YNIMG-12900; No. of pages: 8; 4C: 3, 5

NeuroImage xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/ynimg

Modelling the perceptual similarity of facial expressions from image statistics and neural responses

Mladen Sormaz, David M. Watson, William A.P. Smith, Andrew W. Young, Timothy J. Andrews *

Department of Psychology and York Neuroimaging Centre, University of York, York YO10 5DD, United Kingdom

ARTICLE INFO

Article history:
Received 14 August 2015
Accepted 18 January 2016
Available online xxxx

Keywords:
MVPA
Face
Expression
STS
FFA

ABSTRACT

The ability to perceive facial expressions of emotion is essential for effective social communication. We investigated how the perception of facial expression emerges from the image properties that convey this important social signal, and how neural responses in face-selective brain regions might track these properties. To do this, we measured the perceptual similarity between expressions of basic emotions, and investigated how this is reflected in image measures and in the neural response of different face-selective regions. We show that the perceptual similarity of different facial expressions (fear, anger, disgust, sadness, happiness) can be predicted by both surface and feature shape information in the image. Using block design fMRI, we found that the perceptual similarity of expressions could also be predicted from the patterns of neural response in the face-selective posterior superior temporal sulcus (STS), but not in the fusiform face area (FFA). These results show that the perception of facial expression is dependent on the shape and surface properties of the image and on the activity of specific face-selective regions.

Introduction

The ability to visually encode changes in facial musculature that reflect emotional state is essential for effective social communication (Ekman, 1972; Bruce and Young, 2012). A full understanding of the mechanisms that underpin the perception of facial expression requires understanding both the way in which these processes are driven by visual properties of the image and the way in which different brain regions are involved (Haxby et al., 2000; Bruce and Young, 2012).

Any facial image consists of a set of edges created by abrupt changes in reflectance that define the shapes and positions of facial features and a broader pattern of reflectance based on the surface properties of the face, also known as the albedo or texture (Bruce and Young, 1998, 2012). Shape can be defined by the spatial location of fiducial points that correspond to key features of the face. In contrast, surface properties reflect the reflectance of light that is caused by pigmentation and shape from shading cues. Shape and surface properties have both been proposed to contribute to the perception of identity and expression (Bruce and Young, 1998; Calder et al., 1996), but with the perception of familiar identity being relatively dominated by surface cues (Burton et al., 2005; Russell and Sinha, 2007) and feature shapes being relatively dominant in perceiving facial expressions (McKelvie, 1973; Etcoff and Magee, 1992; Butler et al., 2008). This differential use of image properties in the perception of identity and expression is consistent with models of face perception which propose that they are processed independently (Bruce and Young, 1998, 2012; Haxby et al., 2000).

Support for the critical role of shape information in the perception of facial expression is found in studies that show manipulations of the image that degrade surface information, but leave shape information intact, and have little impact on perceptual and neural responses to facial expression (Bruce and Young, 1998; Magnussen et al., 1994; White, 2001; Pallett and Meng, 2013; Harris et al., 2014). Similarly, image manipulations that completely remove surface information, such as line drawings of faces, also show relatively preserved expression perception (McKelvie, 1973; Etcoff and Magee, 1992).

Although previous studies have suggested that feature shape is the dominant cue for the perception of facial expressions, there is some evidence to suggest that surface information may also play a role. Calder et al. (2001) found that principal components (PCs) that convey variation in surface information could be used to categorise different facial expressions, albeit to a lesser extent than PCs that convey variation in shape. More recently, Benton (2009) found a decrease in the emotional expression aftereffect to facial expressions when images were negated, suggesting that the perception of facial expression can be affected by changes in surface information. So, it remains uncertain how different image properties contribute to the perception of facial expression.

The first aim of this study was therefore to explore the relative importance of shape and surface properties to the perception of facial expression. Specifically, we asked whether the perceptual similarity of different facial expressions could be predicted by corresponding

* Corresponding author.
E-mail address: timothy.andrews@york.ac.uk (T.J. Andrews).

http://dx.doi.org/10.1016/j.neuroimage.2016.01.041
1053-8119/© 2016 Published by Elsevier Inc.

similarities in the shape or surface properties of the image. The perceptual similarity task involved rating the degree of similarity in expression between pairs of pictures of facial expressions. This task was used to generate a matrix of perceived (rated) similarities between exemplars of facial expressions of five basic emotions. This is equivalent to the procedure used to establish widely-adopted perceptual models such as Russell's circumplex (Russell, 1980), where expressions of emotion lie proximally or distally on a two-dimensional surface based on their perceived similarity, with the distance between expressions reflecting their similarity or confusability to human observers.

