International Journal of Psychophysiology 93 (2014) 311–315

Contents lists available at ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

Short communication

The visual mismatch negativity (vMMN): Toward the optimal paradigm

Xiaosen Qian [a], Yi Liu [a,*], Bing Xiao [a], Li Gao [a], Songlin Li [a], Lijie Dang [b], Cuiping Si [c], Lun Zhao [b,**]

[a] Sleep Disorders Center, Civil Aviation General Hospital, Beijing, China
[b] School of Psychological Research, Beijing Yiran Sunny Technology Co. Ltd., Beijing, China
[c] Department of Neurology, Jining No. 1 People's Hospital, Jining, China

ARTICLE INFO

Article history:
Received 5 February 2014
Received in revised form 4 June 2014
Accepted 6 June 2014
Available online 14 June 2014

Keywords:
Visual mismatch negativity
Visual discrimination
Change detection
Optimal paradigm

ABSTRACT

In the present article, we tested an optimal vMMN paradigm allowing one to obtain vMMNs for several visual attributes in a short time. vMMN responses to changes in color, duration, orientation, shape, and size were compared between the traditional 'oddball' paradigm (a single type of visual change in each sequence) and the optimal paradigm in which all the 5 types of changes appeared within the same sequence. The vMMNs obtained in the optimal paradigm were equal or larger in amplitude to those in the traditional vMMN paradigm. The optimal paradigm can provide 5 different vMMNs in the same time in which usually only one MMN is obtained. This short objective measure could putatively be used as an index for visual cognition function especially in clinical research.

1. Introduction

As an important cognitive function for human survival, the automatic change detection occurs at a very early stage of information processing. To date, ample evidence indicated that the mismatch negativity (MMN) of event-related potential (ERP) components is a reliable indicator for exploring automatic change detection, reflecting the brain's detection of an unintentional disruption in the regularity of temporal events (e.g., Näätänen et al., 2007). Generally, MMN can be elicited by infrequent deviant stimuli inserted randomly in a sequence of frequent standard stimuli presented outside of the focus of attention. Although the MMN component has been widely investigated in auditory modality, analog of auditory MMN was also found in response to visual deviants such as color (Czigler et al., 2002), orientation (e.g., Kimura et al., 2009), size (Kimura et al., 2009), shape (Grimm et al., 2009), duration (Qiu et al., 2011) as well as facial expressions (e.g., Zhao and Li, 2006). Although visual MMN (vMMN) is elicited by task-irrelevant events, recent studies have shown that vMMN is influenced by attentional manipulations (e.g., Czigler, 2007; Czigler and Sulykos, 2010; for a review, Kimura, 2012). Therefore, instead of being an index of fully automatic processes, it was proposed that vMMN reflects the existence of unintentional temporal-context-based prediction (Kimura, 2012).

As an inexpensive and non-invasive method, it is not surprising that the vMMN has recently received considerable attention as a tool of clinical research. For instance, vMMN in response to the deviant duration was significantly reduced in depression patients (Qiu et al., 2011) as well as in Alzheimer's disease (Tales and Butler, 2006). It should be noted that different kinds of deviant features elicit distinctive vMMNs, (maybe) with different cortical origins. For instance, the orientation MMN was generated at the medial prefrontal areas as well as at the visual extrastriate area (Kimura et al., 2009), whereas the neural generator of vMMN elicited by directions of motion included the occipital visual extrastriate areas (including motion response areas) (Pazo-Alvarez et al., 2004). Previous vMMN clinical studies tested only a single deviant type and hence, it is not clear whether vMMNs elicited by other deviant types are affected by the disease. Therefore, it is necessary for developing a multi-feature vMMN paradigm with different deviant types integrated in one complex visual context. Indeed, the practical problem, especially in clinical application, is that traditional vMMN paradigms are usually time-consuming when several types of deviants are presented in different stimulus blocks.

Näätänen et al. (2004) developed a new multi-feature paradigm in which five types of acoustic changes (frequency, intensity, duration, perceived sound-source location, and gap) were presented in the same sound sequence. Indeed, in this paradigm different auditory attributes can elicit different MMNs, and most importantly, the memory trace of the standard stimuli can enhance with respect to the stimulus attributes they have in common. Although the multi-feature paradigm reduced the time of the experiment, the MMNs using the new paradigm did not differ from those using the traditional oddball-paradigm. To date, only few studies investigated vMMN using the multi-deviant paradigm. For example, Grimm et al. (2009) found that the vMMN depended on the changed feature, which might reflect either the differences in saliency between the feature changes or the natural hierarchy

* Correspondence to: Y. Liu, Sleep Disorders Center, Civil Aviation General Hospital, Beijing 100123, China.
** Correspondence to: L. Zhao, School of Psychological Research, Beijing Yiran Sunny Technology Co. Ltd, Beijing 100088, China.
E-mail addresses: ly20140102@163.com (Y. Liu), zhaolunlun@aliyun.com (L. Zhao).

http://dx.doi.org/10.1016/j.ijpsycho.2014.06.004
0167-8760/

in processing of various visual stimulus dimensions. Kreegipuu et al. (2013) compared vMMNs elicited by angry and happy schematic faces in a traditional oddball design (deviant stimuli, 12.5%) and in an optimal multi-feature paradigm with several deviant stimuli (altogether 37.5%) and found that the expressional MMN (EMMN) was equally elicited in both paradigms. They considered that in order to save time and other experimental resources the use of the optimum (multi-feature) design for EMMN should be encouraged (Kreegipuu et al., 2013). However, in their study, the presentation probability for a single deviant in the oddball paradigm was about twice as high as in the optimum paradigm, that is, the refractory state of same event-related potential components was different between two paradigms (Kreegipuu et al., 2013). On the basis of the auditory MMN optimal paradigm by Näätänen et al (2004), we recently proposed a time-saving and multi-feature visual MMN paradigm, in which 5 different vMMNs could be recorded with low-probability deviant stimuli (color, duration, orientation, shape, and size) inserted randomly in a sequence of frequent standard stimuli (Shi et al., 2013). However, in order to successfully address the reliability of multi-feature visual MMN paradigm, it is necessary to show that in fact the vMMNs recorded from the multi-feature deviant paradigm are identical or not smaller than to those recorded in the same subjects using traditional single-feature deviants. This possibility will be investigated in the present study.

