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Overlapping facial expression representations are identity-dependent

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ABSTRACT

Influential cognitive models of face perception posit that facial expression and identity are processed by independent visual systems. Recent research indicates these systems interact and that representations of different expressions also interact. Here we used a visual adaptation paradigm to test whether the overlapping visual representations of anger and disgust expressions are modulated by identity. In Experiment 1, adaptation to a disgust face biased perception away from anger when the adaptation and target face were congruent in identity. When the adaptation and target face were incongruent in identity this effect was significantly smaller, also, the magnitude of identity-dependency was not affected by target expression. Experiment 2 demonstrated the same modulating effect of identity when stimulus-specific effects are controlled. These results indicate that the facial expression system consists of identity-independent and identity-dependent elements within a representational framework supporting overlapping expression representations.

1. Introduction

According to the dominant cognitive model of face perception information about facial identity and expression is processed in parallel by separate systems after structural encoding is complete (Bruce & Young, 1986). This proposal is supported by neuropsychology evidence that there are patients with severe face recognition deficits that have relatively preserved expression recognition and others that show the reverse pattern of performance (e.g., Humphreys, Donnelly, & Riddoch, 1993). Neuroimaging studies also indicate that whereas processing of identity is associated with activation of the lateral fusiform gyrus (Kanwisher, McDermott, & Chun, 1997) changeable aspects of the face such as emotional expression activate the superior temporal sulcus (Haxby, Hoffman, & Gobbini, 2000). However, a number of behavioural experiments have challenged the idea that the systems representing facial identity and expression operate independently. In one early study Schweinberger and Soukup (1998) found that irrelevant variation in identity slowed speeded classification of facial expression (as well as facial speech) (see also Ganel & Goshen-Gottstein, 2004). Other behavioural research has shown the reverse effect with facial expression influencing the speed of familiar faces recognition (Kaufmann & Schweinberger, 2004). Furthermore, research examining the statistical properties of facial identity and expression shows that a number of the dimensions that code identity can also be used to discriminate expressions (Calder et al., 2001). One explanation for the apparent interaction of expression and identity is that the underlying facial structure influences the specific facial configurations that accompany different emotional states and therefore needs to be taken into account during expression discrimination (Ganel & Goshen-Gottstein, 2004; see also Martens, Leuthold, and Schweinberger (2010) for alternative models of identity and expression representation).

Adaptation has emerged as a valuable tool for probing the representations that support perception of different face attributes (see e.g., Clifford & Rhodes, 2005). It is now well established that prolonged exposure to a face biases perception towards structural properties opposite to the adaptation face (e.g., Leopold et al., 2001). In a recent study, Fox and Barton (2007) showed that adaptation to a facial expression biases perception of target faces along an emotional expression continuum away from the adaptation expression (e.g., adaptation to a fear face makes faces from a fear–anger continuum look angrier, see also Webster et al., 2004). Fox and Barton (2007) also found this effect when the identity of the adaptation face differed from that of the target face. However, the strength of the effect was significantly smaller than when the adaptation and target face were congruent in identity. These results were interpreted as evidence that the human visual system includes visual representations of expression that are independent of identity and representations that are dependent on identity (Fox & Barton, 2007). In support of Fox and Barton, several subsequent adaptation studies have found similar effects with a range of different methodologies and expressions (Campbell & Burke, 2009; Ellamil, Susskind, & Anderson, 2008; Vida & Mondloch, 2009). In the latest study to explore identity-dependent expression aftereffects Skinner and Benton (2012) tested whether

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identity effects originate at the early structural encoding level of face processing or at higher-level representations. To reduce potential effects of structural representations related to idiosyncratic variations in expression production, they applied prototypical facial expression transformations to their identities. And to test for effects related to invariant aspects of facial features, they measured the differences in location and shape of the major features between their pairs of adapting and test identities. Consistent with earlier studies they found a decrease in expression aftereffects for incongruent identity pairs relative to congruent identity pairs. Moreover, there was no correlation between aftereffect magnitudes and the size of the structural differences between identity pairs. These results therefore support Fox and Barton's (2007) proposal that there are higher-level identity-dependent and identity-independent expression representations (see also Ellamil, Susskind, & Anderson, 2008). Intriguingly, research examining whether facial expression interacts with identity representations indicates that identity aftereffects are not influenced by variations in expression (Fox, Oruç, & Barton, 2008). This suggests that although aspects of expression representation are dependent on identity, the visual representation of facial identity is independent of expression (although see Ganel & Goshen-Gottstein, 2004; Soto & Wasserman, 2011).

