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N170 ADAPTATION EFFECT FOR REPEATED FACES AND WORDS

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Abstract—Using ERP adaptation paradigms, studies have shown that the N170 adaptation effect is a stable phenomenon for both faces and words. However, the N170 adaptation effect for repeated identity remains unclear, so we have addressed this with two experiments. In Experiment 1, we investigated the face-related N170 repeated adaptation effect in a short interstimulus interval (ISI) and found that the N170 response elicited by faces was smaller when preceded by a same face adaptor than by another face adaptor. Experiment 2 addressed whether this repeated N170 adaptation effect generalizes to words. For the first time, the results indicated that the N170 response elicited by words was larger with a different word as an adaptor relative to the same word as an adaptor. Our results demonstrate that the face-related N170 response is sensitive to visual face features and extend the characteristics of N170 with the sensitivity to repeated items to other familiar objects of expertise (i.e. words). The results also suggest that there are some common characteristics between faces and words in the early perceptual processing.

Key words: N170, adaptation effect, repeated items, faces, words.

INTRODUCTION

The human visual system is capable of recognizing faces and words quickly and efficiently (Bruce and Young, 1986; Sereno and Rayner, 2003; Barragan-Jason et al., 2013). Event-related potential (ERP) studies have shown that visual processes are specialized for faces and words within the first 200 ms of stimulus presentation. Such specialized brain processes have most consistently been indexed by an increased occipito-temporal ERP component (N170/N1) elicited by visual stimuli (Bentin et al., 1996; Maurer et al., 2005). ERP studies have shown that the N170 response elicited by faces is stronger than that elicited by non-face stimuli (Bentin et al., 1996; Eimer, 2000; Rossion and Jacques, 2008). Recently, ERP studies have employed the adaptation paradigm to investigate the face-sensitive properties on the N170 (Eimer et al., 2010). Neural adaptation refers to the phenomenon that neural responses become smaller when exposure to stimuli is repeated (Grill-Spector et al., 2006). Using ERP adaptation paradigms, studies have found support for a face-related N170 adaptation effect, in which the N170 response elicited by face test stimuli is reduced on trials with face adaptors relative to the control trials where non-face stimuli (e.g. houses) were used as adaptors (Kovacs et al., 2006; Jacques et al., 2007; Eimer et al., 2010, 2011; Nemrodov and Itier, 2011, 2012). Importantly, evidence suggests that the face-related N170 is sensitive to face repetition. Namely, when the same face is presented on consecutive trials, the N170 amplitude is reduced relative to when two different faces are presented successively (Jacques and Rossion, 2006; Jacques et al., 2007). This evidence suggests that the N170 component is sensitive to repeated faces (Zheng et al., 2011, 2012; Xu et al., 2012; Zimmermann and Eimer, 2014), though other studies suggest it is sensitive to individual faces (Caharel et al., 2009).

In contrast to the N170 response for faces, previous ERP studies indicated that printed words also produce stronger N170 (the literature also refers to this component as N1 or recognition potential) response than other stimuli (Bentin et al., 1999; Maurer et al., 2005; Cao et al., 2011; Zhao et al., 2012). In addition, the N170 response elicited by word test stimuli is sometimes smaller when the adaptor is a word compared to a house in a short interstimulus interval (ISI) adaptation paradigm (Fu et al., 2012; Cao et al., 2014). However, two studies with the long ISI (1000 ms or 1500 ms) did not show this word-related N170 adaptation effect (Maurer et al., 2008; Mercure et al., 2011). Unfortunately, whether the N170 adaptation effect is sensitive to repeated words is still unclear.

Taken together, these results suggest that the N170 adaptation effect is a stable phenomenon for both faces and words in a short adaptation paradigm; but the N170 adaptation effect for repeated faces is disputed. Despite reports that many factors affect the N170/N1 response (Thierry et al., 2007a,b), variable ISIs could be the reason for the inconsistent individual face-related N170 adaptation effects. Rossion and colleagues investigated the N170 adaptation effect using an ISI of 150–350 ms (Jacques and Rossion, 2006; Caharel et al., 2009), which was shorter than the 577 ms used in Amihai et al. (2011) or the 567 ms used in Xu et al. (2012). Many studies have suggested that the duration of ISI has a large effect on

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Abbreviations: ERP, event-related potential; fMRI, functional magnetic resonance imaging; IOR, inhibition of return; ISI, interstimulus interval; MANOVA, multivariate analysis of variance; RT, response time.

