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Congruency reversals in an accessory signal Simon task with auditory and visual stimuli

Eric Soetens *, Kathleen Maetens, Peter Zeischka, David Henderickx

Vrije Universiteit Brussel, Brussels, Belgium

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ABSTRACT

In visual two-choice reaction-time tasks, a Simon-like effect occurs when a peripheral accessory signal is presented shortly before or together with the response signal. However, the effect reverses when the peripheral signal appears shortly after the response signal. This pattern also occurs when the peripheral signal appears relative to a go (nogo) signal, with the relevant signal presented well in advance. The reversal has been explained as the inhibition of exogenous response-code activation as soon as an action plan has been developed. In three experiments we investigated whether the inhibition also occurred with auditory and crossmodal stimuli. A Simon effect appeared in all experiments, but the reversal only occurred when peripheral and relevant response signals were auditory, and not when the relevant and irrelevant signals were in a different modality. We suggest that planned actions are protected against exogenous interference by a modality-specific inhibitory process, determined by the relevancy of the modality of the peripheral accessory signal.

1. Introduction

Irrelevant task attributes can influence the processing of relevant response and stimulus attributes (for an overview, see Hommel & Prinz, 1997). Maetens, Henderickx and Soetens (2009) recently showed that with visual stimuli, the influence that irrelevant spatial information exerts on the response depends on the processing and binding stage of relevant stimulus and response features. In the present study we wanted to examine whether these effects also occur with auditory and crossmodal stimulation. More specifically, we wanted to find out whether the response inhibition process, suggested by Maetens et al. (in press) is a general mechanism, or whether it depends on the modality of the task relevant signal.

The influence of irrelevant stimulus location on the processing of relevant information has been studied extensively by means of congruency tasks, such as the Simon task. (for reviews, see Lu & Proctor, 1995; Umiltá & Nicoletti, 1990). In a Simon task (Simon, 1969; 1990) participants respond to the (non-spatial) identity of a stimulus (e.g., colour), that is mapped to spatially defined responses (e.g., left and right response keys). Although the stimulus can appear left or right from fixation, participants are instructed to ignore the location. Nevertheless, responses are faster and more accurate when the location of the stimulus matches the location of the response than when it does not (SE = Simon effect).

A widely shared assumption is that the SE occurs during response selection, due to response competition between the response spatially corresponding to the stimulus and the response required by the task instructions. (e.g., De Jong, Liang, & Lauber, 1994; Proctor & Pick, 2003). If the irrelevant spatial stimulus feature and the relevant spatial response feature overlap, the stimulus code primes the corresponding response location, resulting in fast RTs when both codes activate the same response (Kornblum, Hasbroucq, & Osman, 1990). If not, the automatic activation has to be aborted, resulting in longer RTs for non-corresponding compared to corresponding trials, causing the SE.

An important issue in the literature is the relation between the size of the SE and the relative timing of the processing of different stimulus features along the automatic and intentional routes. Several studies (e.g., Hommel, 1993, 1996; Ivanoff, 2003; Wühr, 2006) already showed that the SE increases or decreases when relevant or irrelevant information can be processed first. However, it is still not clear how both processing routes interact. Congruency tasks such as the Simon or flanker tasks are limited in respect to the search for temporal aspects of activations, because relevant and irrelevant stimulus features are presented together, making it difficult to disentangle their separate effects on performance. In an accessory signal (AS) Simon task a separate peripheral AS conveys the irrelevant spatial information, and can be presented before, simultaneously with, or after the relevant response signal. This makes it possible to better investigate the time course of the interference of irrelevant activation. In this study we will make use of AS Simon tasks to investigate the time course of activation caused by relevant and irrelevant visual and auditory stimulus features.

* Corresponding author. Experimental and Applied Psychology, Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussels, Belgium. Tel.: +32 2 629 2873; fax: +32 2 629 2489.
E-mail address: esoetens@vub.ac.be (E. Soetens).

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Maetens et al. (2009) used a visual AS Simon task with a central response signal, a peripheral AS and a central go–nogo signal presented separately in time. In one of their studies (Experiment 1), participants had to react to the colour of a target stimulus that was followed by a non-coloured go–nogo signal after 600 ms. A normal SE was found when the peripheral AS appeared 150 ms before or simultaneously with the go (nogo) signal. The authors explained this result in terms of the temporal overlap model (Hommel, 1993), suggesting that the more overlap in time there is between the activation of the relevant and the irrelevant information the larger the SE. Hommel also argued that irrelevant response activation is subject to decay. In agreement with this assumption Maetens et al. (in press) found that there was no SE when the irrelevant peripheral information was presented more than 150 ms before the go (nogo) signal. A more interesting finding in that study was the reversal of the SE when the AS appeared 150 ms after the go (nogo) signal. This pattern of SEs is not easy to explain in terms of the traditional hypotheses, such as the temporal overlap model or the attention shift hypothesis (Notebaert, Soetens, & Melis, 2001; Stoffer & Yakin, 1994).

Maetens et al. (2009) explained the reversal of the SE as a combination of event file binding and the inhibition of exogenous activation. According to Hommel (2007), features of perceived events and planned actions that occur close in time are spontaneously integrated into a common episodic memory trace or "event file". Maetens et al. (in press) suggested that after response selection is terminated, the task-relevant stimulus and response features become integrated in an event file, after which response execution starts. When the features of the event have not yet been integrated into an event file, that is, when irrelevant exogenous information (the AS) is presented before or simultaneously with the go (nogo) signal, a SE occurs due to the interference of the peripheral signal with the overlapping spatial response feature. When the AS is presented after integration and after selection of the task-relevant response, the automatic generated response will be inhibited (Wijnen & Ridderinkhof, 2007). When the location of the AS and the required response correspond, the inhibition interferes with the execution of the task-relevant response, leading to longer RTs on congruent trials. When the AS and the response signal activate opposite responses, no inhibition of the to-be-executed response occurs. This explains the reversed SE when the AS follows the response signal.

