International Journal of Psychophysiology 72 (2009) 260–266

Contents lists available at ScienceDirect

International Journal of Psychophysiology

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

Distraction in a visual multi-deviant paradigm: Behavioral and event-related potential effects

Sabine Grimm [a,c], Alexandra Bendixen [a,d], Leon Y. Deouell [b,e], Erich Schröger [a,*]

[a] Institute of Psychology I, University of Leipzig, Germany
[b] Department of Psychology, The Hebrew University of Jerusalem, Israel
[c] Department of Psychiatry and Clinical Psychobiology, Faculty of Psychology, University of Barcelona, Spain
[d] Institute for Psychology, Hungarian Academy of Sciences, Budapest, Hungary
[e] Interdisciplinary Center for Neural Computation, The Hebrew University of Jerusalem, Israel

ARTICLE INFO

Article history:
Received 8 September 2008
Received in revised form 13 December 2008
Accepted 7 January 2009
Available online 21 January 2009

Keywords:
Attention
Distraction
Visual system
Event-related brain potentials (ERPs)
Visual MMN

ABSTRACT

The present study aimed at investigating visual distraction in a serial, multi-deviant oddball paradigm with deviant stimuli occurring regularly (every third trial), having a larger overall probability (1/3), and low dimension-specific probability (1/9). Participants performed a categorization task (odd/even) on centrally presented digits. Task-irrelevant geometrical forms were presented concurrently in the left and right periphery of the target. These forms were green triangles that, in every third trial, contained a deviancy either in location, color, or shape at the left or right peripheral position. Behavioral performance and event-related potentials (ERPs) were measured during the multi-deviant blocks and during corresponding control blocks to compensate for physical differences. Results revealed prolonged reaction times for the categorization task in trials containing a deviant feature relative to the respective control condition. Furthermore, two negative shifts were observed in the ERPs for deviant compared to control stimuli, the early one at the ascending part of the N1 component, and the later one at the onset latency of the N2 component. Deviant displays violating a sequential regularity on one of the dimensions thus elicit respective posterior ERP components of change detection and a deterioration in task performance even when they occur as frequently as in every third trial of a sequence. In analogy to findings in audition, these results reveal the importance of regularity processing and its immediate consequences for adaptive behavior also in vision.

1. Introduction

Detecting and evaluating unexpected changes in the sensory environment is a crucial prerequisite for adaptive behavior. The human auditory system, for instance, has the ability to automatically extract regularities unfolding over time in the acoustic input, and to detect violations from such regularities (e.g. Alho et al., 2003; Escera et al., 1998, 2000; Schröger and Wolff, 1998) even when they are not relevant for one's current goals, such as during the performance of a specific task. This ability is important because regularity violations signal a change in the environment that may require behavioral adaptation. The task-irrelevant violations may actually lead to a temporary impairment of performance, which is usually explained by an involuntary shift of attention towards the irregular, unexpected event (cf. Escera and Corral, 2007). Similar distraction effects have also been shown for infrequent and unexpected stimuli in the visual modality (Berti and Schröger, 2001, 2004, 2006). In the present study, we were interested in the processing of regularity violations with a newly developed multi-deviant distraction paradigm resulting in a low probability for a specific deviant but high overall deviant-probability. If under these conditions distraction effects were obtained, this new paradigm could be used as a time-saving alternative to previous approaches for studying the processing of visual regularity violations, especially when testing populations with a need for short and simple experiments. Moreover, if indeed performance were disrupted by distractors, despite the fact that distracting events occur relatively frequent and highly regular, it will suggest that regularities on different visual dimensions are evaluated in parallel and in at least partially independent manner.

Similar attempts have recently been made for the auditory distraction paradigm (Grimm et al., 2008; Jankowiak and Berti, 2007). In its original version introduced by Schröger and Wolff (1998), participants classify short and long sounds (occurring equiprobably) by their duration. Randomly and infrequently (with 10% probability), *deviant* sounds occur that differ in spectral frequency. Typically, the frequency deviants are classified with a prolonged reaction time. In the ERP, when compared to the *standard*

* Corresponding author. Kognitive einschl. Biologische Psychologie, Institut für Psychologie I, Universität Leipzig, Seeburgstr. 14-20, 04103 Leipzig, Germany. Tel.: +49 341 9735988; fax: +49 341 9735969.
E-mail address: schroger@uni-leipzig.de (E. Schröger).

0167-8760/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.ijpsycho.2009.01.005

sounds, deviants elicit a fronto-central negative component at around 150 to 250 ms (MMN, N2b) reflecting the detection of the deviation, and a positive component at around 280–400 ms (P3a) indicating an attentional shift (Schröger and Wolff, 1998). In contrast to the original approach, the multi-deviant version of the paradigm presents different deviants within a sequence, such as frequency, intensity, and location deviants during a duration categorization task. Jankowiak and Berti (2007) showed that reaction time prolongation and deviance-related ERP components are obtained even when the overall probability for the occurrence of a deviant is increased up to 33%. More specifically, every third tone in the sequence contained a feature change that randomly concerned one of the three deviant dimensions. Grimm et al. (2008) additionally showed that with this multi-deviant approach, behavioral and electrophysiological distraction effects are of the same amplitude as in the original single-deviant paradigm, despite the fact that deviants are three times as likely to occur, and their occurrence in the sequence is predictable.