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N170 adaptation properties (Martens et al., 2006; Banko and Vidnyanszky, 2010; Kuehl et al., 2013). Kuehl et al. (2013) investigated the effect of ISI on N170 adaptation by five levels of ISI (400, 800, 1200, 1600, or 2000 ms). They found that the N170 adaptation in a paired stimulus protocol critically depends on short ISIs. Specifically, strong adaptation effects were only found for an ISI of 400 ms, but not for ISIs of 800 ms or longer. Using magnetoencephalography (MEG), Harris and Nakayama (2007) also found face-related adaptation effects for short ISIs (100, 200, or 300 ms), but not for an ISI of 500 ms. Moreover, it is also unclear whether this early N170 sensitivity to repeated items is robust enough to generalize to non-face objects of expertise (i.e. words). There are many kinds of evidence suggesting that there may be some common characteristics between faces and words in early perception. For example, Dehaene et al. (2010) found that reading ability was associated with an increase in left fusiform activation for words, and reduced response to faces at this location. A developmental ERP study found that the N170 for face processing was delayed by the reading experience of Chinese characters (Li et al., 2013), and a left occipital arteriovenous malformation resulted in both pure alexia and prosopagnosia (Liu et al., 2011). Cao et al. (2014) found an asymmetric N170 adaptation effect between faces and words in a short ISI (200 ms), which suggests commonalities between the perceptual adaptation mechanisms involved in processing faces and Chinese characters. Given this information, the present study investigated the ERP adaptation effects for repeated faces and Chinese characters using a short ISI adaptation paradigm. On the basis of neural adaptation mechanism and N170 adaptation effect for faces and printed Chinese characters, we predicted that the N170 response elicited by repeated items would produce a reduced activation relative to non-repeated items.

EXPERIMENT 1

Method

Participants. Twenty subjects (nine males) were recruited from local universities and paid for their participation (age 24.5 ± 2 years). All subjects were right handed with normal or corrected-to-normal vision. Written consent was obtained from all of them, and the ethics committee of Zhejiang Normal University approved the study.

Stimuli. Grayscale pictures of faces and houses were used for this experiment. Faces were images of 72 individuals (36 male and 36 female), which were selected from a standard set of faces from our laboratory, displaying a neutral facial expression. They were cropped to remove external features (hair, ears, and jaw line) and replaced with the same oval contour using Adobe Photoshop CS5. In addition, 72 grayscale images of cartoon houses were used. The face stimuli were 180×276 pixels, subtending an angle of $4.0° \times 6.2°$ from a viewing distance of 90 cm. The house stimuli were 198×198 pixels, subtending an angle of $4.5° \times 4.5°$ from a viewing distance of 90 cm.

Procedure. The participants sat with a distance of 90 cm away from the 17″ CRT monitor (1024×768 pixel resolution) on which all stimuli were presented against a dark gray background. E-Prime 2.0 software was used for stimuli presentation and behavioral response collection (Psychology Software Tools, Pittsburgh, PA, USA).

Participants were tested in a dimly lit room. On each trial, an adaptor stimulus and a test stimulus were presented sequentially for 200 ms each with an ISI of 200 ms and followed by a 1500-ms intertrial interval, consistent with Eimer et al. (2010). The faces (F) were used as the test stimuli. Each test stimulus was preceded by one of three possible adaptors: the same face as the test face (FF_s), a different face (FF_d), or a house (HF). In each of three experimental blocks, the three conditions were presented with equal frequency and in random order. There were 72 trials in each block, 64 of which were non-target trials. No response was required on these non-target trials. The remaining eight trials per block were target trials with a red outline shape aligned with the outer contours of the stimulus shape. The aim of using the target trials was to focus participants' attention on the task. Target stimuli, namely the red outline shape, were presented with equal probability as adaptor stimuli or test stimuli in the target trails. These target trials were randomly intermixed with the non-target trials. Participants were instructed to press a response button following the second picture presentation when they detected a target stimulus. Response buttons were counterbalanced across subjects.

EEG recording and data analysis. EEG was recorded using a 128-channel HydroCel Geodesic Sensor Net, with an electrode placed on the Vertex (Cz) serving as reference for the online recording. Electrode impedances were kept below 50 kΩ. Signals were digitized at a 500-Hz sampling rate and amplified with a 0.1–200-Hz elliptical bandpass filter. EEG data were offline digitally filtered with a 0.3–30-Hz band-pass filter and epoched from 200 ms before to 800 ms after stimulus onset with a 100-ms pre-stimulus baseline. Trials with artifacts exceeding ±100 μV were rejected. Trials were also removed from ERP averaging if they contained eye movements (greater than ±70 μV). After incorrect trials and trials containing movement artifacts were eliminated, the mean number of acceptable trials retained for ERP averaging per condition per subject was 51 (range: 38–59). The remaining EEG data were re-referenced to the average of channels.

EEG data were analyzed for non-target trials only. A group of channels over the left occipitotemporal regions (channels 58, 64, 65) and right occipitotemporal regions (channels 90, 95, 96) were analyzed where the N170 components were maximal (Cao et al., 2014). In order to reduce the number of levels in the statistical analyses, these peak amplitudes and latencies were then averaged across the three channels chosen for each hemisphere. EEG waveforms were averaged separately for each presentation condition. Based on visual inspection of the individual data, the N170 time-window was defined as 130–210 ms for adaptor stimuli and 140–220 ms for test