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Norm-based coding of facial identity in adults with autism spectrum disorder

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ABSTRACT

It is unclear whether reported deficits in face processing in individuals with autism spectrum disorders (ASD) can be explained by deficits in perceptual face coding mechanisms. In the current study, we examined whether adults with ASD showed evidence of norm-based opponent coding of facial identity, a perceptual process underlying the recognition of facial identity in typical adults. We began with an original face and an averaged face and then created an anti-face that differed from the averaged face in the opposite direction from the original face by a small amount (near adaptor) or a large amount (far adaptor). To test for norm-based coding, we adapted participants on different trials to the near versus far adaptor, then asked them to judge the identity of the averaged face. We varied the size of the test and adapting faces in order to reduce any contribution of low-level adaptation. Consistent with the predictions of norm-based coding, high functioning adults with ASD ($n = 27$) and matched typical participants ($n = 28$) showed identity aftereffects that were larger for the far than near adaptor. Unlike results with children with ASD, the strength of the aftereffects were similar in the two groups. This is the first study to demonstrate norm-based coding of facial identity in adults with ASD.

1. Introduction

1.1. Autism spectrum disorder

Autism spectrum disorder (ASD) is a pervasive developmental disorder in which affected individuals have measureable anomalies in two key areas: (1) social interactions and communication and (2) restrictive and repetitive interests or behaviours (American Psychiatric Association, 2013). Developing a clear understanding of the behavioural manifestations characteristic of ASD is an important area of scientific research as current diagnosis of ASD relies completely on behavioural observations.

Individuals with ASD have been shown to orient less to social stimuli than their peers from a young age (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Dawson et al., 2004; Zwaigenbaum et al., 2005). As faces are considered to be one of the most important categories of social stimuli, many studies have examined potential qualitative and quantitative differences in face processing abilities of individuals with ASD (see Harms, Martin, & Wallace, 2010; Sasson, 2006; Weigelt, Koldyn, & Kanwisher, 2012, for reviews). Few studies have examined the perceptual mechanisms underlying these face processing skills and how they may differ in the ASD population. The goal of the current study was to measure facial identity aftereffects in individuals with ASD in order to examine whether they show evidence of norm-based coding of facial identity. Norm-based coding is thought to underlie typical face perception but has not been examined in adult ASD populations.

1.2. Norm-based coding in typical face perception

The norm-based coding model of face perception suggests that face identification involves implicit evaluation of how an individual face differs from a face prototype (Rhodes & Leopold, 2011; Webster & MacLeod, 2011). This model suggests that the prototype face is refined by our experience with faces. Norm-based coding provides a model for how individuals are able to efficiently distinguish individual faces that subtly differ from one another (Rhodes et al., 2005).

Evidence supporting a norm-based coding model of facial identity perception comes from studies that employed a variant of an adaptation paradigm. Face adaptation, like other kinds of visual

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adaptation, occurs when prolonged fixation on a face biases perception of subsequently viewed faces (see Webster & MacLeod, 2011 for review). For example, prolonged exposure to a male face biases perception of an ambiguously gendered face in the opposite direction: it is seen as female (Webster, Kaping, Mizokami, & Duhamel, 2004). Face aftereffects have also been demonstrated for emotional expression (e.g., Butler et al., 2008; Rutherford, Chattha, & Krysko, 2008; Skinner & Benton, 2010), facial attractiveness (e.g., Rhodes et al., 2003) and facial identity (e.g., Leopold et al., 2001; Rhodes & Jeffery, 2006).

Previous studies have investigated norm-based coding of facial identity using facial identity aftereffects. In a common paradigm, participants learn a set of target identities (e.g., Ted and Rob, see Fig. 1), view an "anti-identity", a face which physically differs from an average face in the opposite way from the target face (e.g., anti-Ted or anti-Rob; see Fig. 1), and then categorize an average face as being either like Ted or Rob (Jeffery et al., 2011; Leopold et al., 2001; Rhodes & Jeffery, 2006; Robbins, McKone, & Edwards, 2007). Fig. 1 depicts two target identities (Ted and Rob) and their corresponding anti-identities (anti-Ted and Rob). The anti-identities and their corresponding target faces lie on the same identity trajectory, but are on the opposite side of the average face. Weaker versions of each identity can be created by morphing the average and target face by various amounts; for example, morphing Rob and the average face by 60% creates 60% Rob. When individuals are adapted to the anti-identities (e.g., anti-Rob), weaker identity strengths and the average face are more likely to be perceived as the original identity (e.g., Rob) (Rhodes & Jeffery, 2006). Norm-based coding theory predicts that after adapting to an anti-identity, one's average face prototype will be recalibrated in the direction of the adapting anti-identity face. This shift in the prototype has effects on the perception of faces along vectors going through the prototype such that faces on the opposite side of the prototype from the adapting face now look more distinctive (less average and more Rob-like in this example).

