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Brief article

Category-contingent face adaptation for novel colour categories: Contingent effects are seen only after social or meaningful labelling

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ABSTRACT

A face appears normal when it approximates the average of a population. Consequently, exposure to faces biases perceptions of subsequently viewed faces such that faces similar to those recently seen are perceived as more normal. Simultaneously inducing such aftereffects in opposite directions for two groups of faces indicates somewhat discrete representations for those groups. Here we examine how labelling influences the perception of category in faces differing in colour. We show category-contingent aftereffects following exposure to faces differing in eye spacing (wide versus narrow) for blue versus red faces when such groups are consistently labelled with socially meaningful labels (Extravert versus Introvert; Soldier versus Builder). Category-contingent aftereffects were not seen using identical methodology when labels were not meaningful or were absent. These data suggest that human representations of faces can be rapidly tuned to code for meaningful social categories and that such tuning requires both a label and an associated visual difference. Results highlight the flexibility of the cognitive visual system to discriminate categories even in adulthood.

1. Introduction

Given the many potential categories of face that an individual may encounter, one important question concerns how the perception of category arises. For each class of stimuli that the visual system encounters it may develop an internal representation, or prototype, possessing the average of the characteristics of the different exemplars of that type that have been seen (Enquist & Arak, 1994; Giese & Leopold, 2005; Johnstone, 1994; Loffler, Yourganov, Wilkinson, & Wilson, 2005; Valentine, 1991). Computer modeling has shown that algorithms trained to discriminate different stimuli produce a stronger response to stimuli representing the average of the training set (Enquist & Arak, 1994; Johnstone, 1994), suggesting that prototype formation is a property of learning to differentiate stimuli.

Faces have been the focus of much research regarding recognition and prototype formation. While it has been proposed that faces may be coded as representations of individuals unrelated to any representation of the population average (Valentine, 1991), recent neuroimaging, behavioural and single-cell recording studies have supported a prototype-referenced model of face coding (Giese & Leopold, 2005; Leopold, O'Toole, Vetter, & Blanz, 2001; Loffler et al., 2005). Furthermore, other behavioural studies have shown that recent visual experience can systematically bias the representation of faces.

Exposure to faces biases subsequent perceptions of novel faces by causing faces similar to those that were initially viewed to appear more prototypical than they would otherwise be perceived (Leopold, O'Toole, Vetter, & Blanz, 2001; Leopold, Rhodes, Muller, & Jeffery, 2005; Rhodes, Halberstadt, & Brajkovich, 2001; Rhodes et al., 2004; Webster,

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Kaping, Mizokami, & Duhamel, 2004; Webster & MacLin, 1999). For example, adaptation to faces with contracted features causes novel faces with contracted features to be perceived as more normal than prior to this exposure (Webster & MacLin, 1999). Analogous visual aftereffects have been observed following exposure to faces varying in identity (Leopold et al., 2001; Rhodes et al., 2001), ethnicity (Webster et al., 2004), sex (Rhodes et al., 2004; Webster et al., 2004), expression (Webster et al., 2004) and sexual dimorphism (Little, DeBruine, & Jones, 2005).

Different types of faces share many visual properties and could theoretically be represented without category boundaries following dimensions in a single 'face-space'. In other words, all faces could be represented along continua of similarity to a single population average, regardless of categories such as sex, race or age. On the other hand, certain properties of faces may result in grouping of similar faces and each grouping may possess its own population average. Sex, for example, is an important and salient perceptual category. Because male and female faces are similar, they may be represented relative to a single androgynous population average. There are, however, salient differences between male and female faces and so male and female faces will cluster in terms of their representation relative to a single population average. Such clustering may lead to separable representation, different average representations of male and female faces.

Studies using adaptation have demonstrated that humans may have somewhat distinct representations of male and female faces (Bestelmeyer et al., 2008; Jaquet & Rhodes, 2008; Little et al., 2005). Further work on categorical perception has demonstrated that separable processing can occur for faces of different races, ages, and species (Little, DeBruine, Jones, & Waitt, 2008). Importantly, these findings for category-contingent aftereffects occur for faces that belong to different social categories (e.g., male or female) but not for groups of faces that differ only in physical structure and belong to the same social category (e.g., female versus caricatured female, Bestelmeyer et al., 2008). These findings suggest that category-contingent aftereffects reflect adaptation to different face categories, rather than neural mechanisms that code only physical differences among face patterns (see Rotshtein, Henson, Treves, Driver, & Dolan, 2005).