Another important aspect of Skinner and Benton's (2012) study and their previous adaptation research (Skinner & Benton, 2010) is that their aftereffects were generated by anti-expressions rather than 'veridical' emotional expressions. Anti-expressions are created by morphing shape and texture from an average expression (an average of exemplars from the same emotion category) in a linear trajectory through an overall prototype to a point opposite the average expression. Since these anti-expressions have no specific meaning in relation to veridical expressions, Skinner and Benton (2010) argued adaptation to these images should have no systematic effect on perception if expressions are represented as discrete entities (e.g., Ekman, 1999). Contrary to this prediction they found that adaptation to an anti-expression biased perception towards its corresponding expression (e.g., seeing anger after adaptation to anti-anger). This is consistent with previous proposals that facial expression is represented within a multidimensional framework analogous to 'face-space' used to describe the representation of identity (Calder & Young, 2005; Calder et al., 2000; Valentine, 2001). Skinner and Benton (2010) also found that for anti- fear, anti-anger and anti-disgust expression adaptation, perception was biased towards surprise, disgust, and anger respectively as well as the corresponding veridical expression. When considered alongside the results of Skinner and Benton (2012) it would appear that the representational framework underlying facial expression supports overlapping representations of expressions (Cook, Matei, & Johnston, 2011; Rutherford, Chattha, & Krysko, 2008, although see Juricevic & Webster, 2012; Webster & MacLeod, 2011) and comprises identity-dependent and -independent elements.

A more direct way to explore overlapping expression representations is to investigate how adaptation to one expression influences perception of other expressions. In the first study to adopt this method Hsu and Young (2004) tested how adaptation to fearful, happy, and sad expressions affects perception of target faces from the same categories. They found that when the adaptor and target were from the same category (within-emotion adaptation) perception was biased away from the target category. On the other hand, when the adaptor and target were from the different categories (cross-emotion adaptation) perception was typically biased towards the target category. Pell and Richards (2011) used the same approach to explore the interaction of anger, disgust, and fearful expressions. They hypothesized that disgust and fear adaptation would have opposing effects on perception of disgust expressions since these expressions have opposing shape and surface texture properties (Susskind et al., 2007, 2008). It was also predicted that because anger and canonical disgust expressions look similar and have a joint function as signals of social disapproval, adaptation to disgust would affect perception of anger expressions in a similar manner to anger adaptation (Calder et al., 2010; Rozin, Lowery, & Ebert, 1994). Their results were consistent with both these predictions and revealed that anger adaptation has no measureable effect on perception of disgust faces, leading to the proposal that overlap of anger and disgust representations is asymmetric. This latter point is particularly interesting given that influential models of facial expression typically characterize expression overlap as symmetrical (Dailey et al., 2002; Russell, 1980). It also suggests that the visual representations of anger and disgust expressions are shaped by their communicative functions (Pell & Richards, 2011).

In the present study we utilized cross-emotion adaptation to directly test whether facial expressions are coded as overlapping representations within a framework comprising identity-dependent and identity-independent elements. We focused on aftereffects found in anger target faces when the adaptor is a disgust face since these effects have implications for models of facial expression (Pell & Richards, 2011). Evidence that these aftereffects are modulated by identity would suggest that cross-emotion adaptation reconfigures the same higher-level computational space as within-emotion adaptation (Skinner & Benton, 2012). In Experiment 1 we examined whether the aftereffects observed for anger target faces after adaptation to disgust ('disgust–anger aftereffects') are modulated by identity. Another purpose of this experiment was to test whether this modulating effect is influenced by target expression type. Studies targeting individual expressions have found identity-dependence of emotion aftereffects irrespective of whether the target face is entangled with another emotional expression or a neutral expression (Campbell & Burke, 2009; Fox & Barton, 2007). Campbell and Burke (2009) argued that since some expressions appear to be more closely related to identity representations than others, it is important to test whether the effect of identity is driven by the target expression itself rather than the non-target expression. Here two different target continua were used; one featuring anger morphed with a neutral face and one featuring anger morphed with a happy expression. The target faces and same-identity adaptors were selected from those used by Pell and Richards (2011) to show that their effects are replicable. Experiment 2 tested whether the modulating effect of identity found in Experiment 1 could be explained by stimulus-specific effects.

2. Experiment 1

2.1. Method

2.1.1. Participants

Nineteen participants (12 female) were recruited from the University of London. The average age of the sample was 26.37 years (range: 21–38 years). All were naive to the aims and objectives of the experiment and had normal or corrected-to-normal vision. The study was approved by the Birkbeck College Department of Psychological Sciences Ethics Committee and all participants gave informed consent prior to testing.

