Perceptual consequences of face viewpoint adaptation: Face viewpoint aftereffect, changes of differential sensitivity to face view, and their relationship

Juan Chen — Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), Peking University, Beijing, PR China

Hua Yang — YuanPei College, Peking University, Beijing, PR China

Aobing Wang — Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), Peking University, Beijing, PR China

Fang Fang — Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), Peking University, Beijing, PR China

Adaptation to a visual pattern can alter the sensitivities of neuronal populations encoding the pattern, which usually results in a visual aftereffect. However, the functional role of visual adaptation is still equivocal and its relation to visual aftereffect is largely unknown, especially for high-level visual adaptation. In this study, we took advantage of face view adaptation to investigate these issues. In the first experiment, we measured the angular tuning function of the face viewpoint aftereffect in F. Fang and S. He's (2005) study. As the adapting angle increased from 0° to 90°, the aftereffect magnitude increased quickly, peaked at 20°

Apparatus and stimuli

Stimuli were presented on an IIYAMA HM204DT 22-inch monitor, with a spatial resolution of 1024 × 768 and

of the five face views (solid line). We calculated the ratio of discrimination thresholds (post-adaptation/pre-adaptation) at each adapting angle, as an index of the adaptation effect on face view discrimination. The ratios averaged across five subjects were plotted as a function of adapting angle, which is shown in Figure 2C. Ratio values less than 1 indicate performance improvement in face view discrimination after adaptation, and those larger than 1 indicate an impairment.

After adaptation to the front view (0°), subjects' face

to describe response inhibition, bandwidth change, and preference shift, respectively. $\alpha_\phi(\theta_0)$, $\beta_\phi(\theta_0)$, and $\theta_{0\phi}$ denote the peak response, bandwidth, and peak tuning of a model neuron (labeled by θ_0) after adapting to a ϕ degree face view, respectively. In these formulas, λ and σ control the magnitude and the range of response inhibition, respectively, σ_1 and σ_2 codetermine where the largest broadening occurs, μ controls the magnitude of broadening, γ controls the magnitude of preference shift, and σ_ϕ determines where the largest shift occurs.

The percept of face view direction is determined by the response of the model neuronal population, the vector sum of the individual neuronal responses (Pouget, Dayan, & Zemel, adaptation to other face attributes, such as identity (Rhodes et al., 2007), gender (Ng et al., 2008), and expression (Pallett & Macleod, 2007). Face viewpoint adaptation not only improved view discrimination around the adapting view but also impaired discrimination at face views about 30° away from the adapting view. This pattern is also partially similar to how orientation adaptation affects orientation discrimination, although the maximal impairment occurred for orientations about 10° away from the adapting orientation (Clifford et al., 2001). However, orientation adaptation is different from face viewpoint adaptation in that there was no adaptation effect on discrimination threshold with a large adapting angle (e.g., 90°). This finding confirms our hypothesis that face viewpoint adaptation is a promising place to begin looking at the functional advantage of adaptation in high-level vision. Previous studies (Ng et al., 2008; Rhodes et al., 2007) did not find such an effect with face identity adaptation. One possible reason is that face view and identity are coded in different ways in the visual cortex. Face view selective neurons have a bell-shaped tuning curve that is similar to the orientation-tuning curves in V1 (Perrett et al., 1991, 1985). However, identity has been suggested to be coded in a norm-based way in monkey IT (Leopold et al., 2006), rather than an exemplar-based way with bell-shaped tuning functions (Rhodes & Jeffery, 2006; Tsao & Freiwald, 2006).

It should be noted that the adaptation effects observed in Experiments 1 and 2 cannot be explained by low-level proportional to the length of visual experience. For example, tens of hours of visual experience (e.g., perceptual learning) can dramatically improve our discrimination ability (Gilbert, Sigman, & Crist, 2001). However, the visual experience in the current study was only 25 s.

The work by Perrett et al. (1985) on the coding of face view direction suggests that eye gaze, face view, and body posture are encoded within the same system. The directions of face, gaze, and body are primary cues for conveying social attention and they have been the focus of a large body of "social attention" studies in recent years (Nummenmaa & Calder, 2009). Many psychophysical, single-unit recording and functional magnetic resonance imaging (fMRI) studies have been carried out to investigate the neural representations of the directions and have demonstrated their interaction at multiple levels (Bi et al., 2009; De Souza et al., 2005; Langton, 2000; Langton, Honeyman, & Tessler, 2004; Perrett, Hietanen, Oram, & Benson, 1992; Ricciardelli & Driver, 2008; Vander Wyk, Hudac, Carter, Sobel, & Pelphrey, 2009). For example, our recent study (Bi et al., 2009) showed that a gaze direction change in adapting face stimuli could induce a dramatic reduction in the magnitude of the face viewpoint aftereffect. In future studies, it would be interesting to manipulate the directions of face and gaze independently and examine the adaptation effects on the discrimination of face and gaze directions.

In summary, we have found that face viewpoint adaptation could not only bias our perception of face view direction but also alter our face view discrimination ability. We have also shown that the discrimination threshold changes could be inferred from the face viewpoint aftereffect. These results together suggest that the adaptive coding mechanism is employed in face view processing and provide new insights into the functional role of adaptation in high-level vision.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (Projects 30870762, 90920012, and 30925014), the Ministry of Science and Technology of China (2010CB833903), and the Scientific Research Foundation for the Returned Overseas Chinese Scholars, State Education Ministry.