Perceiving categories likely arises through experience. Individuals have an advantage in recognising members of their own race (Malpass & Kravitz, 1969; Valentine, 1991) and of their own species (Pascalis, Coleman, & Campbell, 1998), presumably because experience builds expertise in discrimination. Studies also indicate that early experience may be particularly important. While 6-month-olds, 9-month-olds, and adults can discriminate between human faces, only 6-month-olds can also discriminate between monkey faces (Pascalis, de Haan, & Nelson, 2002), implying that, after 6 months of age, representations of faces have become somewhat specialised for processing commonly seen face types. This system appears flexible; increased abilities to discriminate faces of different species can be maintained by exposing infants to other-species faces between the ages of 6 and 9 months (Pascalis et al., 2005). Indeed, it has been suggested that there may be a sensitive period for the specialised development of face processing abilities (Le Grand, Mondloch, Maurer, & Brent, 2001; Pascalis et al., 2005). Face processing mechanisms must remain somewhat flexible beyond infancy, however, as experience or intensive training with other-race faces can reduce the disadvantages in processing other-race faces (Goldstein & Chance, 1985; Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2005). Visual experience also generates recognisable categories of stimuli in abstract dot patterns in adults (e.g., Posner & Keele, 1968).

Given the many potential categories of face an individual may encounter, we may then expect a system that can rapidly adapt to new category types even in adulthood. The current experiments explored human abilities to process new face categories (red versus blue human faces). We test if individuals process red versus blue faces independently after experience with unlabelled images and when coloured faces are differently labelled. If category-dependent variation can be generated by simple differences in visual appearance, then both labelled and non-labelled tests should exhibit category-contingent adaptation. If category-dependent variation depends on categories being meaningful, then we expect categorical perception to only occur when the two groups of faces are each assigned socially meaningful labels but not for meaningless labels or no labels.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Participants were: 83 in the no labels study (50 women and 33 men, mean age = 31.2, SD = 12.3, 42 red+/blue− and 41 red−/blue+), 82 in the asocial labels study (59 women and 20 men, mean age = 26.0, SD = 9.7, 39 red+/blue− and 40 red−/blue+), and 79 in the social labels study (56 women and 26 men, mean age = 29.7, SD = 11.3, 36 red+/blue− and 46 red−/blue+). All participants were volunteers and were selected for being between the ages of 17 and 65. Participants were recruited via a research-based website and the experiments were administered online without an experimenter present.

2.1.2. Stimuli

Original faces were selected from a database collected by the authors. All stimuli were constructed using established (Little et al., 2005; Perrett et al., 1998) techniques for manipulating the appearance of face images in an objective, systematic manner (for technical details including mathematical algorithms see Rowland & Perrett, 1995; Tiddeman, Burt, & Perrett, 2001). Eye spacing was manipulated by transforming all images relative to a pair of face images, one original image and one image where all the points delineating the eyes had been moved outwards (Fig. 1). The distance change in eye-spacing distance from original (measured from the centre of the eye) in the presented images was 21 pixels for each individual face, either wider (plus) or narrower (minus). The same transform was

