Effects of irrelevant spatial S-R compatibility depend on stimulus complexity

Bernhard Hommel

Max-Planck-Institut für psychologische Forschung, Leopoldstrasse 24, D-80802 Munich, Germany

Summary. Choice-reaction time is known to depend on the spatial correspondence of stimulus and response, even if the stimulus location is irrelevant to the task (Simon effect). An experiment investigated whether this effect depends on stimulus complexity — i.e., on whether properties of the stimulus render stimulus discrimination easy or difficult. It was hypothesized that high demands on discrimination slow down the processing of stimulus identity in relation to location, so that the facilitating or conflicting location code has more time to decay, thus losing impact on response selection. In fact, the results revealed an effect of irrelevant spatial S-R correspondence with easy, but not with difficult, stimulus discrimination. This finding resolves an apparent contradiction between the results of several previous experiments on the Simon effect.

Introduction

The time it takes to respond to a stimulus often depends on the spatial relationship between stimulus and response. First of all, this is the case when the stimulus position is the relevant attribute. It has been shown repeatedly that responses are faster when, for example, left-hand stimuli are reacted to with a left-hand response (i.e., pressing a left-hand key, moving a lever to the left, etc.) and right-hand stimuli with a right-hand response, than when stimulus-response mapping is crossed (e.g., Brebner, Shephard, & Cairney, 1972; Fitts & Seeger, 1953). Moreover, even if stimulus location is completely irrelevant to a task, spatial correspondence of stimulus and response can be shown to speed up spatially defined responses. When, for example, the verbal command to press a left-hand key is presented to only one ear at a time, the response is faster when command location and response location correspond than when they do not (e.g., Simon & Rudell, 1967). This effect of correspondence between irrelevant stimulus location and response location has become known as the Simon effect.

The Simon effect turned out to be very stable and has been replicated several times in a wide range of tasks employing different stimuli and stimulus modalities, responses and response modalities, as well as using various spatial parameters of stimuli and responses (for overviews, see contributions to Proctor & Reeve, 1990). There is, however, an interesting exception on which the present paper is focused: in two experiments of Umiltà and Liotti (1987: Experiments 3 and 4, no-delay conditions), the Simon effect disappeared for reasons that are not yet completely understood.

The arrangement of stimulus display and response keys in one of these experiments (Experiment 3, no-delay condition) is given in Figure 1. In each trial, the subject was presented with two frames either to the left or to the right of a central fixation cross. The stimulus was the outline of either a square or a rectangle, and it appeared simultaneously with the frames and inside one of them. The subject had to press a left- or a right-hand key according to the instructed mapping of stimulus form to response side. The result was that no Simon effect occurred; that is, there was no significant effect of spatial correspondence between stimulus and response. The same negative result was obtained in a further experiment (Experiment 4, no-delay condition), in which the two frames were always presented on opposite sides of the fixation cross.

This disappearing of the Simon effect is important for at least two reasons. First, it has been referred to by Stoffer (1991) and by Umiltà and Nicoletti (1992) as a main argument in favour of an attentional approach to the Simon effect.¹ So, the results of Umiltà and Liotti (1987) are more than a marginal curiosity and bear considerable theoretical importance. The question remains, however, whether they really support conclusions in favour of an attentional approach to the Simon effect. Second, while the results of Umiltà and Liotti were replicated successfully by Stoffer...
Apart from this variation, the experiments of Umiltà and Liotti (1987) (see below) and did obtain a Simon effect. The question, of course, is how this empirical inconsistency can be explained.

In a first attempt to provide an explanation for the results of Umiltà and Liotti (1987), Stoffer (1991) suggested an attentional view. Following Neumann (1980), he assumed that stimulus analysis is necessarily preceded by an attentional operation that can be one of two kinds: (a) spatial attention can be shifted horizontally from one location to another, or (b) it can be zoomed in from a global to a local representational level or zoomed out, respectively, like the zoom lens of a camera. The critical assumption is that a given object is spatially coded (in terms of left or right) only if it is focused by the performance of a lateral shift of spatial attention, but not if its analysis is directly preceded by a zooming operation. Since the Simon effect can be understood as arising from a match or from a non-match of the spatial codes of stimulus and response (Wallace, 1971), a stimulus without a spatial code should not lead to a Simon effect. Thus, the disappearing of the Simon effect could be explained if the specific display conditions suggested that the stimulus proper is focused on mainly by zooming operations.

