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How distinct is the coding of face identity and expression? Evidence for some common dimensions in face space

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ABSTRACT

Traditional models of face perception emphasize distinct routes for processing face identity and expression. These models have been highly influential in guiding neural and behavioural research on the mechanisms of face perception. However, it is becoming clear that specialised brain areas for coding identity and expression may respond to both attributes and that identity and expression perception can interact. Here we use perceptual aftereffects to demonstrate the existence of dimensions in perceptual face space that code both identity and expression, further challenging the traditional view. Specifically, we find a significant positive association between face identity aftereffects and expression aftereffects, which dissociates from other face (gaze) and non-face (tilt) aftereffects. Importantly, individual variation in the adaptive calibration of these common dimensions significantly predicts ability to recognize both identity and expression. These results highlight the role of common dimensions in our ability to recognize identity and expression, and show why the high-level visual processing of these attributes is not entirely distinct.

1. Introduction

There is a long-standing debate about whether face identity and expression are processed in distinct visual pathways or whether a shared perceptual representation underlies coding of both attributes. Early models proposed that identity, which requires the coding of invariant aspects of faces, and expression, which requires the coding of changeable aspects of faces, are processed in functionally and neurally distinct visual pathways (Bruce & Young, 1986; Haxby, Hoffman, & Gobbini, 2000, 2002). These highly influential models were motivated by the existence of dissociable deficits in recognizing identity and expression, and by distinct neural correlates in visual cortical areas for these attributes.

However, others have challenged the idea of independent pathways, noting that dissociations between deficits need not arise at a perceptual level and that the selectivity of neurons and neural areas for these attributes is far from complete (for reviews see Calder, 2011; Calder & Young, 2005). For example, the Fusiform Face Area (FFA), which codes identity, and the posterior Superior Temporal Sulcus (pSTS), which codes expression, are actually sensitive to perceived changes in both attributes (Fox, Moon, Iaria, & Barton, 2009). In addition, parts of the ventral fusiform gyrus near the FFA respond rapidly (within 120 ms) to both dynamic expressions and static aspects of faces such as identity (Kawasaki et al., 2012). These rapid responses seem consistent with some shared feed-forward visual processing of identity and expression,

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although it is difficult to rule out feedback from post-perceptual emotion processing areas. Thus, this evidence for shared processing is equivocal.

Behavioural evidence, mostly from classification studies, also challenges the independent processing of identity and expression. Initial studies reported that changes in identity affected expression judgments, but not vice versa (Schweinberger, Burton, & Kelly, 1999; Schweinberger & Soukup, 1998). This unidirectional influence has also been reported using a visual adaptation paradigm, with changes in identity reducing expression aftereffects (Ellamil, Susskind, & Anderson, 2008; Fox & Barton, 2007; Skinner & Benton, 2012), but not vice versa (Fox, Oruc, & Barton, 2008). However, when discriminability of expression and identity is well matched, both directions of influence have been reported in a variety of paradigms (e.g., Fitousi & Wenger, 2013; Ganel & Goshen-Gottstein, 2004; Wang, Fu, Johnston, & Yan, 2013; Yankouskaya, Booth, & Humphreys, 2012). Assuming that these effects reflect perceptual rather than post-perceptual analysis, then they challenge the independent visual processing of identity and expression. Some support for this assumption comes from evidence that interactions occur in visual adaptation studies (e.g., Fox et al., 2008), which tap perceptual processing, and for upright but not inverted faces (which do not engage face-coding mechanisms very effectively) (Yankouskaya et al., 2012). Finally, recent work on individual differences also fails to support independent visual processing of identity and expression, with a positive correlations observed between identity and expression recognition (Palermo, O'Connor, Davis, Irons, & McKone, 2013).

Taken together these findings may suggest common, rather than distinct, visual processing of identity and expression. But what might common coding mean? One proposal, motivated by impaired holistic processing of both identity and expression in developmental prosopagnosia, is that there is a common processing stage of holistic coding for both attributes (Palermo, O'Connor, et al., 2013; Palermo et al., 2011) (but see Calder, Young, Keane, & Dean, 2000 for evidence of independent holistic processing of identity and expression in neurotypical adults). On this view representations of identity and expression would share a common holistic format (Calder, Burton, Miller, Young, & Akamatsu, 2001). It remains unclear, however, whether the same actual representations are used for identity and expression, or whether there are distinct holistic representations for each attribute. Distinct representations are certainly possible in principle, as distinct image components are able to support accurate discrimination (using linear discriminant analysis) of identity and expression (Calder et al., 2001).

Here we ask whether there is a common perceptual representation underlying the perception of identity and expression. By a common representation, we mean one that contains dimensions used to code both identity and expression (common dimensions), as well as dimensions that are selective for identity or expression (see Fig. 22.5 in Calder, 2011). Principal Components Analysis (PCA) of face images has demonstrated that common image components (cf dimensions) can in principle support the discrimination of identity and expression (Calder, 2011; Calder et al., 2001). However, it is not yet known whether such dimensions exist in human face space.

Our first goal here is to determine whether high-level face space contains any common dimensions that code both identity and expression. If we find that it does, then a second goal is to determine whether adaptive coding of such dimensions contributes to our ability to recognize faces and their expressions. There is increasing evidence that adaptive coding of face dimensions, indexed by face aftereffects, is important for face expertise. Adaptation of identity-related dimensions is linked to identity recognition ability (Dennett, McKone, Edwards, & Susilo, 2012; Rhodes, Jeffery, Taylor, Hayward, & Ewing, 2014) and adaptation of expression-related dimensions is linked to expression recognition ability (Palermo et al., 2015; Palermo, Jeffery, et al., 2013). Therefore, if any common dimensions contribute to coding both identity and expression, then adaptation of those dimensions should be linked to our ability to recognize both attributes.

We used a novel approach that examines individual differences in perceptual aftereffects. Aftereffects are widely used to investigate visual representations and coding mechanisms for faces and other stimuli (Clifford & Rhodes, 2005; Rhodes & Leopold, 2011; Webster, 2011), and have been dubbed the psychologist's microelectrode (Frisby, 1980). They occur when exposure (adaptation) to a stimulus alters neural processing and changes the perception of a subsequently viewed stimulus, as in the classic waterfall illusion when stationary objects appear to move upwards after viewing a downward-flowing waterfall (Mather, Verstraten, & Anstis, 1998). More generally, aftereffects reflect the adaptive updating of perceptual dimensions by experience. This updating helps to dynamically calibrate coding mechanisms to perceptual inputs, and plays an important functional role in perception (Clifford & Rhodes, 2005; Rhodes & Leopold, 2011; Webster & MacLeod, 2011).

We measured face identity and expression aftereffects in a large group of adults. If there are common dimensions that code both identity and expression, then we should find a positive association between these aftereffects, reflecting adaptation of those dimensions. Of course there could be other reasons for such an association, so we measured two other aftereffects with a view to ruling out plausible alternative accounts. We measured gaze aftereffects to test for a broader face adaptability factor, perhaps reflecting individual differences in attention to faces (Rhodes et al., 2011). We measured tilt aftereffects to test for a more general adaptability factor unrelated to face adaptation. Such a factor could reflect either genuine individual differences in perceptual plasticity or perhaps just differences in attention to adapting stimuli. If identity and expression aftereffects correlate with each other, but not with gaze or tilt aftereffects, then we could rule out differences in these other factors as the cause of the link. We used a size change between adapt and test stimuli to minimize the contribution of lower-level, retinotopic adaptation to the aftereffects.

To test whether adaptation of common dimensions is linked to our ability to recognize identity and expression, we used factor analysis to derive a factor reflecting