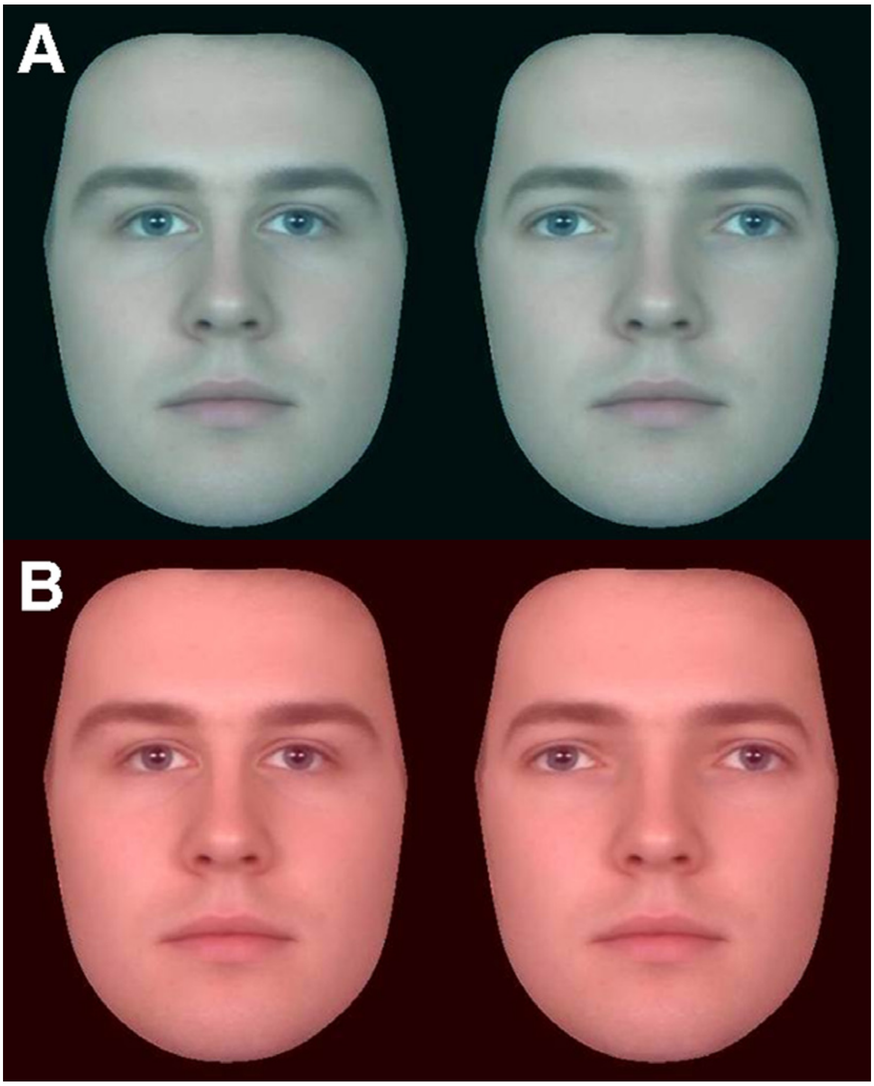

Fig. 1. Examples of face images varying in eye spacing for (A), blue faces (B), red faces. Eye-spacing stimuli were manufactured by increasing (right, plus) or decreasing (left, minus) the distance between the eyes of an original image the same prescribed distance for all images. These images appeared as part of the post-adaptation tests for normality judgements. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

applied to all starting images, ensuring the wide and narrow eye-spacing images differed from the real starting images in an identical manner but in opposite directions. This procedure for manipulating eye spacing in face images is methodologically similar to that in previous studies (Little et al., 2005).

For the adaptation phase, 10 composite images (each made up from two images) from each category were transformed plus and minus for eye spacing. Composite images were created by marking 179 landmark points on each constituent face. The mean shape was calculated for each set of images and each image warped to the average shape. The images were then superimposed to create an image with the average shape and colour of the constituents (Rowland & Perrett, 1995; Tiddeman et al., 2001). For the test conditions, five new composite images (each made up from random pairs of the adapting faces, four images in total) were transformed plus and minus for eye spacing, creating pairs of images where one image had narrow-spaced eyes and wide-spaced eyes.

All images were standardised for size on interpupillary distance prior to transformation. The magnitude of the deviation from average for the wide-spaced version was identical to the magnitude of deviation from average for the narrow-spaced version for each identity used in all parts of the experiment.

Images were transformed in colour using Corel Photo-paint 12. Blue faces were created by changing the colour balance on the cyan/red axis −50 and the red faces created by changing the colour balance on the cyan/red axis +50.

For the label conditions, the same faces from the adaptation phase were labelled with black text. For the asocial labels, red faces were labelled “green” and blue faces were labelled “yellow”. For the social labels, red faces were labelled “Extravert” and blue faces were labelled “Introvert”.

Images were presented at 350 by 435 pixels.