2.1.2. Stimuli and apparatus

Face images were taken from the Ekman and Friesen Pictures of facial affect (PoFA) database (Ekman & Friesen, 1976) and the Karolinska Directed Emotional Faces (KDEF) database (Lundqvist, Flykt, & Ohman, 1998). Images from the PoFA were of the model NR depicting expressions of anger, disgust, and neutral, and of the model A1 depicting disgust. Norms for this database indicate that the NR's anger and disgust expressions are categorized as 'anger' and 'disgust' respectively by 100% and 83% of observers. A1's disgust expression is categorized as 'disgust' by 93% of observers. Images from the KDEF were of the model F07 depicting expressions of anger (BF07ANS), disgust (BF07DIS), and happiness (AF07HAS), and of the model F11 depicting disgust (BF11DIS). Norms for this database indicate that 94% of observers categorize BF07ANS as 'angry' and BF07DIS as 'disgusted', and that BF11DIS is categorized as 'disgusted' by 98% of observers (Calvo & Lundqvist, 2008). At the end of the adaptation experiment participants were asked to use a scale from 1 to 7 to indicate how much 'anger' or 'disgust' they perceived in the adaptors. These ratings were subject to 2×4 repeated-measures ANOVA with factors 'rating type' (anger, disgust) and 'disgust adaptor' (A1, NR, F07, F11). There was a significant main effect of rating type ($F(1,18) = 45.22$, $p < .001$, $\eta p^2 = .72$), but no effect of disgust adaptor ($F(1,18) = 1.41$, $p = .44$, $\eta p^2 = .07$), and no rating type $\times$ disgust adaptor interaction ($F(1,18) = 1.95$, $p = .09$, $\eta p^2 = .10$). A series of Bonferroni corrected t-tests revealed that all disgust adaptors were rated as showing more disgust than anger: NR ($t(18) = 3.11$, $p = .024$), (A1 $t(18) = 4.98$, $p < .001$), F07 ($t(18) = 5.01$, $p < .001$), and F11 ($t(18) = 5.35$, $p < .001$).

Images were cropped with an oval frame (leaving only internal features), resized to 130×180 pixels and set on a black background. Two sets of target faces were created by morphing the shape and texture of NR's neutral face towards her anger face and F07's happy face towards her anger face in 5% steps using Sqirlz Morph 2.1 (www.xiberpix.net). Steps from 5% to 95% were selected giving 19 target faces in each set. For each sequence control points were used to define the key facial features (eyes, mouth, and nose). The number of points was adjusted to give the smoothest possible transition between expressions. To reduce low-level aftereffects, target faces were scaled to 80% the size of the adaptation stimulus. The control adaptor was a 'blank face' image; a uniform grey oval with the same dimensions and average luminance as the adapting faces. A grey outline was used to orientate participants to the location and size of the target face (see Campbell & Burke, 2009). Stimuli were viewed from a distance of 60 cm and a chin rest was used to keep head position constant. Presentation of stimuli was controlled by E-Prime 1.2 (www.pstnet.com).

2.1.3. Procedure

The experiment was divided into two 1-h sessions. Sessions were at least 2 days apart ($M = 3.05$ days). In each session participants categorized target faces in a two-alternative forced choice paradigm following adaptation to the blank face, same-identity disgust face and different-identity disgust face. In one session target faces were NR's neutral–anger morphed expressions and response options were 'neutral' and 'anger'. In the other session target faces were F07's happy–anger morphed expressions and response options were 'happy' and 'anger'. The order of sessions and response buttons was counterbalanced across participants. Each session started with a short practice followed by six blocks of trials; two repetitions of each adaptation condition (control, same-identity disgust, different-identity disgust). Each block began with an adapting stimulus presented in the middle of the screen for 60 s that participants were told to look at thoughout this period. The adaptation period was immediately followed by 500 ms of blank screen then 57 trials (three repetitions of the morph continuum). At the start of each trial the adaptor presented during the adaptation period appeared for 5 s. This was immediately followed by the orientation stimulus presented for 150 ms, and a target face presented for 400 ms. Finally, a question marked appeared and remained on screen until the participant responded (see Fig. 1). The inter-trial interval was 500 ms blank screen. The order of stimuli was randomized within each block and the order of blocks was pseudo-randomized across the session (avoiding back-to-back presentation of the same adaptation condition). Each block lasted approximately 7 min. Participants were given a 1 min break at the end of each block.

2.1.4. Analysis

Data from the two sessions were represented by separate plots, each depicting the percentage of anger responses as a function of adaptation condition and morph percentage. The point of subjective equality (PSE; the point at which the percentage of the two responses is equal) was estimated for each adaptation condition in each subject by fitting a Weibull function to each response plot (Campbell & Burke, 2009). Weibull functions were fit using Sigma Plot Version 10.0 by Systat Software, Inc. Aftereffects were defined as a statistically significant shift in the balance point (expressed as a percentage morph change) of the face adaptation condition compared to control adaptation. The magnitude of the aftereffect for each expression condition was also obtained by subtracting the control PSE from the expression PSE. These values are referred to as 'difference-scores'.

