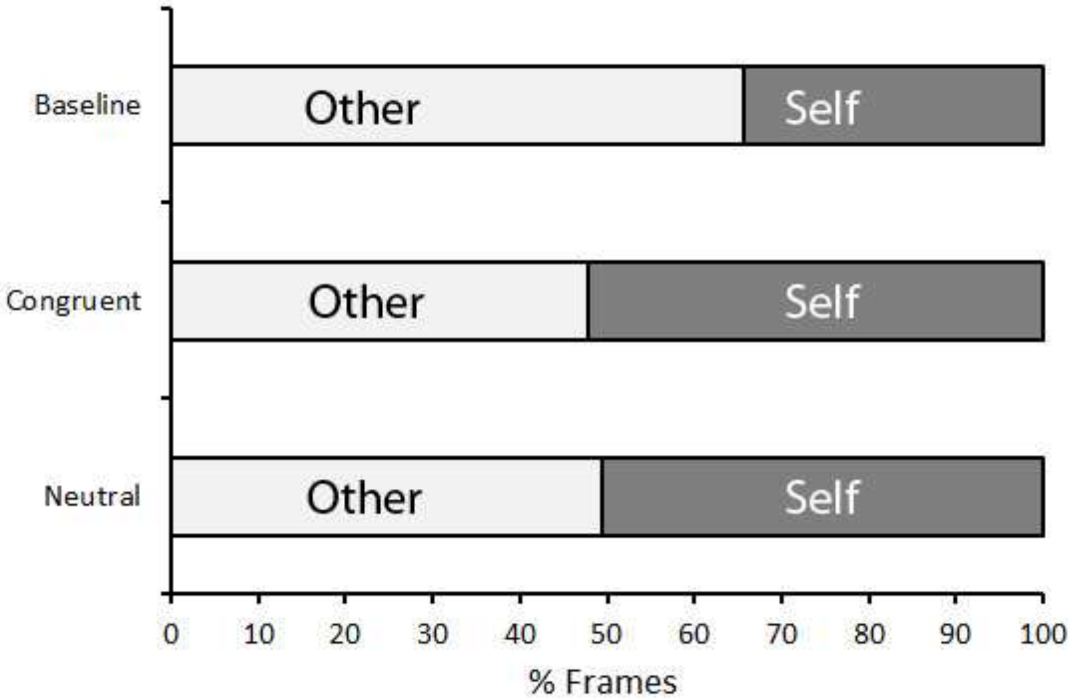

FIGURE 5. Mean Likert responses to each enfacement item for the congruent (black bars) and the neutral (grey bars) conditions in Experiment 2. * $p < .05$; ** $p < .01$; *** $p < .001$.

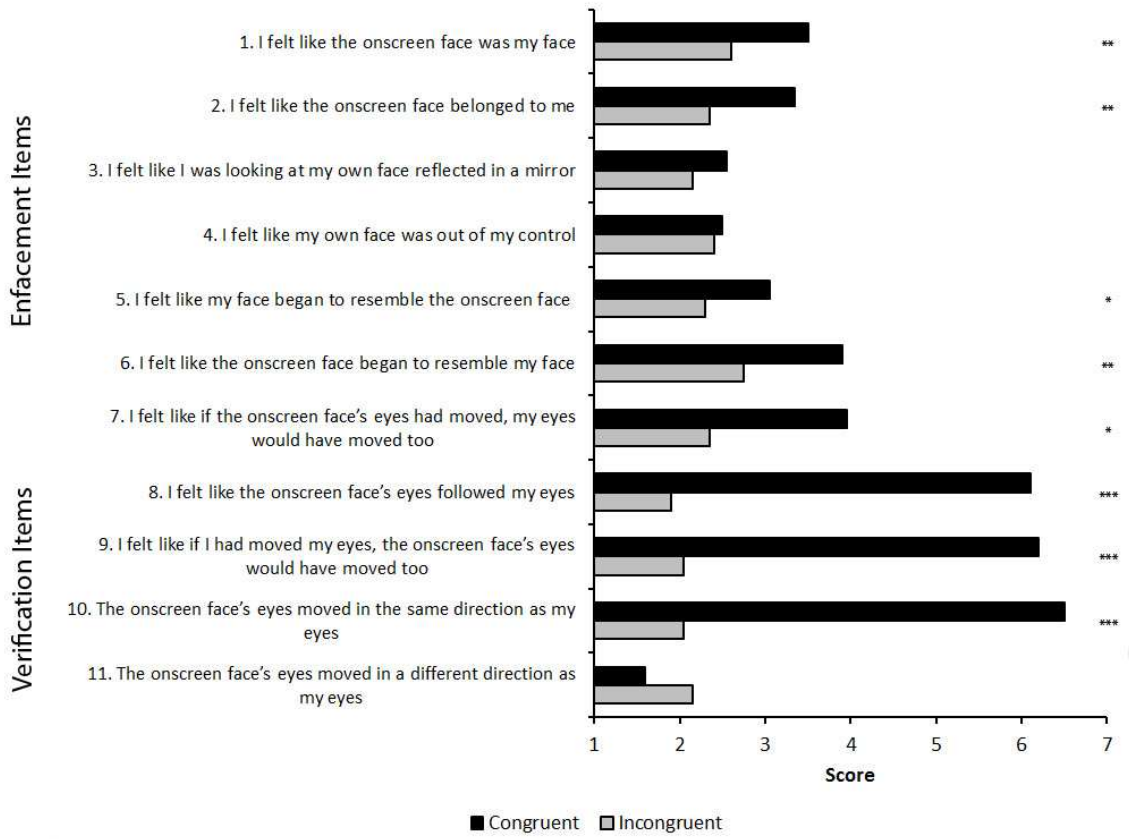

FIGURE 6. Example stimuli for Experiment 3, showing direct and averted eye-gaze.