Stoffer argued that in the experiments of Umiltà and Liotti (1987) the arrangement does, in fact, suggest that their subjects performed zooming operations instead of lateral shifts to focus onto the stimulus. The visual structure, consisting of the two frames and the stimulus proper, is assumed to attract spatial attention to its outline. That is, a lateral shift would be performed, starting from the fixation cross and ending at the whole frame/stimulus structure. Then attention would be zoomed in, because the stimulus is only a part of the whole structure, represented at a more local level. Since it is a zooming operation that directly precedes stimulus analysis, the stimulus would not be coded as left or right, and hence no Simon effect would be expected.

Serious problems for such a view arose from a study of Lamberts et al. (1992: Experiment 2). They performed an experiment quite similar to that of Umiltà and Liotti (1987), yet with completely different results. In this study, the fixation cross was not presented at the centre of the screen, but on the left or right of the median plane some time before the stimulus onset, in order to preduce the hemispace of the presentation. Apart from this variation, each trial ran as in the experiments of Umiltà and Liotti (1987) and of Stoffer (1991). Two frames appeared to the left or to the right of the fixation cross with the stimulus (square or circle) inside one of them. The result was that (additive) Simon-type effects were obtained for all of the three spatial relationships that had been varied. That is, responses were comparatively faster when their spatial position corresponded to the hemispace (side), the hemisphere (relative to fixation), and/or to the relative stimulus position.

There is an obvious discrepancy between the findings of Umiltà and Liotti and of Stoffer and those of Lamberts et al. that begs for an explanation. The purpose of the present experiment is to investigate whether this discrepancy can be resolved by consideration of the complexity of the relevant stimulus in these studies.

In all the studies cited, the stimulus was presented within larger frames, so that the presence of frames as such cannot count as a critical factor. The same is true for the relevant dimension, which was always the form of the stimulus. However, the stimuli used were somewhat different. In the experiments of Umiltà and Liotti (1987) (and in Stoffer's 1991 replication), both stimuli were rectangular frames that only differed in width. As each stimulus was presented within a larger frame that looked just like the stimuli, relative width was no valid criterion to distinguish both between stimulus and background and among the stimulus alternatives. Thus, stimulus identification must have been rather difficult here as compared to the Lamberts et al. (1992) study, in which a square had to be discriminated from a circle. Indeed, responses were about 130–150 ms slower in the experiments of Umiltà and Liotti than in the Lamberts et al. study.

How could the time needed to identify the stimulus influence the Simon effect? There is evidence that the size of the Simon effect depends critically on the temporal overlap between spatial coding and coding of the relevant stimulus information (Hommel, 1993 a; McCann & Johnston, 1992). Specifically, it was shown that the Simon effect can be reduced, and even eliminated, by the introduction of manipulations that slow down the processing of the relevant stimulus information selectively without affecting the timepoint of spatial coding. This implies that the activation of the spatial stimulus code (or of the response code activated by the location cue) decays over time, either spontaneously or as a result of inhibition. The more an experimental manipulation delays the processing of relevant information, the lower the activation of the continuously decaying spatial code, and, thus, the smaller its facilitating or interfering influence on response selection.

Such a decay-based explanation can easily be applied to the experiments under discussion. As has already been pointed out, the relevant stimulus properties may have permitted faster stimulus identification in the Lamberts et al. (1992) study than in the Umiltà and Liotti (1987) experiments. On the assumption that the timepoints of location coding were roughly comparable, there should have been more temporal overlap of code activation in the former than in the latter case. For this reason, the Simon effect may have disappeared in the Umiltà and Liotti experiments (as well as in the Stoffer replication) because of