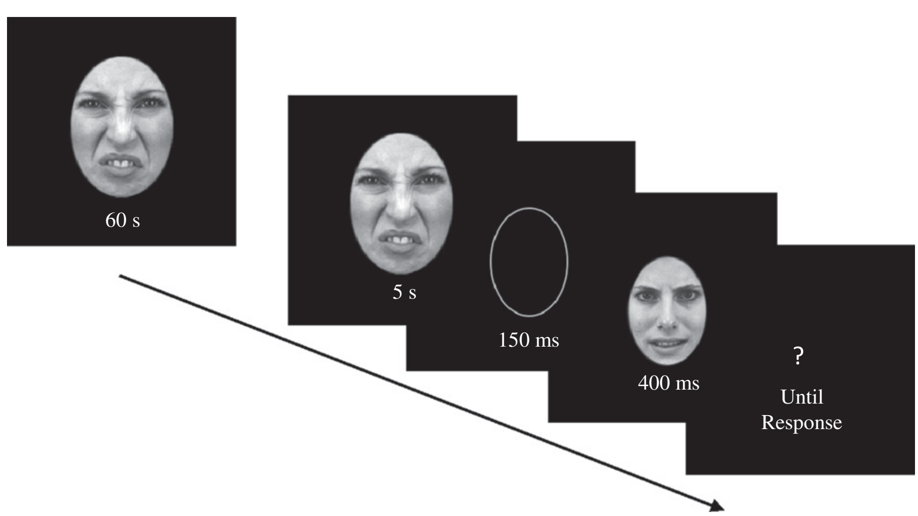

Fig. 1. Design of an experimental block with a Happy–Angry target face featured in a different-identity adaptation–target face pairing. Blocks began with a pre-trial adaptation phase in which participants adapted either a disgust expression or a blank face for 60 s. The pre-trial adaptation period was followed by a series of 57 trials. Each began with the same adaptation stimulus just viewed, this time presented for 5 s. The adaptor was followed by an orientation stimulus presented for 150 ms and a target face presented for 400 ms. At the end of each trial a question mark was presented until the participant responded.

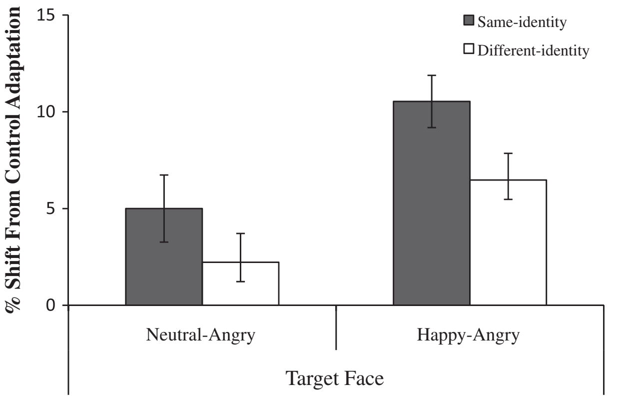

Fig. 2. Magnitude of aftereffects obtained for Neutral–Angry targets and Happy–Angry targets as a function of same- and different-identity disgust adaptation. Error bars indicate ±1 SEM.