Our second aim was to determine if the perceptual similarity of facial expressions is reflected in the patterns of neural responses in face-selective regions of the brain. Neural models of face perception suggest that a network of face-selective brain regions underpins the perception of faces (Allison et al., 2000; Haxby et al., 2000; Ishai, 2008), with the posterior superior temporal sulcus (STS) playing a key role in processing facial expression (Winston et al., 2004; Engell and Haxby, 2007; Harris et al., 2012; Baseler et al., 2014; Psalta et al., 2014). Recent evidence has shown that it is possible to successfully decode some properties of facial expressions from face responsive brain regions (Wegrzyn et al., 2015; Said et al., 2010). Nevertheless, the extent to which the neural response can predict the fine-grained perception of facial expression remains unclear. Using multi-voxel pattern analysis (MVPA) techniques, we asked whether the perceptual similarity of expressions could be explained by the neural response in different face-selective regions. Our prediction was that patterns of response in regions associated with processing of facial expression should predict the perception of facial expression.

Methods

Participants

Twenty-four healthy volunteers took part in the fMRI experiment and the behavioural similarity rating experiment (12 female, mean age = 25.2 years). All the participants were right-handed and had normal or corrected to normal vision with no history of neurological illness. The fMRI work was approved and conducted following the guidelines of the York Neuroimaging Centre Research Ethics Committee, University of York, and the behavioural study by the Department of Psychology Ethics Committee. All the participants gave written consent prior to their participation.

Stimuli

Fig. 1 shows all the stimuli from the five expression conditions. Static images of expressions were presented as these are well-recognised as long as they represent the apex of the pattern of muscle movements involved in producing the expression (see Bruce and Young, 2012). By using well-validated images from the Radboud Face Database (Langner et al., 2010) we ensured that this criterion was met. Images were selected on the basis of high recognisability of their facial expressions and the similarity of the action units (muscle groups) used to pose each of the expressions. Only male faces were used to avoid any confounds from characteristics introduced by gender differences in the images themselves. For each of five models, images of expressions of fear, anger, disgust, sadness and happiness were used.

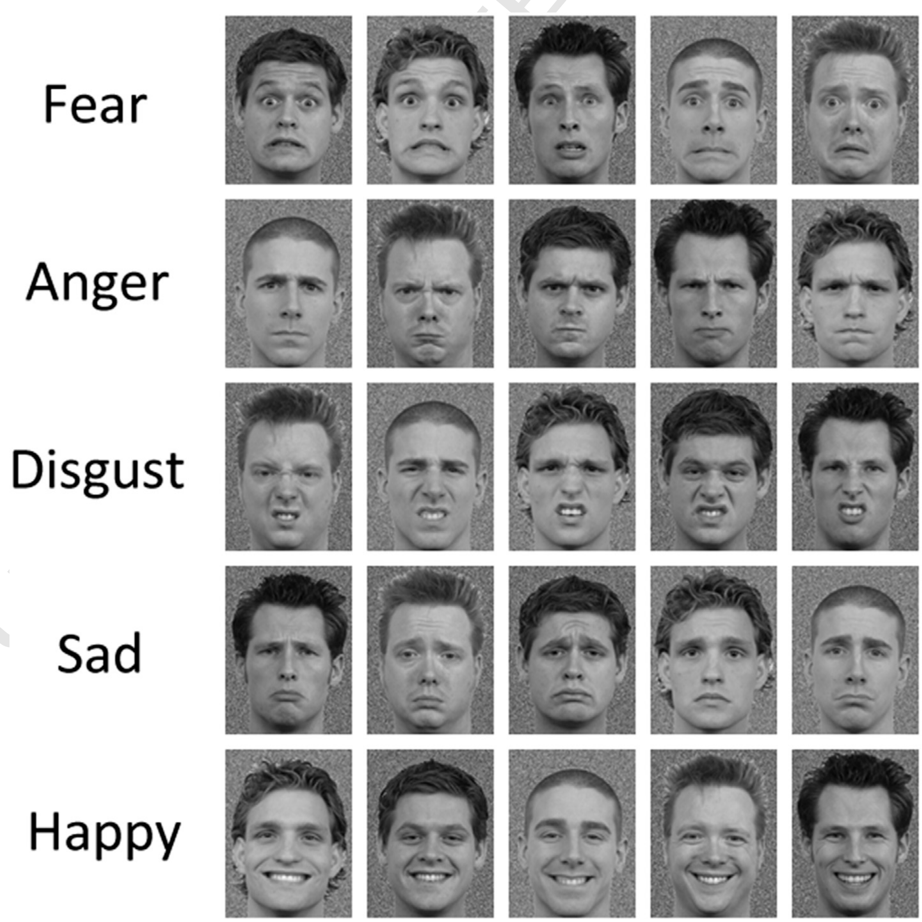

Fig. 1. Images used in behavioural and fMRI experiments. Images were taken from 5 identities posing expressions of 5 basic emotions. Each row shows a typical sequence that might form a block in the fMRI experiment (presenting the images from left to right one at a time).