In the present study we want to examine whether the inhibition process that is assumed to cause the reversal can be generalised to auditory stimuli and whether it also occurs across modalities. There is much evidence for SEs with auditory stimuli (Simon & Craft, 1970) and that also auditory ASs can cause Simon-like effects (Proctor & Pick, 1998). In most of these studies it concerns the influence of auditory irrelevant signals on the processing of visual targets (e.g., Notebaert & Soetens, 2003; Proctor, Pick, Vu, & Anderson, 2005). We therefore predict that also in this study, SEs will be found when an auditory AS is used, for both visual and auditory target stimuli. Uncertain is the prediction concerning the influence of a visual AS on an auditory target stimulus.

The reversal of the SE when an AS follows the relevant stimulus or go-signal is a recent finding and no similar studies with auditory stimuli have been conducted yet. The most straightforward prediction is that also in case of auditory or crossmodal stimuli, there will be a reversal of the SE caused by an inhibition of the exogenously generated response activation, as suggested by Maetens et al. (2009). Alternatively, the reversal could be conditional upon the relevance of the modality of the AS. The inhibitory mechanism may only be activated when the AS is presented in a task-relevant modality. Such a mechanism has been suggested before as an explanation for modality-specific effects in Inhibition of Return (IOR; Van der Lubbe, Havik, Bekker, & Postma, 2006). In that supposition, no reversal of the SE is to be expected in crossmodal designs of the AS Simon task.

We will evaluate both predictions on the basis of two related well-documented phenomena. First, there is much evidence that SEs decrease substantially, and sometimes even reverse when the preceding trial is incongruent (e.g., Notebaert et al., 2001; Stürmer, Leuthold, Soetens, Schröter, & Sommer, 2002; Soetens, Maetens, & Zeischka, 2010). Second, inhibitory mechanisms of exogenously triggered activations, such as suggested by Maetens et al. (2009) have also been proposed to explain why people react faster to stimuli at uncued compared to cued locations, when the cue–target interval exceeds 300 ms (IOR; Posner & Cohen, 1984). Because both phenomena have been studied with stimuli in different modalities, we will assess whether the results of these studies can be used to predict the outcome of the present auditory and crossmodal experiments.

SEs decrease substantially and sometimes even reverse when just before participants had to respond to an incongruent trial. The effect has been ascribed to a blocking or suppression mechanism (Ridderinkhof, 2002; Stürmer et al., 2002), which has been described as a cognitive control mechanism, blocking the automatic priming of congruent response activation. The exact nature of the underlying mechanism is still disputed, but it is generally assumed that the conflict in the preceding trial triggers an inhibitory mechanism. Most research supporting the blocking mechanism has been conducted with visual stimuli, but there is also evidence that the effect occurs with auditory stimuli (Leuthold & Schröter, 2006). As far as we know, no evidence has been found in support of a crossmodal control process.

Alternatively, the parallel with IOR may provide a better grip, because here also crossmodal effects have been studied. IOR is observed in experiments using the cue–target paradigm developed by Posner (1980) where it is generally found that people react faster to stimuli appearing at previously cued locations, compared to noncued locations. With exogenous cues this effect reverses when the time between cue and target exceeds 250 ms, so that reactions are faster to uncued, compared to cued locations (Posner & Cohen, 1984; see Klein, 2000, for a review). IOR interacts with the SE (Ivanoff, Klein, & Lupianez, 2002) suggesting that they share a common process. Interestingly, the influence of cueing on congruent and incongruent trials is comparable with the pattern of results in Maetens et al. (2009). With a short cue–target interval there is a normal SE, whereas the effect reverses with cue–target intervals of 700 ms.

Numerous studies have demonstrated that spatially nonpredictive visual, auditory, or somatosensory cues can facilitate responses to nearby targets when the cues and targets are in different modalities (e.g., Kennett, Eimer, Spence, & Driver, 2001; McDonald, Teder-Salejarvi, Di Russo, & Hillyard, 2003; Schmitt, Postma, & De Haan, 2000; Spence & Driver, 1997; Ward, 1994; Ward, McDonald, & Lin, 2000). Such crossmodal cue effects support claims that involuntary shifts of spatial attention can be based on multimodal representations and that at least part of the neural system controlling those shifts may be supramodal.

In contrast, IOR seems to be limited within modalities (Schmitt et al., 2000). Van der Lubbe et al. (2006) suggested that IOR, in a task with visual targets, is the result of speeded motor inhibition triggered by the visual cue. In general, they suggested that the task set determines which stimulus modality is relevant, and that this in turn determines whether irrelevant response activation should be inhibited or not. These findings seem to suggest that apart from a supramodal orienting mechanism, also separate modality-specific mechanisms for exogenous shifts of attention are active.

Taken together, the available research seems to suggest that SEs are caused by a supramodal attentional mechanism. However, inhibitory mechanisms, like those responsible for IOR, and possibly for the Simon reversal effect in Maetens' studies, rather seem to be modality specific. On the basis of this information we predict a SE and its reversal in the experiment with auditory stimuli, but no reversals in crossmodal experiments.

It should be noted, that results and conclusions based on AS Simon tasks may not apply to SEs in a normal Simon task, because in the latter relevant and irrelevant features belong to the same object, whereas this is not the case in an AS task. Wuhr, Biebl, Umiltà and Müsseler (2009) demonstrated that interference from the location of different objects is much smaller than interference from the location of elements in the same object.