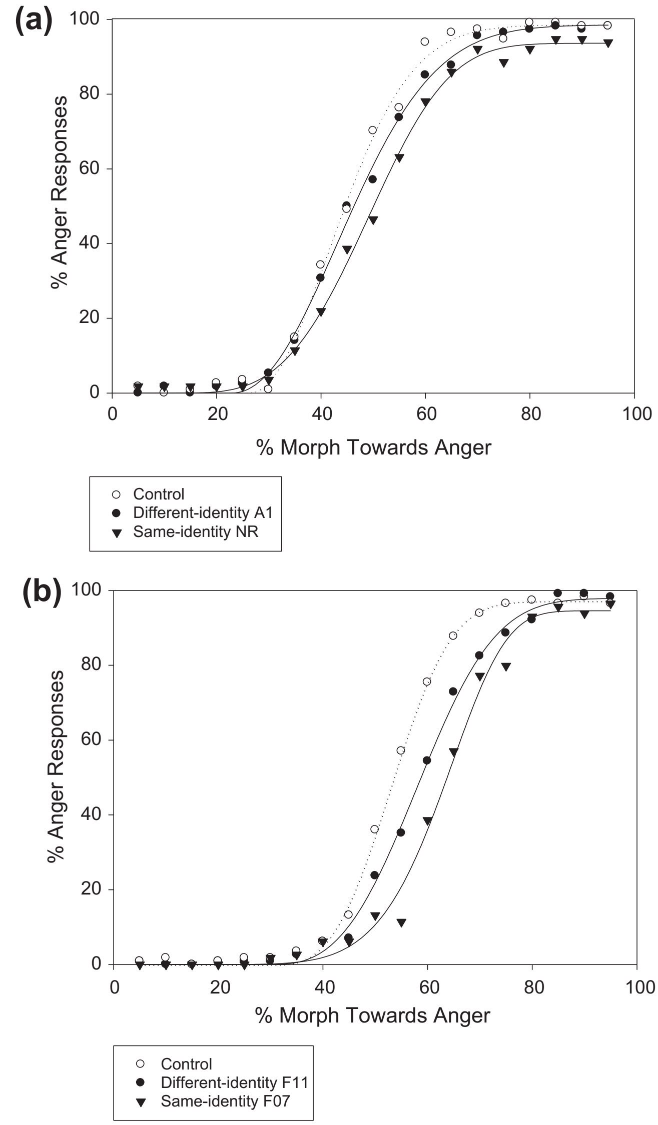

Fig. 3. Group psychometric data showing the shift in the percentage of anger judgements from baseline (dashed line and hollow circles) to test, for both different- (filled circles) and same-identity (filled triangles) disgust conditions. For both Neutral–Anger (a) and Happy–Anger targets (b), adapting and categorizing images that are congruent in identity generates aftereffects that are larger in magnitude compared to adapting and categorizing images that are incongruent in identity.

2.2. Results

An initial analysis was used to test whether the order of sessions had an influence on the results. Difference-scores were subject to a three-way mixed measures ANOVA with two within-subjects factors: 'identity condition' (same-identity, different-identity) and 'target expression' (Neutral–Angry, Happy–Angry), and one between-subjects factor: 'session order' (Neutral–Angry then Happy–Angry, Happy–Angry then Neutral–Angry). There was no main effect of session order and the two- and three-way interactions involving this variable did not reach significance (all $p > .05$). The data were therefore collapsed across the counterbalanced groups (see Fig. 2).

To examine how the magnitude of the disgust–anger aftereffect is influenced by identity and target expression, difference-scores were subject to a two-way repeated measures ANOVA with factors 'identity condition' (same-identity, different-identity) and 'target expression' (Neutral–Angry, Happy–Angry). There was a significant main effect of identity condition ($F(1,18) = 12.75$, $p = .002$, $\eta p^2 = .41$) and a main effect of target expression ($F(1,18) = 6.42$, $p = .021$, $\eta p^2 = .26$). Crucially, however, there was no identity × target expression interaction ($F(1,18) = 0.49$, $p = .49$, $\eta p^2 = .03$). Thus, although aftereffects were stronger for Happy–Angry target faces, the modulating effect of identity was the same across target expressions.

In order to test for replication of the disgust–anger aftereffect (Pell & Richards, 2011) and test the statistical reliability of incongruent identity aftereffects, PSE data were subject to a two-way repeated measures ANOVA with factors 'adaptation image' (control, same-identity, different-identity) and 'target expression' (Neutral–Angry, Happy–Angry). There was a significant main effect of adaptation image ($F(2,36) = 29.28$, $p < .001$, $\eta p^2 = .62$) and target expression ($F(1,18) = 47.47$, $p < .001$, $\eta p^2 = .73$), and a significant adaptation image x target expression interaction ($F(2,36) = 4.03$, $p = .026$, $\eta p^2 = .18$). To further explore these effects two one-way repeated measures ANOVAs were performed; one for each target face. The factor of interest for each test was 'adaptation image'. This had three levels: control, same-identity, and different-identity. For Neutral–Angry target expressions, there was a significant main effect of adaptation image ($F(2,36) = 5.42$, $p = .009$, $\eta p^2 = .23$). Follow-up Bonferroni corrected paired-samples t-tests were then used to compare each face adaptation condition to control. These tests revealed a significant aftereffect for the NR within-identity disgust face ($t(18) = 2.90$, $p = .039$, $r = .56$). This aftereffect was 'repulsive' shifting the PSE towards the anger end of the continuum. The effect was in the same direction for the A1 different-identity face but was not statistically reliable ($t(18) = 1.49$, $p = .60$, $r = .33$). For Happy–Angry target expressions, the main effect of adaptation image was significant ($F(2,36) = 30.75$, $p < .001$, $\eta p^2 = .63$). Subsequent t-tests revealed that adaptation to F07 same-identity ($t(18) = 7.81$, $p < .001$, $r = .88$) and F11 different-identity disgust ($t(18) = 4.70$, $p < .001$, $r = .74$) shifted the PSE towards the anger end of the continuum.

To visualise the effect of identity on aftereffect magnitude across the expression continuum, Weibull functions were fit to the group average response functions for each condition in each continuum (Fig. 3a and b). Consistent with previous research on within-emotion aftereffects (e.g., Fox & Barton, 2007), the strongest cross-emotion aftereffects and identity effects appear to be at the intermediate morph levels 50–70% (i.e., the most ambiguous stimuli on the continuum).

