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Research Report

Visual mismatch negativity is sensitive to illusory brightness changes

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ABSTRACT

The aim of the study was to investigate the sensitivity of the visual mismatch negativity (vMMN) component of event-related potentials (ERPs) to the perceptual experience of brightness changes. The percept could be based on either real contrast or illusory brightness changes. In the illusory condition, we used Craik-Cornsweet-O'Brien (CCOB) stimuli. CCOB stimuli comprised of grey, equiluminant areas and Cornsweet-edges that separated the areas. These specific edges, containing opposing darkening and ligthening gradients, modify the perceived brigthness of the flanking areas. Areas next to the darkening part (of the edges) perceived darker while areas next to the lightening part perceived lighter. Reversing the gradients induces illusory brigthness changes. The normal and reversed stimuli were delivered according to a passive oddball paradigm. In another condition (REAL condition), we used stimuli with real contrast difference. The perceived brightness of the stimuli applied in this sequence was fitted to the normal and reversed CCOB stimuli. In a third condition (CONTROL condition), we tested the ERP effect of the reversing of Cornsweet-edge. In this condition, the changes did not induce illusory brightness changes. We obtained vMMN with double peaks to both real and illusory brigthness changes, furthermore, no vMMN emerged in the CONTROL condition. vMMNs fell in the same latency range in the two conditions, nevertheless the components slightly differed in terms of scalp distribution. Since the perceptual experience (i.e. brightness changes) was similar in the two conditions, we argue that the vMMN is primarily sensitive to the perceptual experience and the physical attributes of the stimulation has only a moderate effect in the elicitation of the vMMN.

1. Introduction

The aim of the present study was to investigate, whether an electrophysiological index of automatic brain activity to visual events violating temporal-sequential regularities was sensitive to illusory perceptual changes, even if such changes were outside the focus of attention. The illusory change of luminance in this study was elicited by the Craik-Cornsweet-O'Brien

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(CCOB) brightness illusion (Cornsweet, 1970; Craik, 1966; O'Brien, 1958). The electrophysiological index we measured was the visual mismatch negativity (vMMN; for reviews see Czigler, 2007; Kimura, 2012). VMMN is a counterpart of the auditory mismatch negativity (for a review see Näätänen et al., 2007) and usually investigated in passive two-stimulus oddball paradigms. In this paradigm, within the sequence of frequently presented (standard) stimuli, infrequent (deviant) ones are presented in unpredictable sequential positions. The function of the standards is to acquire a model of the sequential regularity of stimulation, while deviants represent unpredictable changes. Deviant *minus* standard ERP-difference is considered as a prediction-error signal specific to sequential attributes of the environment (Kimura, 2012). VMMN is a negative on-going ERP component (but see Sulykos and Czigler, 2011) over posterior areas and emerges in the 120–350 latency range after the stimulus onset. It is important to emphasize that the vMMN is considered as an automatic component at least in terms of that attention is not necessary to obtain vMMN (Berti, 2011; Kimura and Takeda, 2013; for a review see Czigler, 2007).