2.1.3. Procedure

Participants were randomly allocated to label condition (no label/social label). Because the asocial label condition

was run later, participants were not randomly allocated to this condition. The conditions were identical except that in the asocial and social label conditions, all faces were labelled during the adaptation phase (see Stimuli). Participants were further randomly assigned to adaptation condition. The two adaptation conditions consisted of slideshows of 10 different faces of one category and 10 different faces of the other. These 20 faces were seen for 3 s each for a total adaptation time of 30 s for each face type. In one adaptation condition, the 10 red faces were transformed to have increased (plus) eye spacing and the 10 blue faces were transformed to have decreased (minus) eye spacing. Transformation was reversed in the other adaptation condition, so that the 10 red faces were transformed to have minus eye spacing and the 10 blue faces were transformed to have plus eye spacing. In the test phase, participants were shown five different novel pairs of faces from one category and five different novel pairs of faces from the other category and were asked to choose the more ‘normal-looking’ of the pair. Pairs were of the same identity, one transformed to have plus eye spacing and one transformed to have minus eye spacing. The 10 post-adaptation pairs were not labelled and were presented on screen until participants made their choice. Average time taken for the post-test across study and condition was 67 s (SD = 31). This procedure and design follows that used by our previous studies on category-contingent adaptation (Little et al., 2005, 2008).

Online participation meant participants used their own computer access and were unsupervised. To prevent multiple instances, duplicate IP addresses were excluded from the set. Written instructions were presented clearly and previous studies of adaptation using online methods have demonstrated results that are consistent with laboratory based tests (Bestelmeyer, Jones, DeBruine, Little, & Welling, 2010; Jones, DeBruine, & Little, 2008; Jones, Feinberg, Bestelmeyer, Debruine, & Little, 2010).

2.2. Results

2.2.1. Combined analysis

A mixed model ANOVA [dependent variable: % of post-adaptation trials on which wide eye spacing was judged as more normal; within-participant factors: test face colour (red, blue); between-participant factors: label (no label/asocial label/social label), adaptation condition (red+/

2.2.4. Extravert/Introvert labels

An identical mixed model ANOVA for the social label study revealed a significant interaction between test face colour and adaptation condition ($F_{1,75} = 9.12$, $p < .01$, Fig. 2). Participants who were exposed to red faces with wide eye spacing and blue faces with narrow eye spacing subsequently chose wide eye spacing as more normal for red than blue faces. The pattern of choice post-adaptation was reversed for those exposed to red faces with narrow eye spacing and blue faces with wide eye spacing. No other within- or between-participants effects or interactions were significant (all $F_{1,75} < 2.25$, $p > 0.14$).

3. Experiment 2

Experiment 1 demonstrates that categorical effects are seen for differently coloured faces only when labels are present and represent meaningful social information. One issue with the labels in Experiment 1, however, was that the colour labels did not refer to any aspect of the individual and were set in contrast to the colour of the picture. Additionally, personality factors are only one type of social information and it is worthwhile examining other types of social information. Experiment 2 was designed to extend the findings of Experiment 1 using new labels, comparing relatively meaningless but valid labels for individuals (born: Monday/Friday) with relatively meaningful social labels which were not personality descriptions (Job: Soldier/Builder).

3.1. Methods

3.1.1. Participants

Participants were: 60 in the meaningless label study (45 women and 15 men, mean age = 26.0, SD = 9.9, 29 red+/blue− and 31 red−/blue+) and 60 in the meaningful labels study (45 women and 15 men, mean age = 25.2, SD = 9.6, 30 red+/blue− and 30 red−/blue+). All participants were selected and recruited in the same way as Experiment 1 except that, additionally, we excluded participants who claimed to have any problems with seeing colour.

3.1.2. Stimuli

Stimuli were identical to those used in Experiment 1 except that they were labelled differently. For the meaningless labels, red faces were labelled "Born: Friday" and blue faces were labelled "Born: Monday". For the meaningful labels, red faces were labelled "Job: Soldier" and blue faces were labelled "Job: Builder".

3.1.3. Procedure

The procedure was identical to Experiment 1 except that participants were randomly allocated to label study (meaningless/meaningful). Average time taken for the post-test across study and condition was 59 s (SD = 19).

