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Effects of face feature and contour crowding in facial expression adaptation

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ABSTRACT

Prolonged exposure to a visual stimulus, such as a happy face, biases the perception of subsequently presented neutral face toward sad perception, the known face adaptation. Face adaptation is affected by visibility or awareness of the adapting face. However, whether it is affected by discriminability of the adapting face is largely unknown. In the current study, we used crowding to manipulate discriminability of the adapting face and test its effect on face adaptation. Instead of presenting flanking faces near the target face, we shortened the distance between facial features (internal feature crowding), and reduced the size of face contour (external contour crowding), to introduce crowding. We are interested in whether internal feature crowding or external contour crowding is more effective in inducing crowding effect in our first experiment. We found that combining internal feature and external contour crowding, but not either of them alone, induced significant crowding effect. In Experiment 2, we went on further to investigate its effect on adaptation. We found that both internal feature crowding and external contour crowding reduced its facial expression aftereffect (FEA) significantly. However, we did not find a significant correlation between discriminability of the adapting face and its FEA. Interestingly, we found a significant correlation between discriminabilities of the adapting and test faces. Experiment 3 found that the reduced adaptation aftereffect in combined crowding by the external face contour and the internal facial features cannot be decomposed into the effects from the face contour and facial features linearly. It thus suggested a nonlinear integration between facial features and face contour in face adaptation.

1. Introduction

Prolonged exposure to one visual attribute (e.g., sadness of faces) biases the perception of subsequently presented visual stimuli toward the opposite attribute (e.g., happiness of faces). This phenomenon is known as visual adaptation. Visual adaptation is used to probe the short-term plasticity of the visual system. There are at least three consequences of visual adaptation: normalization (extreme stimuli become less extreme, and closer to the average/neutral point, e.g., after adapting to a sad face, sad test face becomes less sad), aftereffect (perception of the attributes of test stimuli shifts away from that of the adapter, e.g., neutral test face appears happy) and discriminability (sensitivity of test stimuli near the adapter increases, e.g., discriminability of sad test faces is increased). Sensitivity of test stimuli attributes similar to those of the adapter is increased by adaptation for both simple and complex stimuli, such as orientation (Clifford et al., 2001; Regan & Beverley, 1985), contrast (Abbonizio, Langley, & Clifford, 2002; Greenlee & Heitger, 1988), motion direction (Phinney, Bowd, & Patterson, 1997), speed (Bex, Metha, & Makous, 1999; Clifford & Wenderoth, 1999; Krekelberg, van Wezel, & Albright, 2006), gender (Yang et al., 2011), face viewpoint (Chen et al., 2010), and trustworthiness (Keefe et al., 2013). However, the cause of this increased sensitivity remains unclear. Specifically, this raises the question: what properties of object perception are changed because of adaptation?

Discriminability of adapting stimulus can be manipulated by multiple psychophysical techniques, such as crowding. Surrounding a stimulus by similar stimuli (flankers) reduces discriminability of the stimulus, the crowding effect. Adapting to a crowded stimulus does not reduce the adaptation aftereffect for simple features, such as oriented bars at high contrast (He, Cavanagh, & Intriligator, 1996; Rajimehr, Montaser-Kouhsari, & Afraz, 2003).

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More recent studies suggest, however, that reducing the discriminability of the adapting face by crowding with flanking faces (Louie, Bressler, & Whitney, 2007) reduces the aftereffect for complex stimuli (e.g., faces) at low contrast. Blake et al. (2006) resolved this controversy by showing that crowding does not reduce the aftereffect for simple features (e.g., orientation-dependent threshold-elevation aftereffect, TEAE) at high-contrast, but does so for simple features at low contrast, suggesting the existence of response saturation for adapting stimuli at high contrast levels.

Face crowding is used in discrimination tasks to see if subjects are able to identify the detailed information of a face, such as facial expression, given that they can detect the presence of the face. Visual crowding is an automatic but unwanted binding or grouping of flankers and target. It thus makes the target's details hard to identify. Face crowding can be induced by presenting similar faces nearby the target face (multiple faces) (Louie, Bressler, & Whitney, 2007), or by manipulating the distance among facial features (within the same face), which is internal feature crowding or self-crowding (Farzin, Rivera, & Whitney, 2009; Martelli, Majaj, & Pelli, 2005). Both can reduce the discriminability of facial expression of the crowded face. It has been shown that crowding the adapting face by face flankers can reduce the facial expression aftereffect (Xu et al., 2012). However, the effect of internal feature crowding or self-crowding, is relatively less studied. Furthermore, can external face contour crowding affect facial expression discriminability, as internal feature crowding does? Among all the facial features, the mouth is essential for facial expression judgment, especially for happy or sad emotion (Chen & Chen, 2010; Gosselin & Schyns, 2001). Presenting facial features (e.g., nose) or face contour near the mouth will likely induce crowding effect, and we would expect to see its effect on facial expression adaptation.