3. Experiment 2

The results of Experiment 1 indicate that identity modulates cross-emotion aftereffects. Furthermore, this process parallels the effect of identity on within-emotion aftereffects in two ways. First, the magnitude of cross-emotion aftereffects is significantly larger when the adaptation and target face are congruent in identity than when they are incongruent (e.g., Fox & Barton, 2007). Second, this effect was found irrespective of whether the target face was morphed with a neutral face or an emotional expression (Campbell & Burke, 2009). Based on these results it would appear that facial expressions are coded in a representational framework that supports overlapping representations and comprises identity-dependent and identity-independent components. However, one important limitation of Experiment 1 is that each adaptation face was used as either a same-identity adaptor or a different-identity adaptor. It is therefore not clear whether the pattern of aftereffects is due to identity or the specific adaptor–target face pairings. One possibility is that same-identity adaptors generate larger aftereffects because these expressions are more 'intense' than their between-identity counterparts (e.g., Campbell & Burke, 2009). It seems unlikely that this explanation can account for the results of Experiment 1 since the anger and disgust ratings for the different adaptors were extremely similar (see Stimuli and Apparatus). However, since disgust ratings were near the upper limits of the rating scale for all adaptors (NR: $M = 6.53$, A1: $M = 6.47$, F07: $M = 6.37$, F11: $M = 6.84$) it is possible that intensity differences between these faces were masked by ceiling effects. A further concern is that the same-identity adaptors might be somehow more salient or attention grabbing than different-identity adaptors. This proposal is supported by recent evidence that the strength of identity aftereffects is modulated by the amount of attention directed towards the adaptor (Rhodes et al., 2011). In Experiment 2 we adopted a more balanced design in which each disgust face was used as both a same- and a different-identity adaptor.

3.1. Method

3.1.1. Participants

Twenty-one participants (11 female) were recruited from the University of London. The average age of the sample was 25.29 years (range: 19–39 years). All had normal or corrected to normal vision and were naive to the aims and objective of the experiment. Informed consent was given prior to testing.

3.1.2. Stimuli and apparatus

Face images were taken from the KDEF (Lundqvist, Flykt, & Ohman, 1998). Images were of the model F07 depicting expressions of anger (BF07ANS), disgust (BF07DIS), and happiness (AF07HAS), and of the model F29 depicting anger (AF29ANS), disgust (BF29DIS), and happiness (BF29HAS). Norms for the KDEF indicate that 97% of observers categorize AF29ANS as 'angry' and 92% of observers categorize BF29DIS as 'disgusted'. Consistent with Experiment 1, all disgust adaptors were rated on anger and disgust scales at the end of the second experimental session. These were subject to a 2×2 repeated-measures ANOVA with factors 'rating type' (anger, disgust) and 'disgust adaptor' (F07, F29). The main effect of rating type was significant ($F(1,20) = 17.43$, $p < .001$, $\eta p^2 = .47$), but there was no effect of disgust adaptor ($F(1,20) < 1$, $p > .05$, $\eta p^2 = .01$) and no rating type $\times$ disgust adaptor interaction ($F(1,20) = 1.14$, $p = .30$, $\eta p^2 = .05$). Follow-up Bonferroni corrected t-tests confirmed that both disgust adaptors were rated as more disgusted than angry: F07 ($t(20) = 3.23$, $p = .0083$ and F29 $t(20) = 4.14$, $p < .001$).

3.1.3. Procedure

The experiment was split into two 1-h sessions. Sessions were at least 2 days apart ($M = 2.62$ days). Participants categorized target faces in a two-alternative forced choice paradigm following adaptation to the blank face, F07 disgust face and F29 disgust face. In each session target faces were happy–angry morphed expressions and response options were 'happy' and 'anger'. In one session target expressions were of the identity F07 and in the other target expressions were of F29. The order of sessions and response buttons was counter-balanced. The structure of each trial, block and session was the same as Experiment 1.

3.2. Results

Following Experiment 1 the first analysis was used to test whether the order of sessions influenced the results. Difference-scores were subject to a three-way mixed measures ANOVA with two within-subjects factors: 'identity condition' (same-identity, different-identity) and 'target identity' (F07, F29), and one between-subjects factor: 'session order' (F07–F29, F29–F07). There was no main effect of session order and the two- and three-way interactions involving this variable did not reach significance (all $p > .05$). The data were therefore collapsed across the counterbalanced groups (see Fig. 4).

To test how the strength of disgust–anger aftereffects varies as function of identity condition and target identity, difference-scores were subject to a two-way repeated-measures ANOVA. The factors of interest were 'identity condition' (same-identity, different-identity) and 'target identity' (F07, F11). The main effect of identity condition was significant ($F(1,20) = 7.79$, $p = .011$, $\eta p^2 = .28$), however, there was no significant effect of target identity ($F(1,20) = 0.79$, $p = .39$, $\eta p^2 = .04$) and crucially, no significant identity condition $\times$ target identity interaction ($F(1,20) = 0.28$, $p = .87$, $\eta p^2 = .01$). This indicates that the effect of identity (i.e., larger aftereffects for same-identity adaptation) is not stimulus-specific.