3.2. Results

3.2.1. Combined analysis

A mixed model ANOVA [dependent variable: % of post-adaptation trials on which increased eye spacing was judged as more normal; within-participant factors: test face colour (red, blue); between-participant factors: label (meaningless/meaningful label) and adaptation condition (red+/blue−, red−/blue+); sex of judge was not entered as it had no impact on interactions with condition in Experiment 1] revealed a significant three-way interaction among test face colour, label, and adaptation condition ($F_{1,116} = 8.00$, $p < .001$, Fig. 3). This indicated different effects of adaptation condition on judgments of differently coloured faces according to label. There was also a significant interaction between condition and test face colour ($F_{1,16} = 12.96$, $p < .001$), though this was qualified by the higher-order interaction. There was a theoretically unrelated close-to-significant effect of colour ($F_{1,116} = 3.03$, $p = .09$) indicating that wide eye spacing was seen as more normal in red than blue faces. No other within- or between-participants effects or interactions were significant (all $F_{1,116} < 2.10$, $p > .15$). To interpret the three-way interaction, separate analyses were carried out on the different label conditions, reported below.

3.2.2. Born Monday/Friday labels

An identical mixed model ANOVA as above (without label as a factor) for the meaningless label study revealed no significant interaction between test face colour and adaptation condition ($F_{1,58} = 0.40$, $p = .53$, Fig. 3). There was a significant but theoretically unrelated effect of test face colour ($F_{1,58} = 6.82$, $p = .01$) whereby wide eye spacing was seen as more normal in red than blue faces. There was no significant effect of condition (all $F_{1,58} = 1.00$, $p = .33$).

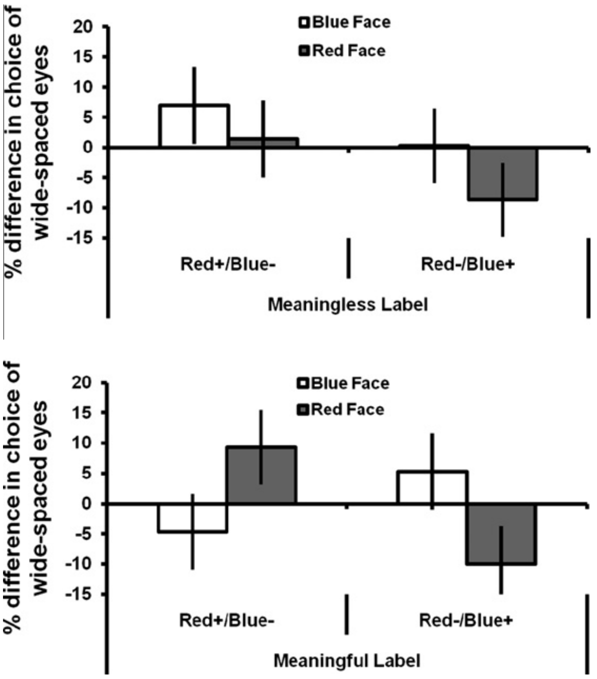

Fig. 3. Difference scores of % choice of red and blue male images with wide eye spacing as most normal looking according to exposure condition and label condition (±1 SE of mean) for Experiment 2. Difference scores represent mean % choice of wide eyes for each study minus the mean choice for each condition.

3.2.3. Job Builder/Soldier labels

An identical mixed model ANOVA for the meaningful label study revealed a significant interaction between test face colour and adaptation condition ($F_{1,58} = 16.50$, $p < .001$, Fig. 3). Participants who were exposed to red faces with wide eye spacing and blue faces with narrow eye spacing subsequently chose wide eye spacing as more normal for red than blue faces. The pattern of choice post-adaptation was reversed for those exposed to red faces with narrow eye spacing and blue faces with wide eye spacing. There was no significant effect of face colour or condition (both $F_{1,58} < 0.34$, $p > 0.56$).