The present study is the first one to test whether this multi-deviant approach can also be applied in the visual modality. Obtaining reliable distraction effects would argue in favor of a uniform theory of involuntary orientation of attention towards unexpected events across the two modalities of vision and audition. Comparison between the visual and auditory domain is often restricted owing to the usage of different paradigms. In the visual modality, distraction has predominantly been measured in response-competition paradigms (e.g., see Kim et al., 2005; Kraft et al., 2007; Lavie, 2005; Lavie et al., 2004) and attentional-capture paradigms (e.g. Eimer and Kiss, 2008; Folk and Remington, 1998; for a review, see Ruz and Lupiáñez, 2002). However, distractibility can also be investigated using distractor stimuli that violate a sequential regularity as usually done in auditory distraction paradigms (with the regularity being the repetition of a standard stimulus or parameter; Escera et al., 1998; Schröger and Wolff, 1998). Following this approach, it has already been shown that the visual system is able to automatically detect infrequent sequential changes in a series of consecutive, otherwise regular displays (e.g. Czigler et al., 2004, 2006; Kimura et al., 2009; Pazo-Alvarez et al., 2003; Tales et al., 1999). Moreover, visual change detection leads to similar distraction effects as in audition, when infrequent regularity violations are presented while participants perform a task. For instance, Berti and Schröger (2001, 2004) presented a sequence of squares containing a triangle at an exposure duration of 200 ms or 600 ms, and participants were instructed to categorize the visual stimuli by their duration. In 12% of the trials, the position of the triangle inside the square was shifted. In these deviant trials, participants responded more slowly, and compared to the ERP elicited in the regular standard trials, the deviant ERPs showed a negativity over parieto-occipital electrodes at around 200 ms (visual MMN, N2b) and a positivity over frontal electrodes at around 400 ms (P3a). Analogous to the auditory modality, the first component is supposed to reflect a process of visual change detection, whereas the second is assumed to reflect a shift of attention towards the irregular change. Even though the effects were smaller than those measured in the auditory modality (cf. Berti and Schröger, 2001), the findings confirm that the visual system likewise extracts sequential regularities in stimulus sequences and interferes with concurrent mental processes (distraction) as soon as a regularity violation appears.

The present test of a visual multi-deviant paradigm will reveal whether distraction effects are still obtained when violations on different visual stimulus features (location, color, and shape) are presented during the same visual sequence with low probability of each feature change per se, but high overall probability of deviant displays (33% as in the auditory multi-deviant paradigm). The presence of deviance-related effects would suggest analogous mechanisms of visual change detection and attentional orienting as previously shown for the auditory modality.

2. Methods

2.1. Participants

18 volunteers participated in the experiment (4 male, 14 female, age range 20–39 years) either for payment (6 €/h) or for course credit. Each of them had normal or corrected-to-normal visual acuity and normal color vision. The volunteers gave written informed consent before participating. Data of two participants had to be excluded from the analysis because too few EEG epochs (less than half of the original trials) remained after eye-blink and movement artifact rejection in at least one of the conditions.

2.2. Apparatus

During the experimental session, participants were seated in an acoustically and electrically shielded chamber. Through a window in the chamber, they watched the sequences of visual stimuli that were presented on a computer monitor directly placed behind the window approximately 95 cm from the participants. The stimulation was run via Matlab (http://www.mathworks.com) using the Cogent2000 toolbox (http://www.vislab.ucl.ac.uk/cogent_2000.php). Participants were holding a keypad on which they had to press the relevant response keys.

2.3. Stimuli and procedure

Each trial started with a stimulus display that was presented for a duration of 150 ms on a grey background. The stimulus display contained a target stimulus (1.2° in height, 0.9° in width) that occurred in the center of the screen, and two peripheral stimuli (3.4° in height, 4.2° in width) that occurred on the left and right of the target (4.5° distance from center of target to center of the peripheral stimulus). The target stimulus was a single digit varying randomly from trial to trial between eight equiprobable digits (2, 3, 4, 5, 6, 7, 8, or 9). Participants were instructed to press one response key in case the digit of the current trial was odd and another response key in case it was even. In standard trials, the concurrently presented peripheral stimuli were equilateral triangles of green color. In deviant trials, one of the peripheral stimuli was an equilateral green triangle while the other stimulus was an

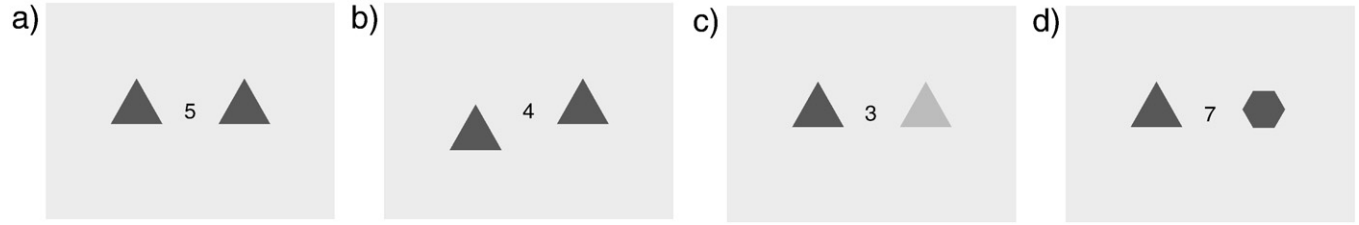

Fig. 1. Examples for stimulus configurations. a) Symmetric display containing the target digit flanked by two vertically aligned green triangles (here shown as dark grey) which served in the experimental blocks as the standard display. b) Display containing a location asymmetry. c) Display containing a color asymmetry in which one of the triangles is presented in red color (here represented by light grey). d) Display containing a shape asymmetry.