Acta Psychologica 153 (2014) 139–146

Contents lists available at ScienceDirect

Acta Psychologica

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

Crossmodal attention switching: Auditory dominance in temporal discrimination tasks☆

Sarah Lukas [a,b,*], Andrea M. Philipp [a], Iring Koch [a]

[a] *Institute of Psychology, RWTH Aachen University, Aachen, Germany*
[b] *Institute of Psychology and Education, Ulm University, Ulm, Germany*

ARTICLE INFO

Article history:
Received 16 December 2013
Received in revised form 28 August 2014
Accepted 11 October 2014
Available online 1 November 2014

PsycINFO classification:
2323
2326
2340

Keywords:
Crossmodal interference
Task switching
Temporal judgment
Modality appropriateness

ABSTRACT

Visual stimuli are often processed more efficiently than accompanying stimuli in another modality. In line with this "visual dominance", earlier studies on attentional switching showed a clear benefit for visual stimuli in a bimodal visual–auditory modality-switch paradigm that required spatial stimulus localization in the relevant modality. The present study aimed to examine the generality of this visual dominance effect. The modality appropriateness hypothesis proposes that stimuli in different modalities are differentially effectively processed depending on the task dimension, so that processing of visual stimuli is favored in the dimension of space, whereas processing auditory stimuli is favored in the dimension of time. In the present study, we examined this proposition by using a temporal duration judgment in a bimodal visual–auditory switching paradigm. Two experiments demonstrated that crossmodal interference (i.e., temporal stimulus congruence) was larger for visual stimuli than for auditory stimuli, suggesting auditory dominance when performing temporal judgment tasks. However, attention switch costs were larger for the auditory modality than for visual modality, indicating a dissociation of the mechanisms underlying crossmodal competition in stimulus processing and modality-specific biasing of attentional set.

1. Introduction

In browsing the research literature about how humans deal with the variety of different sensory impressions, one comes quickly upon the phenomenon of intersensory bias. Intersensory bias is the degree to which stimulus processing in one modality is changed if it occurs simultaneously with a stimulus presented in another modality compared to if it occurs alone. In a variety of studies, a very strong and robust intersensory bias for vision over audition (and also over proprioception) can be found.

For example, Colavita (1974) let his participants react as soon as they detected a visual or an auditory stimulus with separate key presses for each modality. In most of the trials, only one stimulus was presented (unimodal trials), but some bimodal trials were occasionally interspersed. Surprisingly, participants almost always responded only to the visual stimulus. After the experiment, some participants stated that they did not even realize that bimodal trials had occurred. Colavita (1974) termed this effect "visual dominance" and suggested an attentional approach, assuming that information processing of two simultaneously presented stimuli in different modalities was capacity-limited and that visual processing receives attentional priority.

On the basis of such findings, Posner, Nissen, and Klein (1976) developed the theory of directed attention, which also assumes a differential, modality-specific allocation of attention. Specifically, this theory states that vision is not as automatically attention-capturing as audition. To compensate for the ensuing relative disadvantage in crossmodal situations, visual stimuli are processed with attentional priority, which then results in the visual dominance effect.

Findings reported by Egeth and Sager (1977) and Sinnett, Spence, and Soto-Faraco (2007) supported the notion that the visual dominance effect is an attentional effect. The relative dominance of vision over audition could be changed if attention was manipulated. Guiding attention to auditory stimuli either by decreasing the probability of visual stimuli (and increasing the number of bimodal trials) or by instructing participants to respond only to auditory stimuli reduced the visual dominance effect. Likewise, the effect was increased if more attention was allocated to the visual stimulus. These findings suggest that visual dominance is essentially an attention phenomenon.

Ragot, Cave, and Fano (1988) also assumed attentional processes as functional basis of the visual-dominance effect, but they used a different experimental approach. Instead of measuring RT in a stimulus detection

☆ This research was funded by the Deutsche Forschungsgemeinschaft Grant KO 2045/04-03 to Iring Koch and Andrea M. Philipp and was conducted at the Institute of Psychology, Aachen, Germany. We would like to thank Nadine Wahl for conducting the experiments as well as Ben Dyson and Micah Murray for their helpful comments on an earlier version of this article.

* Corresponding author at: Institute of Psychology and Education, General Psychology, Ulm University, Albert-Einstein Allee 47, 89081 Ulm, Germany.
E-mail address: sarah.lukas@uni-ulm.de (S. Lukas).

http://dx.doi.org/10.1016/j.actpsy.2014.10.003
0001-6918/

task, they provided their participants with a spatial localization task. The task was to decide if either a visual stimulus or an auditory stimulus was presented to the left or the right side. Visual and auditory stimuli were simultaneously presented either on the same side (congruent) or on opposite sides (incongruent). On congruent trials, the same response is required for both stimuli; in incongruent trials, different responses are required for each stimulus. The task-relevant stimulus modality was swapped only after the first half of the experiment. That is, participants had to guide their attention only to stimuli in one modality and did not have to be prepared to respond to upcoming stimuli in the other modality. Ragot et al. (1988) found a general congruence effect, but this congruence effect was not larger for the auditory modality. That is, visual distracters did not elicit a stronger crossmodal interference effect than auditory distracters. To explain this symmetric crossmodal congruence effect, Ragot et al. (1988) assumed that attentional focusing on only one of the two modalities led to the disappearance of visual dominance and hypothesized that it might re-appear if attention was less focused (and thus more flexible) because a switch in the task-relevant modality was possible.