4. General discussion

Our experiments have shown that some types of labelling can lead to category-dependent variation in perception of new faces that share certain visual properties. Faces, as a category, can be subdivided into subcategories based on appearance and here we show that new categories can be derived from minimal experience; perception was altered after exposure to very few label-colour pairs. In essence, we have demonstrated, at a simplified scale, what may occur in the learning of other categories of human faces. Individuals appear to be able to rapidly learn to associate facial appearance with meaningful category information and come to process faces differently according to their category. Asocial labels, the colour labels used in Experiment 1, and meaningless labels, day of birth labels used in Experiment 2, did not lead to categorical processing, suggesting categorical processing involves social category information and is not a simple effect of labelling.

The category-contingent effects observed here are further evidence that aftereffects due to exposure to faces cannot be explained simply by retinal adaptation or low-level adaption to colour and structure; face aftereffects can be simultaneously generated in opposite directions for different groups of faces, but only when socially-relevant high-level (i.e., semantic) information is associated with these groups. While these data were collected online, the pattern of results cannot be attributed to the method as participants in all conditions carried out the tests in the same way.

Our data demonstrate that arbitrary colour differences alone or colour differences combined with asocial or relatively meaningless labels are not sufficient to drive categorical perception. This suggests that social information about category and an association with some visual feature or features is important. This finding appears to fit well with the proposed utility of visual categories. While difference in appearance often reflects differences in category, the visual system does not necessarily have an inherent understanding of the need for such boundaries. To give an example, one may encounter two types of rock that can be very different in shape, but their utility, and therefore how they afford interaction, might remain the same and no new categories would be required. Two types of tree, however, may share many visual similarities, but one may provide food and the other firewood. Therefore, learning to differentiate between the two and to categorise other encountered trees into the correct category may become important. Sensitivity to associations between structure and label may then be a reflection of the evolved utility of categories; because it may not be useful to categorise everything that differs into ever smaller and more specialised representations, the visual system might adopt only useful information and associate it with structure to define important categories, which, for faces, are socially meaningful.

Previous studies have suggested that aftereffects following exposure to faces reflect change in the responses of dissociable neural populations that code the stimuli viewed (Little et al., 2005; Rhodes et al., 2004) and this is a parsimonious explanation here. Our results suggest that dissociable neural populations can be rapidly tuned to code for important categories of faces in adulthood. Dissociable neural responses for categories appear likely the result of experience, as it is unlikely that there are neurons in the brain predetermined to code faces of different categories. Rather, visual experience of faces of different categories coupled with the salience of the category may recruit neurons to become selective to only one category.

A previous study has demonstrated that identity aftereffects were independent of facial expression (Fox & Barton, 2007), and, given we generate categorical perception quickly using labels, it might be seen as surprising that categorical effects are not seen based on expression. Expressions, however, are fleeting aspects of facial appearance, with which individuals have much experience, and expressions have long been considered ‘special’ in terms of processing (Haxby, Hoffman, & Gobbini, 2000). Different expressions may not cause categorical perception because processing of expression is perhaps parallel and somewhat independent of processing structure and identity (Haxby et al., 2000), whereas the labels we employ may generate categories that are related to identity. Additionally, another study has previously found no colour contingent adaptation (Yamashita, Hardy, De Valois, & Webster, 2005), in line with our unlabelled or asocial/meaningless labelled studies. Yamashita et al. did note that contingent aftereffects were evident when the two faces appeared to belong to different rather than the same identities. Potentially, our labels may not have marked the images as the same category, but instead resulted in images being processed as if they were the same identity. We note, however, that we used different identities in the adaptation and test phases (and in fact the same identities were used for red versus blue coloured faces in all parts of the test), which should mean category was more relevant than identity. Whether the labels cause effects based on different categories or whether the labelling causes the faces to be processed as if they are same identity, labelling causes contingent aftereffects because it differentiates the image types in a meaningful way. Other studies have demonstrated that adaptation can be caused when a person’s name is presented as the adaptor (Hills, Elward, & Lewis, 2008). That such semantic information alters the processing of visual images is an interesting avenue for future research.

Overall, our data add to research showing that exposure to faces biases subsequent perceptions of novel faces, additionally demonstrating that category-specific effects can be generated through meaningful labelling. The category-differentiated adaptation here shows that only minimal social category information is required to cause human adults to process novel faces differing in colour in a categorical fashion, highlighting the flexible nature of human visual categorisation.

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In the original printed version Figure 2 was incorrect.
This version of the article contains a corrected version of Figure 2.