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adapting to the 30° side view impaired discrimination. Similarly, Rhodes, Watson, Jeffery, and Clifford (2010) discovered that 5 min of adaptation to an average Asian or Caucasian face reduced identification thresholds for faces from the adapted relative to the unadapted race.

In this study, we performed three experiments to test whether visual adaptation can improve gender discrimination. In the first and the second experiments, subjects adapted to male, female and gender-neutral faces, and then gender discrimination thresholds were measured for female faces (Experiment 1) and male faces (Experiment 2). If the re-calibration theory of adaptation (Barlow, 1990) can be applied to high-level vision, face adaptation should enhance discrimination around the adapted state. Specifically, adapting to a male/female face should reduce discrimination thresholds for male/female faces. In the third experiment, we tested whether the discrimination enhancement induced by face adaptation could be generalized to a different face view. Subjects adapted to the front view and the 30° side view of female faces, and then gender discrimination thresholds were measured for the front view of female faces.

2. Methods

2.1. Participants

A total of 36 undergraduates (15 male and 21 female) from Peking University participated in the study, 12 for each of the three experiments. They were right-handed with reported normal or corrected-to-normal vision and had no known neurological or visual disorders. Their ages ranged from 19 to 23. They gave written, informed consent in accordance with the procedures and protocols approved by the human subjects review committee of Peking University.

2.2. Apparatus and stimuli

Stimuli were presented on an IIYAMA HM204DT 22 in. monitor, with a spatial resolution of 1024×768 and a refresh rate of 100 Hz. Subjects viewed the stimuli from a distance of 57 cm. Their head position was stabilized using a chin rest and a headrest.

Three pairs of faces were generated by FaceGen Modeller 3.1 (http://www.facegen.com/). Two pairs were Asian faces and one pair Caucasian faces. In each pair, one face was fully female and the other fully male. Fully female/male faces were determined by setting the gender slider position to 100% female/male in FaceGen Modeller 3.1. We then morphed between faces in each pair using

In Experiment 2, we attempted to measure gender discrimination thresholds at the gender strength of 20 without adaptation and after adaptation to faces with gender strengths of 20, 50 and 80. The experimental procedure was identical to that in Experiment 1. In Experiments 1 and 2, all adapting and test faces were face front views.

In Experiment 3, we measured gender discrimination thresholds at the gender strength of 80 without adaptation and after adaptation to a front face view and a 30° face side view (Fig. 2B). The 30° side view were generated by projecting a 3D face model with a 30° in-depth rotation angle onto the monitor plane. These two adapting faces had the same identity and had a gender strength of 80. Test faces were around the front face view. Similar

($t(11) = 3.951$, $p = 0.002$). Although the thresholds after gender-neutral face adaptation were higher than those after male face adaptation, their difference was not significant ($t(11) = 1.245$, $p = 0.239$).

ence (e.g. perceptual learning) can dramatically improve our discrimination ability (Bi, Chen, Weng, He, & Fang, in press; Fahle & Poggio, 2002). However, the visual experience in the current study was only 25 s.

Experiment 3 demonstrated that the gender discrimination improvement induced by adaption could be generalized to a different face view, which resonates with the finding that face identity aftereffect could transfer across a substantial change in three-dimensional viewpoint (Jiang, Blanz, & O'Toole, 2006). In monkey's high-level visual areas, view-depend and view-independent face neurons mixed together (Booth & Rolls, 1998; Perrett, Hietanen, Oram, & Benson, 1992). Psychophysical adaptation studies provide evidence for both view-dependent and view-independent codings of face identity in the human visual system (Jeffery, Rhodes, & Busey, 2006; Jiang, Blanz, & O'Toole, 2006; Welling et al., 2009). It has been suggested that view-independent representation (recognition) is achieved by using a hierarchy of neural mechanisms with view-dependent responses (Riesenhuber & Poggio, 2002). Our finding suggests that face gender adaptation took place (at least partially) at the level of view-independent face representation. Meanwhile, it also provides further evidence to rule out low-level adaptation as an explanation of the performance improvement.

In this study, we measured discrimination threshold reductions not only when the adapting face was identical to the test face, but also when they were different in gender strength. Results in Experiments 1 and 2 show the same pattern. That is, significant reductions were observed only when the adapting and the test faces were identical. When the adapting and the test faces became more and more dissimilar, discrimination threshold reductions gradually diminished. This pattern is different from the effects of orientation adaptation (Clifford et al., 2001) and face view adaptation (Chen et al., 2010). For these two kinds of adaptations, discrimination thresholds after adaptation also reduced significantly when adapting and test stimuli were identical. However, when adapting and test stimuli differed moderately, discrimination thresholds increased and subjects' performance was impaired. One possible reason for this difference is that, in the visual cortex, face gender is coded in a different way from face view and orientation. Both face view selective neurons and orientation selective neurons have a bell-shaped tuning function responsive to a specific face view or orientation (Perrett et al., 1992), whereas identity (e.g. gender) has been suggested to be coded in a norm-based way in monkey inferotemporal (IT) cortex (Leopold, Bondar, & Giese, 2006).

Although our data provide a clear demonstration that face adaptation can improve gender discrimination, the precise mechanisms underlying the improvement remain uncertain. A possible mechanism is that adaptation to a female/male face could temporarily bias the generic norm towards the adapted gender, which might improve discrimination (Rhodes et al., 2010). Wilson and colleagues (2002) found that the discrimination threshold for face sets around the average (norm) face was lower than that for face sets far from the average face (but see also Rhodes et al., 2007), which is consistent with the neurophysiological finding that IT neurons were most often tuned around the average face (Leopold et al., 2006). In the future, complementary to psychophysical studies, more single-unit and brain imaging studies are needed to carry out to obtain a full understanding of the mechanisms of face adaptation. Indeed, we know little about how adaptation influences neuronal tuning functions to faces (and objects) in the high-level visual cortex.

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