In the majority of studies vMMN was investigated by deviations in elementary stimulus dimensions such as color (Czigler et al., 2002), orientation (Astikainen et al., 2008; Kimura et al., 2009, 2010), motion direction (Pazo-Alvarez et al., 2004), spatial frequency (Heslenfeld, 2003) and contrast (Stagg et al., 2004). Nevertheless, the mechanism underlying vMMN is well beyond the simple, feature-specific change detection processes. First, visual (as well as auditory) MMN is elicited by infrequent conjunction of two features (Winkler et al., 2005). VMMN to feature conjunction shows that the memory system underlying vMMN is capable of registering bound features. Similar conclusion was drawn by a study of Sulykos and Czigler (2011). In this study, concurrent deviancies in two features elicited a sub-additive response compared to the sum of the vMMNs to single feature deviancies. Second, vMMN is impacted by object formation as reported by Müller et al. (2009, 2013). In the Müller et al. (2009) study, the standard patterns comprised of 8 equicolored (green or red) filled circles coupled by black thin lines. The bound circles were regarded as separated objects. In case of deviant patterns two of the circles were colored the alternative color. The two deviant circles belonged either to the same or to different objects. In the latter case, they registered a single vMMN to color deviancy. However, when the deviancies occurred within the same object, it elicited an additional vMMN at a later latency range. In the Müller et al. (2013) study, the stimulus pattern comprised of two white ellipses and two grey circles. The ellipses represented the objects. The grey circles were either in the same or in different ellipses. The assignment of the circles (whether the two circles belonged to the same or different objects) defined the difference between the standard and the deviant. They obtained vMMN to deviant assignment of the circles; therefore, repeatedly supported that vMMN is sensitive to object formation. Finally, vMMN is elicited by deviant categories of facial expressions (e.g. Stefanics et al., 2012), laterality of hands (Stefanics and Czigler, 2012), symmetry (Kecskés-Kovács et al., 2013a) and gender (Kecskés-Kovács et al., 2013b). In these studies, the deviant and standard stimuli did not differ in terms of a certain stimulus dimension. Instead, the deviant-standard difference manifested only at the level of category representation. The effect of categorization is not restricted to the process of complex stimulus pattern such as face or bilateral symmetry (for a detailed review about the categorization-effect, see Czigler, 2013). A few recent studies (Thierry et al., 2009; Clifford et al., 2010) pointed out that the vMMN to color-deviation (as an elementary feature change) is modulated by the category of the color. Clifford and her colleagues (2010) demonstrated that the same distance in color-space elicited larger vMMN if the standard and deviant colors belonged to different color-category (e.g. dark blue vs. light blue or green vs. light blue). Thierry et al. (2009) investigated the cross-cultural language effect on deviant-related processing of color. The Greek language differentiates between light (ghalazio) and dark (ble) blue while English language does not. Contrary to the blue, both languages use one word for the green color. The authors used light and dark shades of the colors (green and blue in separate conditions) as standards and deviants. In case of Greek speakers, they registered larger vMMN to blue condition than to green condition. That is, the vMMN was larger if the deviation occurred across color-categories (ghalazio and ble) than within the category (green). In case of English speakers, they obtained similar vMMNs in the two conditions. The authors argued that the cross-cultural effect was due to the differences in category representations, since the differences in language-labels reflect the differences in the mental structures of categories. Furthermore, category-representations affect the perceptual experience of the incoming stimulation even at the level of elementary feature changes (linguistic relativism; Whorf, 1956). As the above mentioned studies pointed out, these category-effects resulted in differences not just in the perceptual experience but in the process of automatic deviance-detection also (the results of cross-cultural effect were replicated by Athanasopoulos et al., 2010).

Based on the previous findings, we suppose that, the formation of conscious perceptual experience and the automatic deviance detection (vMMN) is affected by similar factors. As a consequence, we also suppose that cognitive processes underlying the vMMN and the cognitive processes underlying the perceptual experience are similar. Since similar cognitive processes probably result in similar representation forms, we presume that the representations underlying both responses (the vMMN and the perceptual experience) are also similar. In other words, the vMMN is primarily sensitive to the representation form correspond to the perceptual experience. This supposition does not contradict to the vMMN-literature since the perceptual experience is also sensitive to elementary features, binding of features, object formation and category-representation just as the vMMN. The aim of the present study was to investigate the presumption; i.e. to explore the relationship between the perceptual experience and the vMMN. To this end, we chose the field of visual illusions for generating the experimental stimuli. We had two main reasons for doing so. First, by using illusions, we are able to induce significant changes in the perceptual experience with negligible changes in the physical properties of the stimulus. Therefore, we can measure the automatic deviance-detection processes to changes in the perceptual experience with minimal (contaminating)