Available online at www.sciencedirect.com
SCIENCE DIRECT®
Biological Psychology 72 (2006) 51–58
BIOLOGICAL PSYCHOLOGY
www.elsevier.com/locate/biopsycho

Lateralized irrelevant speech alters visuospatial selective attention mechanisms

Michael Schaefer [a,*], Uwe Tewes [b], Thomas F. Münte [c], Sönke Johannes [d]

[a] *Human Cortical Physiology Section, National Institute of Neurological Disorders and Stroke, National Institutes of Health, Bldg. 10, Room 5N-234, Bethesda, MD 20892, USA*
[b] *Department of Medical Psychology, Medizinische Hochschule Hannover, Germany*
[c] *Department of Neuropsychology, Otto-von-Guericke Universität, Magdeburg, Germany*
[d] *Klinik Bellikon, Bellikon, Switzerland*

Received 7 November 2004; accepted 11 July 2005
Available online 26 September 2005

Abstract

Recent studies indicate that the coordination of spatial attention across modalities may in part be mediated by a supramodal attentional system. We try to extend the concept of a supramodal system and hypothesized that involuntary modulations of auditory attentional processes by irrelevant speech signals influence visuospatial attention, suggesting crossmodal links between vision and speech. In order to test this we recorded event-related brain potentials (ERPs) of 12 healthy subjects in a visuospatial selective attention task. The task to identify target stimuli appearing at lateral visual field locations caused the expected enhancements of the early P1 and N1 ERP components to attended visual stimuli. Understandable and ununderstandable task irrelevant speech was presented either at the visually attended position or in the opposite visual field location. Speech contralateral to unattended visual stimuli led to a decreased N1 amplitude. This effect was stronger for understandable speech. Thus, speech influences the allocation of visual spatial attention if it is presented in the unattended location. The results suggest crossmodal links of speech and visuospatial attention mechanisms at a very early stage of human perception.

Keywords: Selective attention; Spatial attention; Visual attention; Event-related brain potentials; Irrelevant speech effect; Multisensory

1. Introduction

In everyday life we are not only exposed to stimuli of a single modality, but rather, most of the time, events are multimodal, i.e. they provide adequate input to more than one sensory system. In many situations, the adaptive control of behavior requires the integration and coordination of information about relevant objects and events that originates from different input modalities, but from overlapping spatial locations. The identification of the underlying neural mechanisms remains a key challenge for neurobiological research. A number of studies have shown that there are crossmodal links between the auditory and the visual modality (e.g., Spence and Driver, 1996; Eimer and van Velzen, 2002).

Within one modality, stimuli which are relevant to a given task are processed with greater speed and accuracy than task irrelevant stimuli (e.g., Posner, 1980). ERPs have shown that endogenous (voluntary) direction of attention to a location in space influences neural processes starting less than 100 ms after stimulus presentation (e.g. Eason et al., 1969; Heinze et al., 1990). This effect has been interpreted to indicate changed perceptual processes (Downing, 1988; Eriksen and James, 1986) and has been termed sensory gain control mechanism (Eason, 1981; Harter and Aine, 1984; Hillyard and Mangun, 1987). The sensory gain control mechanism operates within modality-specific brain areas but interactions between attentional mechanisms within different modalities have also been demonstrated (e.g. Eimer, 2001; Eimer and Driver, 2000; Hötting et al., 2003).

Several behavioral studies have found evidence for crossmodal interactions in endogenous spatial attention between vision and audition. In most of these experiments, participants had to direct their attention to the expected location of the target stimuli. On a minority of trials stimuli of a different modality were presented. Superior performance for stimuli at the expected location was observed for both modalities, suggesting that the focus of attention within one modality may influence

* Corresponding author. Tel.: +1 301 40 29283; fax: +1 301 40 27050.
E-mail address: schaefem@ninds.nih.gov (M. Schaefer).

0301-0511/$ – see front matter
doi:10.1016/j.biopsycho.2005.07.007

the processing of information in other modalities (e.g., Spence and Driver, 1996).

However, these behavioral studies show crossmodal interactions in voluntary spatial attention between vision and audition, but they do not allow any strong conclusions with respect to which stages in the processing of visual and auditory information are affected by such links. Hence, they do not give any direct insight into the neural processes associated with such interactions (Eimer and van Velzen, 2002). To examine the neural correlates of crossmodal attentional interactions, a number of ERP studies have been conducted (Alho et al., 1992; Woods et al., 1992; Spence and Driver, 1996, 1997; Eimer and Schröger, 1998; Luo and Wei, 1999). Their results suggest that the coordination of spatial attention across modalities may in part be mediated by a common supramodal attentional control system. For example, Eimer (1999a) investigated ERP effects of crossmodal attention between vision and audition. It required the detection of auditory and visual stimuli at the same or at opposite visual field locations. Eimer found attentional modulations of the early (visual) P1 component in the "attend same" but not in the "attend opposite" condition whereas the later (auditory) Nd component did show an attentional modulation even in the "attend opposite" condition.

