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Accessing the meaning of invisible words

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ABSTRACT

Previous research has shown implicit semantic processing of faces or pictures, but whether symbolic carriers such as words can be processed this way remains controversial. Here we examine this issue by adopting the continuous flash suppression paradigm to ensure that the processing undergone is indeed unconscious without the involvement of partial awareness. Negative or neutral words projected into one eye were made invisible due to strong suppression induced by dynamic-noise patterns shown in the other eye through binocular rivalry. Inverted and scrambled words were used as controls to provide baselines at orthographic and feature levels, respectively. Compared to neutral words, emotion-described and emotion-induced negative words required longer time to release from suppression, but only for upright words. These results suggest that words can be processed unconsciously up to semantic level since under interocular suppression completely invisible words can lead to different processing speed due to the emotion information they carry.

1. Introduction

Words play an important communicative role in modern societies, allowing abstract concepts and elaborate ideas, in addition to statements about facts and events, to be conveyed in visual form. Through years of experience, skilled readers' word recognition process becomes automatic, as revealed by the Stroop effect (Stroop, 1935): Naming the color in which color words are printed is difficult (slow and error prone) when the color of the ink and the color word itself are not the same (i.e., saying "red" when shown the word "blue" written in red ink). Other researchers have shown that emotion words presented for a very brief period can be processed up to a semantic level (Huang, Baddeley, & Young, 2008; Zeelenberg, Wagenmakers, & Rotteveel, 2006). Nevertheless, the question of whether words' meanings can be accessed implicitly *without any awareness* remains unsettled, and this is the main issue tackled in this study.

From the scandal created by James Vicary's subliminal slogan for Coca Cola (see in Karremans, Stroebe and Claus (2006)) to the rigorous test using the masked priming paradigm for unconscious semantic processing (e.g., Marcel, 1983), the major controversy is about whether the evidence for implicit semantic processing of words is genuine (Abrams & Grinspan, 2007b; Gaillard et al., 2006; Naccache & Dehaene, 2001). Some researchers have questioned that the apparent semantic priming effect might have been obtained through sub-word processing (Abrams, 2005; Abrams & Greenwald, 2000; Kouider & Dehaene, 2007) or partial awareness (Kouider & Dupoux, 2004). In order to solve methodological shortcomings, we used the continuous flash suppression (CFS) paradigm (Fang & He, 2005; Tsuchiya & Koch, 2005) in the current study.

In this paradigm, a critical stimulus is presented to one eye, and constantly changing high-contrast Mondrians (masks) are presented to the other eye. Due to the interocular suppression from the continuous flash masks, the critical stimulus cannot be consciously perceived for quite some time. Compared to other paradigms in studies on implicit processing, this method has several advantages. First, the exposure duration can be extended long enough for full (implicit) processing, and during

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this relatively long duration, the physical properties of the critical stimulus can remain constant while participants' awareness state of the critical stimulus changes (Kim & Blake, 2005). Furthermore, this paradigm offers a clear criterion (e.g., simple detection of any part of the critical stimulus or no response as to the critical stimulus is required), rather than ambiguous or partial rivalry, for the observer. Finally, the critical stimuli always compete with the same Mondrians so as to provide the same baseline for different critical stimuli (Jiang, Costello, & He, 2007).

Several studies using this CFS paradigm have demonstrated that in addition to low-level properties (e.g., Hong & Blake, 2009; Maehara, Huang, & Hess, 2009; Tsuchiya & Koch, 2005) high-level information can also be processed in the interocular suppression phase. This includes facial identity and facial expression (Jiang & He, 2006; Yang, Zald, & Blake, 2007), genders of body images (Jiang, Costello, Fang, Huang, & He, 2006), and tools (Fang & He, 2005). Can the list be extended to include symbolic carriers such as the semantics of words? Using the CFS paradigm to measure the reaction time (RT) for the participants to perceive the critical stimulus (the time to release it from suppression), Jiang et al. (2007) found shorter RTs when the critical stimulus was a recognizable word than when it was an unrecognizable word. These findings imply that familiar stimuli could be processed differently from unfamiliar ones even when the critical stimuli were invisible to the observer. However, it is still unclear whether this difference between familiar and unfamiliar stimuli is due to its form (i.e., a word template) or meaning.