2. Method

2.1. Participants

Fourteen undergraduate volunteers (8 females, all right-handed) with normal or corrected-to-normal visual acuity served as participants (the average age = 22.3 years, age range = 19–25 years). All participants received payments for their contribution. This research was approved by the Ethical Committee of Civil Aviation General Hospital in accordance with the Declaration of Helsinki and all participants gave their written informed consents before the experiment.

2.2. Stimuli and procedure

The subject sat on a comfortable chair in a darkened, sound attenuated and electrically shielded room. In the center of screen, a black cross was displayed throughout the stimulus blocks. From time to time, the cross became bigger or smaller unpredictably. Subjects were instructed to ignore the peripheral stimuli and press the left or the right button as quickly and accurately as possible when the size of the cross became bigger or smaller. The number of targets was 18–22 (mean 20) in each sequence.

In the peripheral sides of the field, two identical visual stimuli were simultaneously presented from a distance of 1 m, with the stimulus onset asynchrony (SOA) of 600 ms. The concurrently presented peripheral stimuli occurred on the left and right of the cross (4.5° distance from center of cross to center of the peripheral stimulus). The solid red rectangles (30 mm in length and 10 mm in width) served as standard with duration of 50 ms. As presented in Fig. 1, five types of deviant stimuli were included: two solid blue rectangles (color deviant), two shifted 90° solid red rectangles to the standard stimuli (orientation deviant), two red rectangles with 100 ms duration (duration deviant), two solid red ellipse (shape deviant) and two wide red rectangles (size deviant). There were 2 different conditions in the present study (Fig. 1): the traditional oddball paradigm (a single type of deviant in a sequence) and another condition (denoted as 'Optimum'), in which all 5 types of deviants occurred within the same sequence (Näätänen et al., 2004).

In line with the method proposed by Näätänen et al (2004), in the *Optimum condition*, all 5 deviants (p = 10% for each; total 50%) were presented in the same sequence so that every other visual stimulus was a standard stimulus (p = 50%). The rationale of this paradigm was that the other deviants can strengthen the memory trace of the standard with respect to those levels of stimulus attributes they had in

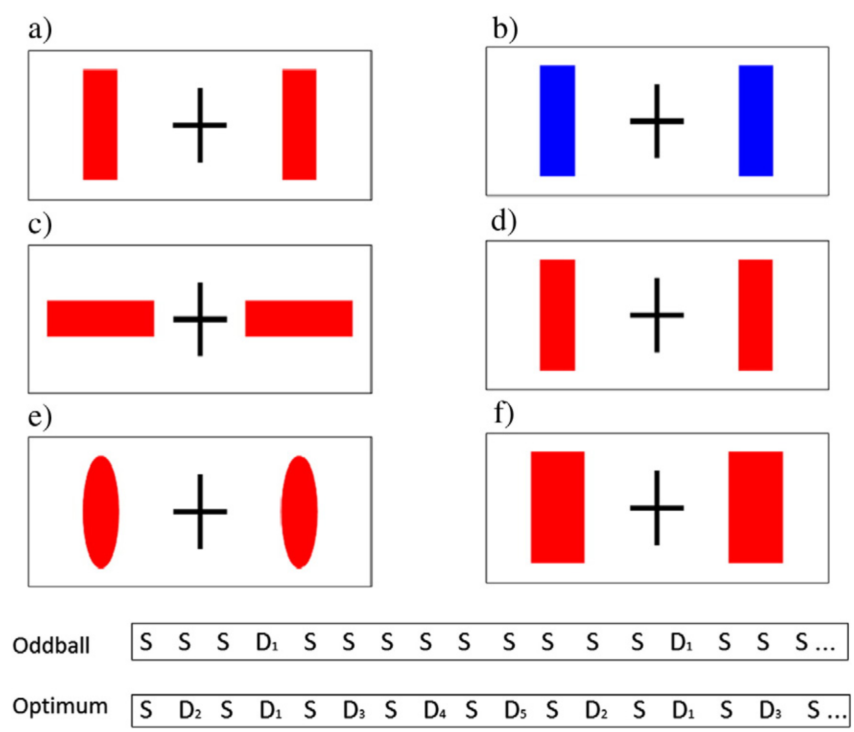

Fig. 1. Top: Examples for stimulus configurations: a) standard display, b) color deviant display, c) orientation deviant display, d) duration deviant (duration: 100 ms) display, e) shape deviant display, f) size deviant display. Down: Schematic illustration of the 2 stimulus conditions used: traditional Oddball and Optimum conditions. S denotes standard stimulus and D_X stimuli of different deviant types (D_1 — color deviant, D_2 — orientation deviant, D_3 — duration deviant, D_4 — shape deviant, D_5 — size deviant).