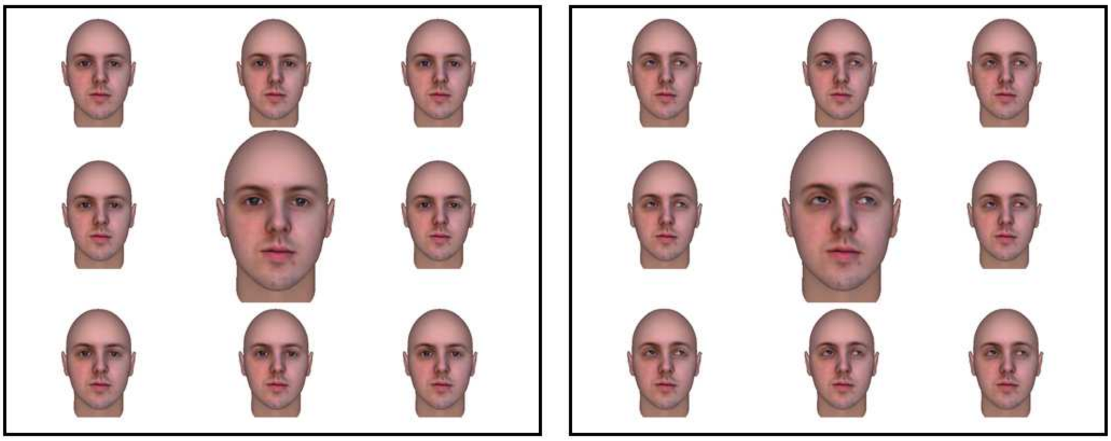

FIGURE 7. Performance in the self-other discrimination task in Experiment 3, expressed as the percentage of frames that observers judged to show their own face or that of the onscreen face, for the baseline measure and after congruent and incongruent stimulation.

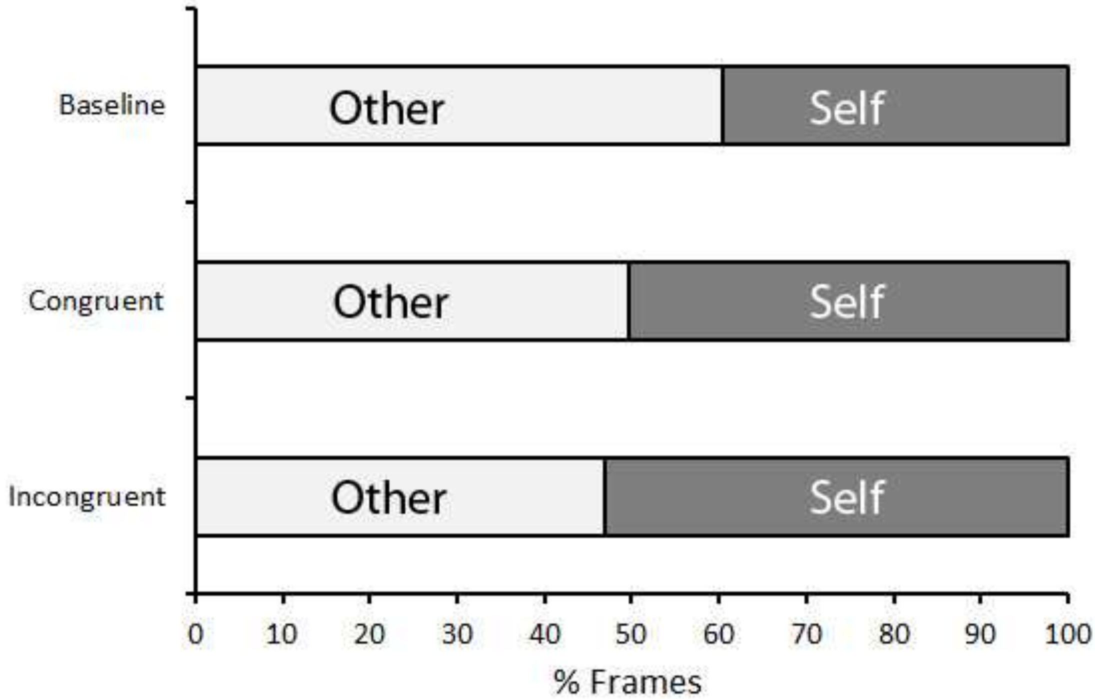

FIGURE 8. Mean Likert responses to each enfacement item for the congruent (black bars) and incongruent (grey bars) conditions in Experiment 3. * $p < .05$; ** $p < .01$; *** $p < .001$.