To our knowledge, there has not been any report so far showing genuine and pure semantic processing of invisible words using the CFS paradigm except for a recent study that found semantic priming with a visible prime (e.g., Costello, Jiang, Baartman, McGlennen, & He, 2009, see Section 4), and yet no consensus has been reached in previous studies using other paradigms that have been questioned for their claims about truly implicit semantic processing (Abrams, 2005; Abrams & Greenwald, 2000; Abrams & Grinspan, 2007a; Kouider & Dupoux, 2004, 2007). The main goal of this study was to examine whether word semantics can be processed and accessed implicitly by using emotional words with a negative valence as the critical stimulus in the CFS paradigm and to see whether RTs would be different for negative words than for neutral words in the suppressed phase. If there is a reliable difference between the processing times of the two kinds of invisible words, one can infer that the semantics of words is extracted, even when they are invisible.

2. Experiment 1

We chose Chinese words with a negative valence as the critical stimulus in the CFS paradigm to test whether negative words (e.g., "angry") are processed differently than neutral words in the suppressed phase of binocular rivalry. To prevent any emotional connotation in the neutral-word category, we put functional words (e.g., "however") in this category. In order to provide baselines at the levels of orthography and low-level local features in space domain between negative and neutral words, we also used inverted and scrambled words for comparison at the two levels, respectively.

Following the two most relevant studies using CFS (Costello et al., 2009; Jiang et al., 2007), we also performed a manipulation check to ensure that the result obtained was not caused by response bias – different criteria used for different kinds of critical stimuli *after* but not *during* the interocular suppression phase. In this control experiment, the critical stimulus was superimposed on the Mondrians, and both were projected into two eyes, thus changing the viewing from dichoptic to binocular. This percept mimics the percept in the dichoptic viewing condition but the critical stimulus is not suppressed. If the differential results between negative and neutral words are due to response bias such as different criteria set for the two kinds of words after the release from suppression (i.e., becoming consciously perceived), similar results in the binocular viewing condition and in the dichoptic viewing condition should be obtained.

2.1. Method

2.1.1. Participants

Twelve National Taiwan University undergraduate students participated in this experiment for course credit. They were all skilled readers of Chinese, naïve about the purpose of this experiment, and had normal or corrected-to-normal vision.

2.1.2. Stimulus, materials, and apparatus

Stimuli were displayed on a 22-inch ViewSonic P225f CRT monitor (1024 × 768 resolution at 60 Hz frame rate) and presented via E-Prime software (Psychological Software Tools, Pittsburgh, PA) and controlled by an IBM compatible personal computer. The participant sat in a dark chamber, with his or her head positioned on a chin-rest at a viewing distance of 60 cm.

In the dichoptic viewing condition, two different images were projected onto each eye through a four-mirror stereoscope, which consisted of two mirrors fixed in the center and angled +/− 45° orthogonally, and two adjustable mirrors mounted on the two sides. The two images included a gray Chinese word presented on a white background and a Mondrian pattern changing at a rate of 10 Hz. The two images were each surrounded by an outer square frame (10.70° × 10.70° visual angle, with a thickness of 0.2°) to assist the binocular fusion of the two outer frames. The Mondrians (extended 5.50° × 5.50°, generated by Matlab 7.0) contained small rectangles (randomly chosen with different sizes, having a width and length from 0.02° to 1.07°, and with different colors, having RGB values from 0 to 255). To prevent the possibility that the abrupt onset of a word would cause suppression of the other side and thus make the word suddenly visible (Yang et al., 2007), the contrast