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Automatic Conflict Monitoring by Event-Related Potentials Could be used to Estimate Visual Acuity Levels

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Abstract—Numerous studies have explored the physical attribute features or face perceptions in conflict processing, while complicate gradient conflicts were rarely discussed. The aim of the study was to discuss the relationship between the event-related potential (ERP) component features and different visual acuity levels by using the modified S1–S2 task under non-attention status. Three visual acuity levels were applied, each with four orientations of "E" optotype stimuli randomly presented in the center of the visual field while participants were required to concentrate on listening to stories. The results showed that the amplitudes of P1 and P3 as well as difference P3 were larger in supra-threshold condition. In threshold condition, larger amplitudes for both N2 and difference N2 exhibited in frontal and central areas. In sub-threshold condition, there was no endogenous component elicited by mismatch stimuli except smaller anterior N1. Meanwhile, the specific distributions of N1 and N2 were presented and compared with previous face processing. The findings showed that visual conflict processing took place not only at an early stage but also at the late period, which might be as the consequences of interaction between conflict strength and involuntary attention. We concluded that automatic conflict detecting of visual icons by the serial ERP components could distinguish different visual acuity levels. The involvement of endogenous components could reveal the specific mechanism of more precise and fine conflict identification of complex physical attributes under non-attention status, furthermore could be used as valid markers to estimate the magnitude of visual acuity objectively.

Key words: event-related potentials, visual acuity, conflict processing, automatic processing.

INTRODUCTION

According to the view of stimulus conflict, visual conflict appeared because the presentation of stimulus dimensions in parallel processing were incongruent with each other (Stroop, 1935) or the conflicted visual perception existed after the onset of a stimulus with the attributes different from the preceded one (Wang et al., 2000). The capacity of individuals to detect visual conflict, to store relevant information and to plan or execute corresponding tasks are all based on top-down modulations during visual conflict processing, and cognitive control plays an important role in the entire procedure (Gazzaniga et al., 2009). Cognitive control including higher level cognitive processes are used to evaluate environmental conflict, the cognitive system would improve the efficiency of control in subsequent performance when a conflict was detected. According to conflict monitoring theory (Botvinick et al., 1999, 2001, 2004), conflict detection and resolution were main aspects of conflict control.

Given the importance of cognitive control in regulating behavior, a large number of researches have used different paradigms to discuss conflict control. For example, in a traditional Stroop task (Stroop, 1935), participants were asked to speak out the color of the word in the presentation of the color-word sequence, when the color and word were congruent or the color and word were incongruent. In another classical Flanker task (Eriksen and Eriksen, 1974), participants were instructed to respond to the direction of the central target stimulus, while flanking stimuli were in both sides with either congruent or incongruent direction from the target.

Both of the typical models found the characteristics of the conflict processing in the term of the electrophysiology by the event-related potential (ERP), which presented the early and late components indicating the perceptual processing, selective attention and conflict cognition. And the Stroop N450 and flanker N2 were usually defined as the second negative component, which represented distinct monitoring processes that reflected

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Abbreviations: ACC, anterior cingulate cortex; ANOVA, analysis of variance; CVC, Chinese standard logarithmic visual acuity chart; dACC, dorsal anterior cingulate cortex; EEGs, electroencephalograms; EOGs, electro-oculograms; ERPs, event-related potentials; fMRI, functional magnetic resonance imaging; LPC, late positive complex; vMMN, visual mismatch negativity.

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conflict detection (Larson et al., 2014). According to prior studies, by using S1–S2 matching task in detecting conflict processing which revealed that a second negative ERP component with peak latency about 270 ms was elicited on human scalp. The variant matching tasks for conflict processing were undertaken such as shape (Cui et al., 2000; Zhang et al., 2003, 2008), face (Zhang et al., 2001), color (Wang et al., 2004; Kimura et al., 2005), crossmodal gender mismatch (Wang et al., 2002), spatial position(Yang and Wang, 2002) and arithmetic conflict (Wang et al., 2000). To sum up, N270 was related to detect conflict information rather than novel information (Zhang et al., 2003) and might reflect automatic detection of visual changes in specific brain regions, regardless of relevant and irrelevant conflicts (Wang et al., 2001). The mismatch N2 had a fairly broad distribution in conflict tasks while the regions were biased in different experimental paradigms, but it was mostly evoked in the fronto-central region of the scalp (Folstein and Van Petten, 2008). In instance, in a crossmodal gender task, a widely distributed N2 could be observed with the maximal amplitude at the fronto-central (Wang et al., 2002). Meanwhile, the study on the allocation of the cerebral regions of conflict processing revealed that the N2 component was evoked by the dorsal anterior cingulate cortex (dACC), and the functional magnetic resonance imaging (fMRI) study showed that conflict information increased activation in the anterior cingulate cortex (ACC) together with the right dorsolateral prefrontal cortex (Zhang et al., 2008). The regional findings indicated that the conflict perception might be originated from some certain areas of the brain, though the difficulty of the different detecting tasks would be varied and complex.