A final set of analyses were used to test whether the same- and different-identity disgust–anger aftereffects are statistically reliable. Since the difference-score analysis described above indicates that aftereffect magnitude is not modulated by target identity, PSE data were collapsed across target identity. These were then subject to a one-way repeated-measures ANOVA with the three-level factor 'adaptation image' (control, same-identity, different-identity). There was a significant effect of adaptation image ($F(2,40) = 18.79$, $p < .001$, $\eta p^2 = .48$) and subsequent Bonferroni corrected t-tests revealed that there was a significant repulsive aftereffect for the same-identity condition ($t(20) = 5.66$, $p < .001$, $r = .78$) and different-identity condition ($t(20) = 3.52$, $p = .004$, $r = .62$).

Finally, Weibull functions were fit to the group average response functions for each condition (Fig. 5a and b). Similar to the results of Experiment 1, the strongest aftereffects and identity

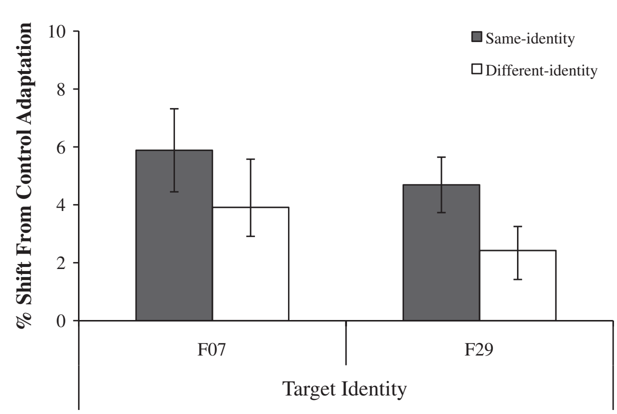

Fig. 4. Magnitude of aftereffects obtained for F07 and F29 Happy–Angry target faces as a function of same- and different-identity disgust adaptation. Error bars indicate ±1 SEM.

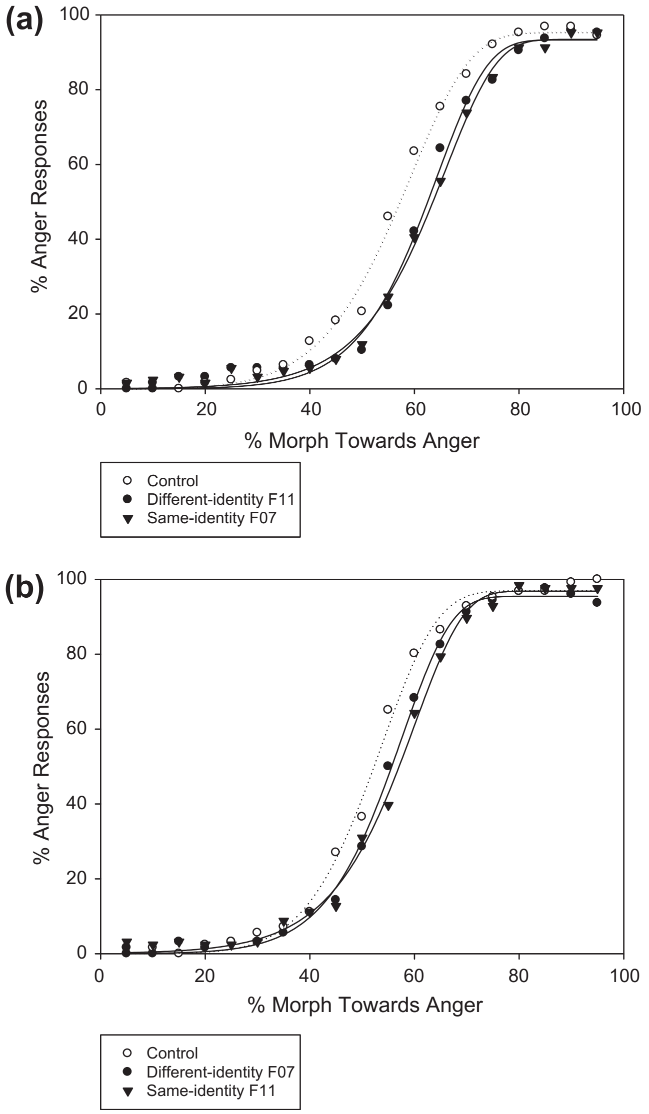

Fig. 5. Group psychometric data showing the shift in the percentage of anger judgements from baseline (dashed line and hollow circles) to test for both different-(filled circles) and same-identity (filled triangles) disgust conditions. For both adaptor–target pairings ((a) F07–F29 (b) F29–F07) adapting and categorizing images that are congruent in identity generates aftereffects that are larger in magnitude compared to adapting and categorizing images that are incongruent in identity.

effects appear to cluster around the middle of the expression continuum (55–70%).

