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Research Report

The visual representations of words and style in text: An adaptation study

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ABSTRACT

While the nature of face representations in the human perceptual system has been extensively studied using adaptation, there has been little investigation using this technique of the neural basis of another parallel class of high-level objects, words. We used the perceptual-bias technique to determine if aftereffects could be generated for either the word content or stylistic properties of textual stimuli, and if these aftereffects showed invariance for the non-adapted dimension. In a first experiment, we examined adaptation for word versus handwriting style. In a second experiment we contrasted adaptation for words with adaptation for computer font. The third experiment performed a similar study of aftereffects for words and case. In all three experiments we consistently found adaptation for words, which were not diminished by changing the style between the adapting and probe stimuli: hence word aftereffects are invariant for handwriting, font and case. Aftereffects were negligible for style. Additional analyses showed that discriminative ability was better for word than for style content. These results confirm that the neural representations of words can be probed with the adaptation technique and suggest that adaptation accesses word representations at an abstract level, where the identity of a word is invariant for stylistic properties.

1. Introduction

Words and faces are complex multi-dimensional stimuli. While both are necessarily composed of low-level properties like luminance, contrast, curvature and orientation, these elements are integrated into intricate higher-order structures that carry important perceptual and social information. How these structures are represented in the human perceptual system is an interesting question: investigating this issue can help us understand how the neural system encodes complex form and object information.

The nature of face representations has been explored extensively through the use of adaptation. Although after-effects for low-level properties such as luminance, colour and motion have long been known, adaptation for faces has only recently been demonstrated. Controlled studies show that face aftereffects are not merely the effect of adaptation for its low-level stimulus properties, but also reflect effects at the

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level of the face representation itself (Butler et al., 2008; Leopold et al., 2001; Zhao and Chubb, 2001). Subsequently, numerous studies have used this technique to probe how the human visual system encodes faces: for review, see Webster and MacLeod (2011). We have shown, for example, that face identity aftereffects are entirely independent of facial expression while adaptation to facial expression or facial age is only partially invariant for facial identity (Fox and Barton, 2007; Fox et al., 2008; Lai et al., 2012), that the organization of 'face-space' shows centre–surround inhibition (Rostamirad et al., 2009), that face representations have a mandatory first-order relation structure – i.e. eyes above nose above mouth – but incorporate both feature properties and second-order structure – i.e. the precise distance between the eyes and nose (Pichler et al., 2012), and that for at least some faces, age representations are derived 77% from skin texture and 23% from facial shape, while identity representations are derived 32% from skin texture and 68% from facial shape (Lai et al., 2013). This partial list illustrates the power of the adaptation technique to reveal the encoded content of our perceptual experience of complex objects.

Despite a growing body of reports on face adaptation, there has been far less work investigating the nature of word representations in the human visual system. Words form an interesting parallel stimulus class to faces, with commonalities and differences. Both words and faces are examples of highly expert visual processing, requiring fine discriminations among a large class of exemplars that closely resemble each other. On the other hand, while face processing may be a universal experience among humans, the specific written language learned by a given individual is an accident of birth and culture, and indeed sometimes not learned at all among illiterate members of society. Neurally, studies with functional magnetic resonance imaging show that both words and faces activate a network of regions in the fusiform gyri, postero-lateral temporal gyri, and inferior frontal gyri, among others (Cohen et al., 2000; Haxby et al., 2000; McCandliss et al., 2003). On the other hand, they are distinguished by the different hemispheric asymmetries, with the network showing stronger activation in the left hemisphere for words (Cohen et al., 2002) and in the right hemisphere for faces (Kanwisher et al., 1997).

These similarities and contrasts between words and faces raise interesting questions about the nature of the visual representations for both, what they share and how they differ. Differences in these representations would also be illuminating for long-standing debates about purported distinctions in perceptual mechanisms of the two hemispheres (Ivry and Robertson, 1998). For these reasons it is desirable to develop probes that can study both words and faces in an equivalent manner.

The main aim of this report is to determine if a perceptual bias method commonly used by us and others to examine face aftereffects can be imported to study word representations with the adaptation technique. A second aim is to determine whether the word aftereffects found originate at a high level of representation, by studying the degree to which adaptation is invariant for the stylistic properties

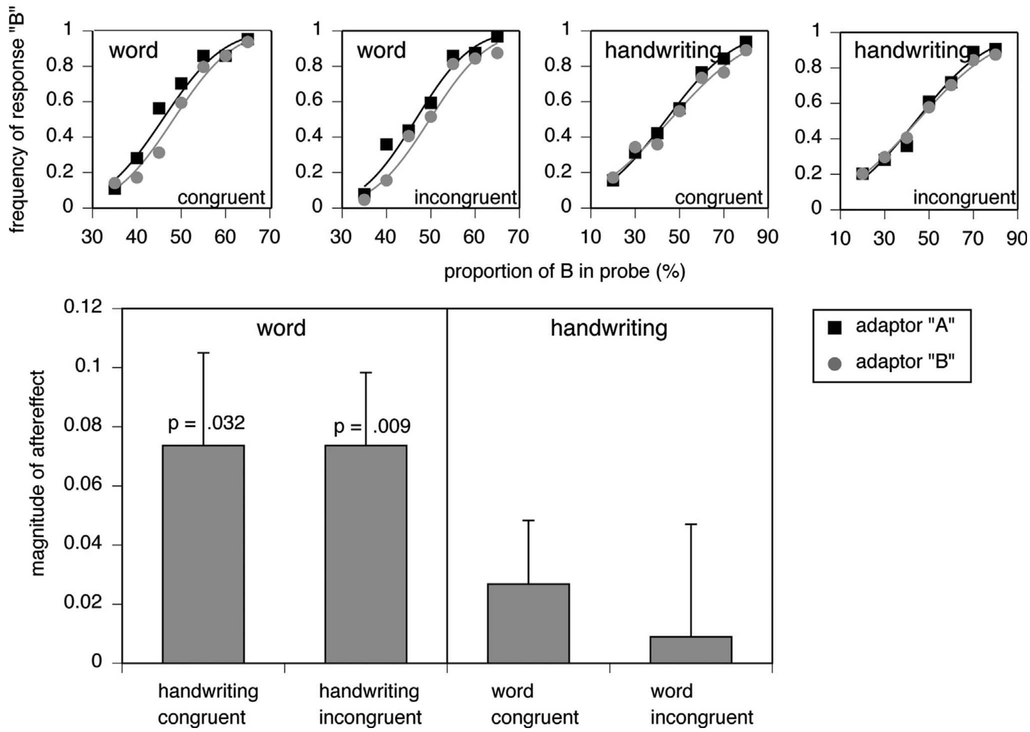

Fig. 1 – Results, Experiment 1. Top graphs are the psychophysical curves for group data in the four different conditions: word adaptation with congruent and incongruent handwriting, and handwriting adaptation with congruent and incongruent words, showing the curves for adapting to the two different stimuli, arbitrarily labelled A and B. Bottom bar graph shows aftereffect magnitude for those four different conditions, with error bars indicating one standard error. Word aftereffects are significant, while those for handwriting are not.