Supramodal attentional processes seem to incorporate not only visual and audition modalities. Behavioral studies have found evidence for crossmodal interactions in endogenous spatial attention between vision and touch (Spence et al., 2000). Recently, ERP studies confirm these results and give evidence for crossmodal links in voluntary spatial attention between vision and touch (Eimer and Driver, 2000; Eimer and van Velzen, 2003), between tactile and auditory stimuli (Hötting et al., 2003) and between vision, touch and auditory stimuli (Eimer et al., 2002). Overall, these ERP results suggest that relatively early stages of visual, auditory, and tactile information processing can be affected by crossmodal interactions.

The aim of the present study was to extend the concept of a supramodal attention system by investigating crossmodal links between visuospatial attention and speech. We hypothesized that modulations of attentional processes in one modality may influence attentional processes in a different modality via the control system. Auditory distractors are known to interfere with visuospatial selection processes (Spence and Driver, 1997). Thus, task irrelevant auditory stimuli of a high ecological validity like speech may influence visuospatial selection processes if presented at the (visually) attended location as compared to the opposite location.

To this end we recorded event-related brain potentials in a paradigm that combined a visuospatial selective attention task with the irrelevant speech effect. The irrelevant speech effect refers to an impaired recall of visually presented items when task-irrelevant speech is presented in the background at the time of encoding (Salamé and Baddeley, 1982). It has been shown that meaningful speech disrupts recall more than does meaningless speech (LeCompte et al., 1997; Neely and LeCompte, 1999). Thus, irrelevant speech appears to automatically capture attentional resources and should be able to influence visuospatial selection processes. The experimental effect should be stronger for understandable than for ununderstandable speech. This was tested by presenting meaningful (a tape device played forwards, "understandable") and meaningless (a tape device played backwards, "ununderstandable") speech in a standard sustained visuospatial attention task.

2. Methods

2.1. Subjects

Twelve subjects (four women) with a mean age of 26.4 years (range 21–32 years) participated in the experiment. All were right handed as measured by the Edinburgh Handedness Inventory (Oldfield, 1971) and had normal or corrected-to-normal vision. Two persons were unable to maintain eye fixation and were replaced prior to data analysis.

2.2. Stimulus material

The visual stimuli consisted of vertical bars, which subtended 6.5° of visual angle in vertical and 4.2° in horizontal diameter. They were presented in one of two different colors. Ninety percent of the stimuli were white (non-targets) and 10% of stimuli were red (targets when appearing at the attended side).

The stimuli were flashed one at a time in a pseudorandom order for 60 ms to the left and right visual field locations 42.5° of horizontal visual angle as measured from the center of the visual field to the inner margins of the stimuli. The vertical position was 5° above the meridian measured to the lower margins of the stimuli. The inter-stimulus interval varied randomly between 540 and 840 ms (rectangular distribution).

The story, "Wenn die Gondeln Trauer tragen" by Daphne du Maurier was played forwards ("understandable") on a double-track recording tape (Revox Type A 77) in one and backwards ("ununderstandable") in another experimental condition. The speakers were located at the sites of visual stimulation. Thus, they were located 42.5° lateral of the horizontal meridian and slightly above the vertical meridian. Both, speech forwards and backwards were presented in the left and right positions. This resulted in a total of four different "speech" conditions: Left forwards, left backwards, right forwards, right backwards.

2.3. Procedure

Prior to and during the duration of each run, the subjects were required to maintain eye fixation on a central fixation point between the two monitors. Eye position was monitored with an electrooculogram (EOG). The electrodes were placed above the right eye and beneath the left eye to check for the vertical movements. For the horizontal movement the electrodes were placed on the outer canthus of the right and the left eye.

For each experimental run, the subjects were instructed to selectively attend to the left ("attend left" condition) or right ("attend right" condition) visual field location and to press a button held in the right hand whenever the target was detected on the attended side. The subjects were told to respond as quickly and as accurately as possible and to ignore all stimuli on the unattended side. They were also told to ignore the speech.

One experimental run consisted of 200 visual stimuli and lasted about 3 min. A total of 80 runs was administered on two separate experimental days. There was a total of eight different experimental conditions: the "attend left" and "attend right" attention conditions each combined with the four different speech conditions "left forwards", "left backwards", "right forwards", "right backwards". Thus, each experimental condition comprised 10 runs. Whereas the "attend left" and "attend right" attention conditions were randomly varied on a run-by-run basis the speech conditions were altered in blocks of 10 runs. Hence, each speech condition was administered twice. The order of blocks was counterbalanced across subjects. Rest periods were given after 3 or 4 runs with longer rest periods after 10 runs or as needed.

The responses to targets at the attended location were classified as hits when they occurred within a time window from 200 to 1200 ms post stimulus. After each run the subjects were given feedback about their performance.