Lukas, Philipp, and Koch (2010b) tested this hypothesis with a crossmodal attention-switching paradigm using lateralized visual and auditory stimuli in each trial. Critically, employing task-switching methodology (see, e.g., Kiesel et al., 2010, for a review of task switching research), participants were explicitly instructed to switch attention between modalities, as indicated by an explicit cue at the beginning of each trial. If the cue was visual (an asterisk in the center of the monitor), participants had to decide if the visual stimulus was presented left or right by pressing a left vs. right response key. If the cue was auditory, participants had to respond to the location of the auditory stimulus. The authors found indeed strong evidence for a visual dominance effect. RTs were generally shorter for visual stimuli than for auditory stimuli, and the congruence effect was much larger for auditory target stimuli than for visual target stimuli. That is, visual distracters induced more crossmodal interference while processing auditory stimuli than vice versa. Notably though, the attention switch costs that were found in modality switches relative to modality repetitions across trials were similar in both modalities, even though a subsequent study suggested differentially increased auditory switch costs if the cuing interval was very short (Lukas, Philipp, & Koch, 2010a).

These findings are in line with the theory of directed attention. However, the study of Ragot et al. (1988) as well as Lukas et al. (2010b) used a spatial task, which is, according to the modality appropriateness hypothesis, the more “appropriate” dimension for vision (e.g., Welch, DuttonHurt, & Warren, 1986; Welch & Warren, 1980). In most cases, the stimulus input is complex and consists of a variety of dimensions (e.g., space, and time) and modalities (e.g., vision, audition, and touch). According to Freides (1974), each modality is specified to process information about its “appropriate” dimension. For example, vision is especially accurate in the dimension of space, whereas audition performs better in the dimension of time.

Empirical evidence for the modality appropriateness hypothesis comes particularly from findings revealing auditory bias on vision (e.g., Aschersleben & Bertelson, 2003; Shams, Kamitani, & Shimojo, 2000; Walker & Scott, 1981; Welch et al., 1986). For example, Aschersleben and Bertelson (2003) used a sensorimotor synchronization task, in which the participants should reproduce a sequence of light flashes with tapping movements while ignoring simultaneously presented auditory distracters. In a second experiment, the converse task was assigned, that is, reproducing an auditory sequence while ignoring the visual distracters. A much stronger bias towards the auditory distracters could be found in Experiment 1 than towards the visual distracters in Experiment 2 (though this bias was significant, too).

In a recent study, Sandhu and Dyson (2012) found first hints of a relative advantage for processing auditory stimuli in a modality-switch study that was quite similar to the studies by Lukas et al. (2010a,b). In Sandhu and Dyson's (2012) study, subjects were required to process auditory stimuli in a temporal duration judgment task, whereas visual stimuli required a spatial localization task. These authors found increased RT switch costs for auditory stimuli on incongruent trials, but the error rates showed exactly the opposite pattern, with increased error switch costs for visual stimuli and thus evidence for auditory dominance. However, given the opposing patterns in RT and error rates, it is not easy to interpret these findings as clear evidence for auditory dominance in crossmodal attention switching (i.e., as opposed to the findings of Lukas et al., 2010a,b), but what is clear though is that the dominance relations between vision and audition may indeed depend on the specific processing requirements of the task.

Based on Sandhu and Dyson's (2012) findings and previous findings reported by Lukas et al. (2010a,b), it is obviously important to examine whether the dominance relation in visual–auditory crossmodal attention tasks is crucially mediated by task demands. Tasks requiring spatial processing might lead to visual dominance (which has been already shown by Lukas et al., 2010a,b), but tasks requiring temporal processing might result in auditory dominance. As Sandhu and Dyson (2012) used two different tasks for auditory and visual stimuli, a design in which the same task for both stimulus modality is used (in this case a temporal task) is needed to close the gap. The aim of the present study was to demonstrate auditory dominance in crossmodal attention switching when using a temporal processing task. Specifically, we presented visual and auditory stimuli simultaneously and let the participants decide if the stimulus in the relevant modality was presented for a short vs. long duration. Across trials, the relevant stimulus modality switched unpredictably, as indicated by an explicit instructional cue in the same modality prior to target-stimulus onset.

We report two experiments. In Experiment 1, we used an intermediate cuing interval of 600 ms. In Experiment 2, we manipulated the duration of the cuing interval to examine the influence of cue-based preparation for crossmodal attention switches with respect to temporal discrimination judgments.

2. Experiment 1

2.1. Method

2.1.1. Participants

18 participants took part in the experiment (12 female, 6 male between 19 and 28 years; $M = 22.6$, $SD = 2.4$). All reported normal or corrected-to-normal vision and audition. They received partial course credit or 6 €.

2.1.2. Stimuli and tasks

The visual stimulus was a white diamond (1.5 cm × 1.5 cm) on a black background presented at the center of the monitor. Participants were seated about 50 cm from the monitor, resulting in a visual angle of 1.72° of the visual stimulus. The auditory stimulus was a tone of 400 Hz binaurally presented via earphones. Both stimuli were presented simultaneously and randomly for either 100 ms (short presentation time) or for 500 ms (long presentation time). On congruent trials, both stimuli were presented for either the short or long presentation time. On incongruent trials, one stimulus was presented for the short presentation time, and the other for the long presentation time (see Fig. 1). Before stimulus presentation, explicit cues were shown, indicating the task-relevant stimulus modality. An asterisk, presented at the center of the monitor for 200 ms, indicated that the visual stimulus was task-relevant. A 600 Hz tone, also presented for 200 ms, indicated the auditory stimulus as relevant. The task was to decide if the stimulus in the relevant modality was presented for a short or long time interval. Response keys were the left and right ALT keys on a German QWERTZ keyboard. The stimulus-response mapping was counterbalanced across participants. The experiment was programmed with ERTS (Version 33.33e, BeriSoft Cooperation, Frankfurt am Main, Germany).