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Research Report

Attentional origins of the Simon effect: Behavioral and electrophysiological evidence

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ABSTRACT

An electrophysiological analysis of classification in the Garner paradigm was performed to investigate processing origins of the Simon effect. This effect is faster responding when stimulus location, though irrelevant to the task, is congruent with the response to the relevant stimulus dimension than when it is not. Participants used lateral keys to classify the timbre of tones presented to left or right headphones. Differences between S-R congruent and S-R incongruent trials were observed initially in the N2 ERP component (250 ms after stimulus onset), after the N1 component (100 ms after stimulus onset) showed evidence of a failure of selective attention to stimulus location. Reaction times to congruent and incongruent stimuli were strongly associated with the peak latency of the P3 decisional component. The results are consistent with models that attribute the Simon effect to the evidentiary weight attention assigns to spatial location when classifying the stimulus as signaling left or right.

1. Introduction

The activities of everyday life require taking appropriate actions to precipitating signals. Often, a signal and its response have a natural or well-established link. Northbound drivers readily turn their heads to the right at the sound of an easterly ambulance siren. Yet many responses to environmental stimuli are task specific. A new driver must learn the relation between a red light and the action of his foot against the brake pedal. Simon and Small (1969) were among the first to study systematically how an arbitrary response to a task-specific stimulus is affected by a tendency to emit an opposing response. On each trial of their study, low- or high-pitched tones were presented to the left or right ear. Participants were asked to identify each tone's pitch by pressing a key with the left or right hand. Despite being irrelevant to the task, the location of the tone nevertheless affected the participants' speed of identification: Participants responded faster when the tone and the response key were located on the same side of the body than when they were located on opposite sides of the body. This finding has since been labeled the *Simon effect* (Hedge and Marsh, 1975). The purpose of the present study was to use a combined behavioral and electrophysiological analysis to examine processing origins of the Simon effect.

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Abbreviations: ERP, event-related potential; LRP, lateralized readiness potential; EEG, electroencephalogram; EOG, electrooculogram; VEOG, vertical electrooculogram; HEOG, horizontal electrooculogram; IFG, inferior frontal gyrus

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1.1. *Dual-route models*

Simon (1990) considered the eponymous effect to be rooted in a processing competition occurring during response selection. He claimed that the location of a stimulus elicits an unlearned tendency to respond in its direction. When the required response is directionally opposite this natural tendency, the observer must overcome the latter in selecting the correct response, an effort that yields the Simon effect. Although many theorists do not subscribe to Simon's idea of reflexive orienting (e.g., Dutta and Proctor, 1992; Hasbroucq and Guiard, 1991), there is widespread agreement (see Lu and Proctor, 1995) that the Simon effect emerges primarily from competition at a response-selection stage.

A common approach for characterizing response competition is embodied in dual-route models of the Simon effect (De Jong et al., 1994; Hommel, 1993a; Kornblum et al., 1990; Toth et al., 1995). Although differing in particulars, dual-route models concur that each stimulus feature activates response tendencies along one of two processing pathways: automatic (unconditional) or intentional (conditional; see Fig. 1A). Natural or well-learned relations between a stimulus feature and the response it evokes are processed along the automatic route. For example, dual-route accounts suggest that in Simon and Small's (1969) experiment, sound location (left or right) was coded automatically in long-term memory, quickly activating the corresponding response location. Arbitrary, task-specific relations between stimulus and response elements – between pitch and response location in Simon and Small's study – are processed along the intentional route using working memory, proceeding more slowly than the automatic activation of long-term memory.

As shown in Fig. 1A, the Simon effect occurs in dual-route models after the value of the stimulus on the relevant dimension has been identified, from processes that speed or slow selection of the appropriate response. Response selection is facilitated on the *congruent* trials of a Simon task – those in which the location of the correct response coincides with the actual stimulus location – because fast automatic activation primes the code for the correct response. However, response selection is hindered on the *incongruent* trials – those in which the location of the correct response (left key in Fig. 1A) mismatches the stimulus location (right ear) – because here the automatic activation of long-term memory primes the incorrect response code. The intentional route must then overcome or inhibit the automatically primed response code before selecting the correct one, a competitive process that yields response interference.

1.2. *Tectonic theory*

An alternative approach for understanding the Simon effect considers how category decisions about non-spatial features are affected by two types of spatial information: (1) the short-term, or task-defined, associations between the relevant stimulus value and the response location and (2) the long-

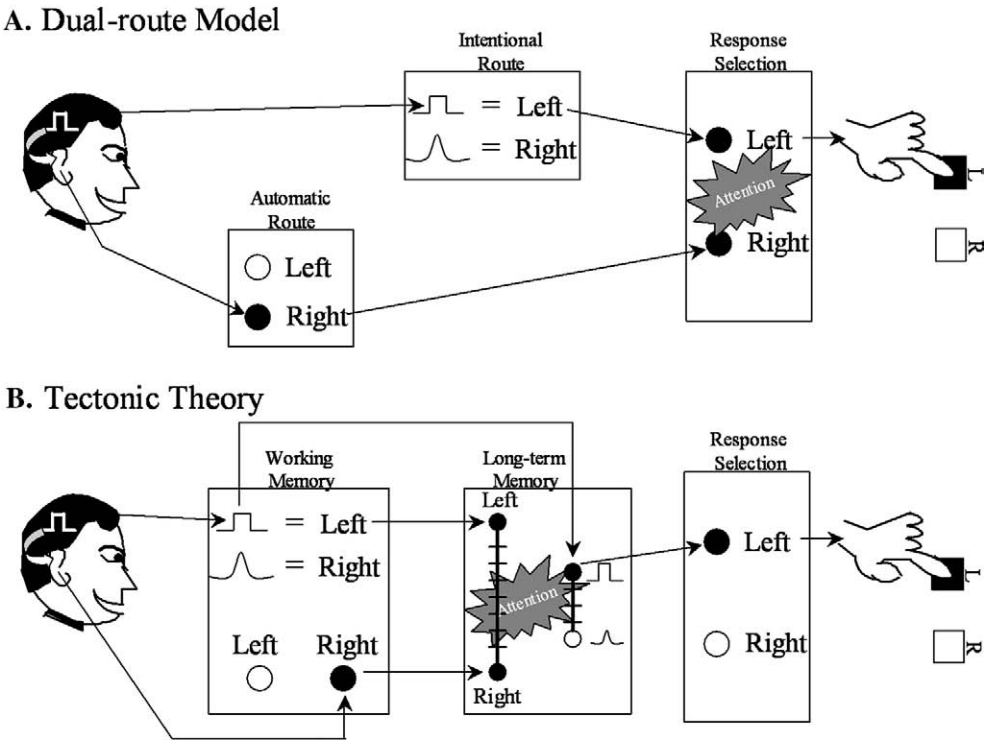

Fig. 1 – A graphic depiction of two alternative models of the Simon effect. Dual-route models explain the Simon effect as the outcome of competition between processing pathways during response selection (Panel A). Tectonic theory attributes the Simon effect to attentional disruption in memory during stimulus classification, prior to response selection (Panel B). In the example, a square-wave tone is presented to the participant's right ear but requires a left-key response, an S-R incongruent trial.