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# The influence of response grouping on free-choice decision making in a response selection task

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ABSTRACT

Previous research has demonstrated an advantage for the preparation of fingers on one hand over the preparation of fingers on two hands, and for the preparation of homologous fingers over that of non-homologous fingers. In the present study, we extended the precuing effects observed with finger responses to response selection under free-choice conditions. Participants were required to choose from a range of possible responses following the presentation of a precue that indicated which response to prepare (go-to precue) or prevent (no-go-to precue). In Experiment 1 the choice was between homologous and non-homologous finger responses on the hand opposite to the precue while in Experiment 2 the choice was between finger responses on the same or different hand to the precue. In the go-to precue condition, the frequency of homologous finger choices was more frequent than non-homologous finger responses. Similarly, participants chose finger responses on the same hand as the precue regardless of whether they were instructed to prepare or prevent the precued response. The hand effect bias was stronger than the finger effect bias. These findings are consistent with the Grouping Model (Adam, Hommel, & Umilta, 2003).



## 1. Introduction

In order to interact with a complex environment, people will allocate attention selectively to events that they believe to be most pertinent. It is well known that reaction times to predicted stimuli are faster than to those that are unexpected (Posner, 1980). For example, a tennis player would react quicker to a shot to their forehand if it was expected than if they predicted a shot to their backhand. The influence of advance information on reaction time has numerous practical applications for strategy and tactics in sport and combat situations. From a theoretical standpoint, it also provides a basis for understanding the processes underlying selective attention and movement preparation. Interestingly, while most research on selective attention has been directed towards understanding how excitatory and inhibitory processes influence latency measures, relatively little attention has been given to how these processes influence which response is actually chosen. In real world situations (e.g., sport, combat and driving), people are often placed in conditions of free choice where they have a certain degree of freedom to use an internal mode of selection to choose from a range of possible responses. In the present research, we consider how advance information and the mechanisms underlying selective attention influence selection processes when participants have the freedom to choose a response option from several alternatives (i.e., free choice).

A common technique used to investigate mechanisms of selective attention and movement preparation is the precue paradigm. Precues give participants advance information about features of an upcoming stimulus and/or required response. This advance information may be valid or invalid depending on whether stimulus/response features match that of the precue. The typical finding is that reaction time for valid precue trials is quicker compared to when no advance information is provided whereas there is a reaction time cost on invalid precue trials. These reaction time benefits and costs have served as a basis for testing theories of selective attention (e.g., Bekkering & Pratt, 2004; Egly, Driver, & Rafal, 1994) as well as processes underlying movement selection and preparation (e.g., Larish & Frekany, 1985; Rosenbaum, 1980).

In most research on selective attention, either a many:1 or a 1:1 stimulus/response mapping has been employed. In the case of many:1 mappings, the response is specified from the outset and hence response selection processes are not involved. For 1:1 stimulus/response mappings, the response to be produced is fully

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specified by the characteristics of the stimulus. Therefore, regardless of whether one must react to a situation that is expected or unexpected, the selection of responses is externally determined since there is only one appropriate response on any particular trial. On the other hand, paradigms involving a 1:many stimulus/response mapping allow participants to make internal decisions when choosing freely from a subset of possible responses. It has been suggested that mechanisms of selection that underlie decision making in internal versus external choice situations are fundamentally different (e.g., Baylis, Tipper, & Houghton, 1997; Buckolz, Goldfarb, & Khan, 2004; Keller et al., 2006). However, it is interesting to note that most research on attention and speeded decision making has employed forced choice situations in which the selection of responses is externally determined.

Although the study of how advance information influences speeded free choice is relatively limited, it has been demonstrated that the presentation of a subliminal cue influences response selection (Klapp & Haas, 2005; Schlaghecken & Eimer, 2004). In these studies, participants were first presented with a masked arrow that pointed left or right. This was followed by a stimulus arrow that pointed either to the left or right (forced choice trials) or a double headed arrow (free choice trials). It was demonstrated that on free choice trials, responses that corresponded to the precue were produced more often when the interval between the precue and the stimulus was short. At longer precue-stimulus intervals, there was a bias towards selecting responses that were opposite to the precue. Thus, it appears that the presentation of subliminal precues leads to activation and subsequent inhibition of motor responses resulting in systematic response selection biases. Posner, Rafal, Choate, & Vaughan (1985) have provided similar evidence that inhibition influences free choice by demonstrating that the selection of eye movements is biased away from locations that have been associated with earlier inhibition.