Therefore, three questions remain: (1) Which form of crowding, internal feature crowing or external contour crowding, is more effective in reducing discriminability of facial expression? (2) How are the adaptation properties (e.g., aftereffect and sensitivity) related to the discriminability of the adapting face? (3) Can the combined crowding effect by both external face contour and internal facial feature be decomposed into the effects from the face contour and facial features linearly?

In the present study, we used visual crowding to manipulate the facial expression discriminability (FED) to address the above questions. We varied the distance of facial features and/or face contour to the mouth to generate a series of faces, and examined its effect on facial expression judgment of these faces. We then investigated the facial expression aftereffect (FEA) by adapting to these faces.

2. Experiment 1

Our first experiment investigated the effect of crowding induced by different manipulations of surroundings to the mouth – facial features, face contour, or hair. Effect of crowding is related to the proximity and similarity between the target and the flankers such that the more similar the target and flankers are, the larger the crowding effect is (e.g., presenting flanking faces near the target face). This suggests strong grouping between the target face and flanking faces. However, few studies have explored grouping among distinct low-level features (such as different facial features) to form a coherent high-level perception (such as a face image), with the exception of within-face or facial feature crowding (Farzin, Rivera, & Whitney, 2009; Martelli, Majaj, & Pelli, 2005). Martelli, Majaj, and Pelli (2005) found that self-crowding of facial features (internal feature crowding) could induce crowding effects by reducing the distance among face parts (independent of size), just like crowding words by reducing the distance between letters. In comparison, crowding induced by face contour has been largely overlooked, because most facial information (e.g., identity and emotion) is sufficiently contained in facial features. We aim to investigate whether external crowding (induced by face contour) is effective in reducing the discriminability of facial emotion in Experiment 1.

In this experiment, to induce stronger grouping, we introduce a new form of crowding to generate a new set of face stimuli by reducing the size of the face contour, in addition to the internal feature crowding (Farzin, Rivera, & Whitney, 2009; Martelli, Majaj, & Pelli, 2005). These faces are labeled as *external contour and internal feature crowded faces*. In comparison, the *internal feature crowded faces* are generated by reducing the distances of other facial features (nose, eyes, and eye brows), but keeping the size of the facial features and face contour the same as the uncrowded expanded caricature face (similar to the feature crowding studies by Martelli, Majaj, & Pelli, 2005).

2.1. Methods

2.1.1. Observers

Ten subjects, with normal or corrected-to-normal vision, participated in Experiments 1. Two of the subjects were experimenters (PL and AC), and the others were naïve to the purpose of the study. All subjects were allowed sufficient practice on facial expression judgment of caricature faces before data collection for each condition. All subjects were given written consent before testing. This study was approved by the Ethics Committee of the Division of Psychology, and the Internal Review Board (IRB) at Nanyang Technological University, Singapore, in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving human subjects.

2.1.2. Apparatus

Stimuli were presented on a 17-in. Samsung monitor (SyncMaster 793MB) with a refresh rate of 85 Hz and a spatial resolution of 1024×768. The monitor was controlled by an iMac Intel Core i3 computer. Subjects were seated in a dimly lit room and viewed the stimuli from a distance of 57 cm. Each pixel on the screen subtended a visual angle of 0.032° at this distance. A chin rest was used to stabilize the subject's head position. A Minolta LS-110 photometer measured the luminance values. All experiments were run in Matlab (V2010a for Mac) with Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997).

2.1.3. Stimuli

Caricature faces were used in the experiments. We selected a caricature face ($f_{\text{originial}}$, Fig. 1a) from the Lar DeSouza database (http://www.lartist.com/celebrity.htm) and then modified facial features, especially the mouth shape to make the curvature more salient and flexible for facial expression manipulation. We generated seven caricature face images for the experiments by modifying the facial features and face contour of the original caricature face using Adobe Photoshop CS5 (Adobe Systems Incorporated, California, U.S.A.). All faces had the same facial features (mouth, nose, eyes and eye brows), sized $0.77° \times 0.26°$, $0.26° \times 0.57°$, $0.42° \times 0.38°$, and $0.42° \times 0.42°$, respectively. We extracted the facial features to create the mouth-only image (m, Fig. 1b), pure internal facial-feature-crowded face (f_{internal}, Fig. 1c), and pure external face-contour-crowded face (f_{external}, Fig. 1d).

During the task, we required the subjects to maintain fixation on a cross, and the faces were presented in the periphery (center-to-center distance between the face and fixation point was 3.45° horizontally and 0.29° vertically). Therefore, to ensure a clear view of the facial expression of the faces in the periphery, we enlarged the distances between facial features of the original