4. General discussion

Increasing evidence indicates that facial expression and identity are processed interdependently (Calder & Young, 2005; Ganel & Goshen-Gottstein, 2004) and that visual representations of different facial expressions overlap (Hsu & Young, 2004; Pell & Richards, 2011). In this study we a used a cross-emotion adaptation paradigm to test whether facial expressions are coded as overlapping representations within a framework comprising identity-dependent and identity-independent elements. In Experiment 1 the magnitude of disgust–anger aftereffects generated by images of the same person were significantly larger than aftereffects generated by images of different people. Furthermore, the same effect was found irrespective of whether the target face was entangled with a happy expression or a neutral face. Experiment 2 demonstrated that the effect of identity cannot be attributed to stimulus-specific differences.

These results challenge the assumption that facial identity and expression are processed independently (Bruce & Young, 1986) and support the hypothesis that computation of expression is integrated with identity (e.g., Ganel & Goshen-Gottstein, 2004). This latter perspective is also consistent with Bruce and Young's updated view that analysis of identity and expression is to some extent interdependent (Young & Bruce, 2011). A number of recent adaptation studies have shown that emotion aftereffects in individual expressions (when one of the target expressions matches the adapting face) are also modulated by identity (Campbell & Burke, 2009; Ellamil, Susskind, & Anderson, 2008; Fox & Barton, 2007; Vida & Mondloch, 2009). In each of these studies aftereffects for the same-identity conditions were larger than aftereffects for different-identity conditions. This was interpreted as evidence that there are at least two visual representations of emotion expression; one that is identity-dependent and one that is identity-invariant (Fox & Barton, 2007; Fox, Oruç, & Barton, 2008). Preliminary evidence has also recently emerged that the overlapping visual representations of emotional expressions are characterized by identity-dependent and identity-independent components (Skinner & Benton, 2010, 2012). Using a cross-emotion adaptation paradigm that examines the direct effect of one expression on another, we found further support for this representational structure. Our results also build on previous evidence that there is considerable overlap of expression representations (Cook, Matei, & Johnston, 2011; Hsu & Young, 2004; Rutherford et al., 2008) and indicate that overlapping expression representations reconfigured by cross-emotion adaptation are the part of the same computational space as individual expression representations. This is latter point is important because previous cross-emotion adaptation research has revealed asymmetric interactions between disgust and anger that are not accounted for in influential models of facial expression (e.g., Russell, 1980). It was also notable that when the data were visualized across the entire morph continuum, the strongest aftereffects were observed for the most ambiguous images in the middle of the continuum, consistent with within-emotion aftereffects.

An important question for research exploring the systems (or perhaps system) that code facial expression and identity is where in the face processing hierarchy their representations interact (Calder & Young, 2005). Skinner and Benton (2012) addressed this question by testing whether two properties that relate to early structural processing; idiosyncratic variation in expression production and invariant aspects of facial features, can account for identity effects in expression adaptation. Their results showed that identity effects emerge even when variations in expression production are controlled (see also Ellamil, Susskind, & Anderson, 2008) and that measures of feature position do not correlate with aftereffect magnitude. This indicates that the effect of identity congruence in expression adaptation reflects the operation of higher-level facial representations (Skinner & Benton, 2012). In the present study we tested whether the modulating effect of identity in cross-emotion aftereffects is explained by differences the intensity or salience of the adaptor expression (disgust) across individuals. Results from Experiment 2 indicate that this is not the case since larger aftereffects were found for same-identity adaptor–target pairings when the same faces are used as same- and different-identity adaptors. Furthermore, in both experiments a size-transformation between adaptor and target face was used to reduce low-level adaptation effects. Thus, it would appear that aspects of identity effects in cross-emotion adaptation also arise at higher-level representation. To further test this hypothesis future research could follow the methodology of Skinner and Benton (2012) and precisely control the geometry of face configurations by applying average expression geometry to adaptors and target faces from different emotion categories.

4.1. Conclusion

In summary, the experiments performed here indicate that the visual representations of different emotional expressions overlap and interact with identity representations. More specifically, it would appear that at least two elements underlie overlapping expression representations; an identity-dependent representation and an identity-independent representation. Taken alongside adaptation research targeting individual expressions (e.g., Campbell & Burke, 2009; Fox & Barton, 2007), the present study also indicates that cross-emotion adaptation reconfigures the same computational space that codes individual expressions.

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