The goal in the present research was to examine whether the instruction to prepare or prevent a precued response would influence which response option is chosen from a subsequently specified range of alternatives. The rationale behind our investigation was that when participants are instructed to prepare a particular response, the activation of this response will bias selection towards alternatives that share similar features (e.g., the hand or homologous finger). Conversely, when participants are instructed to prevent a particular course of action, the inhibition of a response option might bias response selection away from alternatives that share similar features. An underlying assumption is that response selection biases will arise from the grouping of response features between sets of alternatives. Strong evidence in support of this assumption stems from studies that have used the finger-cuing paradigm to investigate the efficiency of finger grouping processes.

The finger-cuing paradigm was developed by Miller (1982), who adapted Rosenbaum's movement precuing technique (Rosenbaum, 1980, 1983). In the finger-cuing task, a visual cue signal temporally precedes the target signal. The cue specifies a subset of two of four possible (keypress) responses (implemented by the index and middle fingers of both hands), thus prompting a process of subgroup making. In the hand-cued condition, the cue specifies two fingers on the same hand (e.g., the left-index finger and the left-middle finger). In the finger-cued condition, the cue specifies the homologous fingers on different hands (e.g., the two index fingers). In the neither-cued condition, the cue specifies non-homologous fingers on different hands (e.g., the left-middle and right-index fingers). Also, a neutral (control) condition is included, which provides no advance information, and thus precludes the grouping and preparation of any combination of two finger responses. Cue effectiveness is inferred from a significant RT advantage for the informative cue conditions (i.e., hand-cued, finger-cued, and neither-cued) over the control, uninformative (neutral) cue condition.

The consistent finding from the finger-cuing paradigm is a pattern of differential cuing benefits that is apparent with short preparation intervals (i.e., intervals shorter than about 2–3 s). RTs are shortest for the hand-cued condition and longest for the neither-cued condition, with RTs for the finger-cued condition being intermediate (for reviews see Adam et al., 2003, 2005;, Reeve & Proctor, 1990). A recent account of this pattern of differential cuing benefits is the Grouping Model (Adam et al., 2003, 2005), which is an extension of the salient-features coding principle advanced by Proctor & Reeve (1988) & Reeve & Proctor (1990). The key idea of the Grouping Model is that the individual elements of multi-element visual displays and multi-element response arrays are not processed independently but are pre-attentively organized or "grouped" according to low-level grouping factors that depend on stimulus driven factors (e.g., Gestalt principles) and on response-related factors (e.g., inter-response linkages). Preattentive processing is done quickly, effortlessly and in parallel without the need of focused attention (cf. Treisman, 1986). In other words, the basic assumption is that, each stimulus set and each response set has a default organization established automatically by the bottom-up computation of perceptual and motoric units or subgroups; this process is fast and effortless. With additional, top-down processing, however, alternative organizations can be attained; this process is slow and effortful. Thus, the pattern of cuing effects that emerge in the finger-cuing task critically depends on the nature of these default groupings and on the time available to reorganize these representations, if necessary.

According to the Grouping Model, the processing advantage of hand-cues simply reflects the natural, strong grouping of two fingers on the same hand. The co-activation of directly adjacent and overlapping cortical finger representations in areas of the motor cortex corresponding to the same-hand finger set could be at the basis of this grouping (e.g., Dechent & Frahm, 2003). The bilateral finger- and neither-cues, on the other hand, are more difficult to process because they require slow, effortful, top-down modulation to breakup the anatomically based left–right motor organization and to create a new motor organization represented in two hemispheres. Moreover, the advantage of finger-cues over neither-cues can be attributed to the fact that finger-cues require the grouping of homologous fingers whereas neither-cues require the grouping of two different, non-homologous fingers. Because homologous fingers are neurally and functionally linked (e.g., Stinear, Walker, & Byblow, 2001; Ugawa, Hanajima, & Kanazawa, 1993), they are easier to group or co-activate than non-homologous fingers. Hence, the existence of facilitatory connections between homologous motor areas in the brain implies that the preparation and activation of one finger may spill over to its homologous counterpart in the opposite hemisphere.

In the present experiments, we extended the precuing effects observed with finger responses to response selection under free-choice conditions. A novel paradigm was employed in which participants were required to choose from a range of possible responses following the presentation of advance information. On each trial, a precue was presented that indicated to the participant which response to prepare (i.e., go-to precue). This was followed by the imperative stimulus that specified a subset of possible responses rather than a specific response (1: many stimulus–response mapping). In Experiment 1, the imperative stimulus specified the finger responses on either the left or right hand. When the precued response was on the same hand specified by the imperative stimulus, participants were required to produce the precued response. However, if the imperative stimulus specified the other hand, participants were placed in a free-choice situation. Hence, they could choose between a homologous and non-homologous finger relative to the finger specified by the precue. Based on the above reviewed evidence that supports homologous