Author contributions: Juan Chen and Hua Yang contributed equally to this work.
Commercial relationships: none.
Corresponding author: Fang Fang.
Email: ffang@pku.edu.cn.
Address: Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), Peking University, 5 Yiheyuan Road, Beijing 1-37[(T8(sh)--37zthoon,)]T9vhoon,24(al.,)]TJ0Tm[(Acknow)5(ledgments)]TJ0316.7432690

Fang, F., Ijichi, K., & He, S. (2007). Transfer of the face in the macaque temporal cortex. *E perimental Brain Research, 86,* 159–173.

Perrett, D. I., Smith, P. A. J., Potter, D. D., Mistlin, A. J., Head, A. S., & Milner, A. D. (1985). Visual cells in the temporal cortex sensitive to face view and gaze direction. *Proceedings of the Ro al Societ of London B: Biological Sciences, 223,* 293–317. [PubMed]

Phinney, R. E., Bowd, C., & Patterson, R. (1997). Direction-selective coding of stereoscopic (cyclopean) motion. *Vision Research, 37,* 865–869. [PubMed] [Article]

Pouget, A., Dayan, P., & Zemel, R. (2003). Inference and computation with population codes. *Annual Review of Neuroscience, 26,* 381–410. [PubMed]

Pouget, A., Zhang, K., Deneve, S., & Latham, P. E. (1998). Statistically efficient estimation using population coding. *Neural Computation, 10,* 373–401. [PubMed]

Regan, D., & Beverlay, K. I. (1983). Spatial frequency discrimination and detection: Comparison of post-adaptation threshold. *Journal of the Optical Societ of America A, 73,* 1684–1690.

Regan, D., & Beverlay, K. L. (1985). Postadaptation orientation discrimination. *Journal of the Optical Societ of America A, 2,* 147–155. [PubMed]

Rhodes, G., & Jeffery, L. (2006). Adaptive norm-based coding of facial identity. *Vision Research, 46,* 2977–2987. [PubMed]

Rhodes, G., Jeffery, L., Watson, T. L., Clifford, C. W., & Nakayama, K. (2003). Fitting the mind to the world: Face adaptation and attractiveness aftereffects. *Ps chological Science, 14,* 558–566. [PubMed]

Rhodes, G., Maloney, L. T., Turner, J., & Ewing, L. (2007). Adaptive face coding and discrimination around the average face. *Vision Research, 47,* 974–989. [PubMed] [Article]

Ricciardelli, P., & Driver, J. (2008). Effects of head orientation on gaze perception: How positive congruency effects can be reversed. *Quarterl Journal of E perimental Ps cholog , 61,* 491–504. [PubMed]

Ross, J., Speed, H. D., & Morgan, M. J. (1993). The effects of adaptation and masking on incremental thresholds for contrast. *Vision Research, 33,* 2051–2056. [PubMed]

Ryu, J., & Chaudhuri, A. (2006). Representations of familiar and unfamiliar faces as revealed by viewpoint-aftereffects. *Vision Research, 46,* 4059–4063. [PubMed] [Article]

Sawamura, H., Orban, G. A., & Vogels, R. (2006). Selectivity of neuronal adaptation does not match response selectivity: A single-cell study of the FMRI adaptation paradigm. *Neuron, 49,* 307–318. [PubMed]

Tsao, D. Y., & Freiwald, W. A. (2006). What's so special about the average face? *Trends in Cognitive Sciences, 10,* 391–393. [PubMed] [Article]

Vander Wyk, B. C., Hudac, C. M., Carter, E. J., Sobel, D. M., & Pelphrey, K. A. (2009). Action understanding in the superior temporal sulcus region. *Ps chological Science, 20,* 771–777. [PubMed]

Verhoef, B. E., Kayaert, G., Franko, E., Vangeneugden, J., & Vogels, R. (2008). Stimulus similarity-contingent neural adaptation can be time and cortical area dependent. *Journal of Neuroscience, 28,* 10631–10640. [PubMed] [Article]

Watkins, D. W., & Berkley, M. A. (1974). The orientation selectivity of single neurons in cat striate cortex. *E perimental Brain Research, 19,* 433–446. [PubMed]

Watson, A. B., & Pelli, D. G. (1983). QUEST: A Bayesian adaptive psychometric method. *Perception & Ps choph sics, 33,* 113–120. [PubMed]

Webster, M. A., Kaping, D., Mizokami, Y., & Duhamel, P. (2004). Adaptation to natural facial categories. *Nature, 428,* 557–561. [PubMed]

Webster, M. A., & Maclin, O. H. (1999). Figural aftereffects in the perception of faces. *Ps chonomic Bulletin and Review, 6,* 647–653. [PubMed]

Webster, M. A., & Mollon, J. D. (1991). Change in colour appearance following post-receptoral adaptation. *Nature, 349,* 235–238.

Wenderoth, P., & Johnstone, S. (1987). Possible neural substrates for orientation analysis and perception. *Perception, 16,* 693–709. [PubMed]