Notice that in our example, the average face is intermediate between the target identity and its anti-identity, and this is critical in the test for norm-based coding. Previous studies have demonstrated that although adapting to an anti-identity enhances recognition of the original identity, adapting to a non-opposite face (a face that lies on a separate identity continuum) does not facilitate recognition of the original face to the same degree (Leopold et al., 2001; Rhodes & Jeffery, 2006). This pattern provides evidence for the norm-based coding model of facial identity, as it suggests that facial identity is coded in relation to an average, or norm.

Further evidence of norm-based coding of facial identity comes from experiments looking at differences in the magnitude of facial aftereffects created by varying how much a face differs from the norm or average face (extremeness). The norm-based coding model predicts that more extreme adapting faces (i.e., adapting faces that are very different from the average face) will produce a greater amount of adaptation and hence pull the prototype of the average face more towards the direction of the adapting face, leading to a larger shift in the perception of the average face (for a detailed description of why the norm-based coding model predicts these patterns of results, see Jeffery et al., 2011; Robbins et al., 2007). The effect of more extreme adaptors is measureable as a larger bias in perception of subsequently viewed faces. This pattern of results has been demonstrated with expression aftereffects (Skinner & Benton, 2010), with facial feature-spacing aftereffects (Robbins et al., 2007) and with facial identity aftereffects in typical adults and children (Jeffery, Read, & Rhodes, 2013; Jeffery et al., 2011).

1.3. Face perception in autism spectrum disorder

Many studies have examined the ability of individuals with ASD to process facial identity, but have yielded equivocal results (see Weigelt et al., 2012, for review). For example, several studies that examined individuals with ASD's ability to discriminate recently

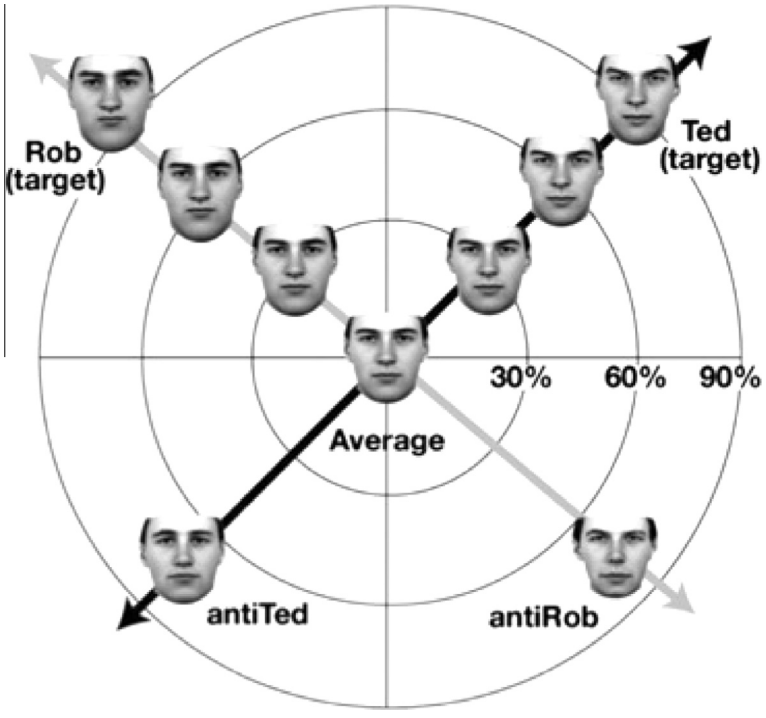

Fig. 1. Two target identities (Ted and Rob) and the anti-identities, which lie on the same identity trajectory but on the opposite side of the average. "Weaker" identity strengths of the target identities are created by morphing the average face and target face by varying amounts (e.g., 60% to create 60% Ted). The norm-based coding model predicts that adapting to an anti-identity will bias perception of the weaker identity targets, as well as the average face, towards the original identity target (i.e., adapting to anti-Ted will lead to the perception of the average face as Ted).