Among the large approaches, face conflict processing has drawn wide attention. As we know, a human face is a complex multidimensional visual pattern and conveys a wide variety of information about an individual (identity, sex, age, mood, etc.), which make it particularly well suited for studying visual perception. In prior face conflict processing studies, the higher acuities could be modulated by attentional linkage, even though the different tasks were adopted with attention or non-attention condition for conflicting studies. For instance, in a deviant-standard reversal oddball paradigm under non-attention status, the participants were asked to ignore the peripheral face stimuli and press the corresponding button as quickly and accurately as possible when the cross became bigger or smaller displaying in the center of the screen throughout the stimulus. The results showed that a larger visual mismatch negativity (vMMN) was elicited by deviant orientation (90°) at temporal and frontal lobes during the time range from 100 ms to 300 ms under non-attention status, which supported that the disruption of facial configuration processing caused by inverted faces was relatively independent of attentional resources (Wang et al., 2014a,b). Some approaches considering attention allocation in the study of the different conflict processing of shape and face by using visual S1–S2 matching task. In the experiment the subjects were required to discriminate whether S2 was same as S1 or not and then press the left or the right button. The results showed that both the shape and face mismatch pairs could produce N270 at all sites, while face mismatch evoked N270 with a longer peak latency and another component N450 at the left occipitotemporal and parietal areas (Zhang et al., 2001). The delayed N270 reflected that it took more time to distinguish the complex face features and only demonstrated the automatic detection of conflict. The subsequent N450 was not the Stroop N450 component what we mentioned above, which was possibly linked with the "classical N400" because of the same latency range, suggesting that the additional neural activity was involved in the comparisons of the semantically incongruous information of face features. As Kanwisher and his colleagues reported that face processing might be different from the other conflict perception under non-attention condition, which involved in a special brain area of fusiform face area which was located in occipitotemporal sulcus cortex (Kanwisher et al., 1997). In the functional magnetic resonance imaging (fMRI) study, subjects were instructed to maintain fixation on the dot when it was present, looking at the stimuli attentively without carrying out any other mental activities simultaneously. An area in the fusiform gyrus was found to be more active when the subjects viewed faces than a variety of common objects (houses, human hands, etc.).

In sum, there existed a special system for conflict processing of faces with various personal information in the human brain by analyzing N2 component and its processing source on task-relevant or task-irrelevant conditions. From our point of view, the physical attributes such as the shape "E" with different orientations and visual angles could be the relatively controllable variables compared with face conflict states. What was more, substantial evidence revealed that MMN was a reliable indicator for the ability of human being to evaluate the automatic change detection that not only elicited by deviant stimulus in auditory (Naatanen et al., 2007, 2011) but also by changes of visual features (Czigler et al., 2006; Berti, 2011). Therefore, we would investigate and compare the mechanism of the shape "E" and the prior face conflict processing, by analyzing the N2 relevant components and regional distributions with modified S1–S2 task under non-attention visual status.

As we know, the Chinese standard logarithmic visual acuity chart (CVC) consists of various sizes of shapes with two-dimensional line "E". The common used visual acuity charts in most visual researches that the subjects were often required to report in the testing by themselves, therefore the reliability was prone to be affected by their statements due to some subjective factors. The researchers had been trying to explore the objective electrophysiology methods for estimating visual acuity, Heinrich and colleagues used a visual oddball paradigm under attention status with visible gratings and with Landolt Cs, respectively. They found the P300 was sensitive to identify the resolution threshold and thus could be useful with visual impairments (Heinrich et al., 2010, 2015). Our previous study exhibited the relationship between the ERP