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The role of task history in simple reaction time to lateralized light flashes

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Abstract

In lateralized simple reaction time (SRT) tasks with unimanual responses, reaction times (RTs) are faster with ipsilateral (uncrossed) than with contralateral (crossed) response hand–target hemifield combinations. The difference between crossed and uncrossed responses (CUD) is typically interpreted to reflect callosal transfer time. Indeed, split brain patients have much longer CUDs than control subjects. However, while many studies have supported the hypothesis that the CUD reflects callosal transmission time, a few studies have suggested that the CUD may be affected by non-anatomical factors. We investigated the nature of these inconsistent results in two experiments. In the first, we asked half of our subjects to cross their arms while performing the task. The CUD was not affected by arms crossing, supporting the anatomical model of the CUD. In the second experiment, however, all subjects were asked to cross their arms in half of the trials. In this experiment, arms crossing significantly affected the CUD, thus showing that spatial attention modulates the CUD. These latter results cannot be readily explained by a simple callosal relay interpretation of the CUD. Rather, the CUD seems to reflect a mix of anatomical and non-anatomical factors produced by task history. Thus, the seemingly inconsistent results of previous studies can be reconciled by taking into account differences in task history across studies.
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Keywords: Reaction time; Poffenberger paradigm; Interhemispheric transfer; Spatial attention; Task context

1. Introduction

In lateralized simple reaction time (SRT) tasks, ipsilateral, or uncrossed, responses (i.e., the left hand responding to a left visual field (LVF) stimulus or the right hand responding to a right visual field (RVF) stimulus) are faster than contralateral, or crossed, responses (i.e., left hand—RVF or right hand—LVF) (Clarke & Zaidel, 1989; di Stefano, Sauerwein, & Lassonde, 1992; Marzi, Bisiacchi, & Nicoletti, 1991; Poffenberger, 1912). This pattern of responses is typically explained in terms of an anatomical model in which in the uncrossed condition, the same hemisphere that receives the stimulus controls the manual response, while in the crossed condition, the hemifield of the stimulus and the responding hand are controlled by opposite hemispheres, thus requiring transfer of information between the hemispheres and consequently a longer reaction time (RT). The crossed–uncrossed difference (CUD), where the two uncrossed conditions are subtracted from the two crossed conditions and then divided by 2, is taken as a measure of interhemispheric transmission time through the corpus callosum and is typically ~3–4 ms in normal subjects (Marzi et al., 1991). Evidence in support of the anatomical hypothesis, that the CUD measures interhemispheric transfer time via callosal fibers, comes from commissurotomy (Aglioti, Berlucchi, Pallini, Rossi, & Tassinari, 1993; Clarke & Zaidel, 1989; di Stefano et al., 1992; Forster & Corballis, 1998; Iacoboni & Zaidel, 1995), and callosal agenesis (Aglioti et al., 1993; di Stefano et al., 1992; Forster & Corballis, 1998; Milner, Jeeves, Silver, Lines, & Wilson, 1985) patients in whom absence of the corpus callosum results in much longer RT to lateralized light stimuli in the crossed condition than in the uncrossed condition (for a review, see Zaidel & Iacoboni, 2003).

Anzola, Bertoloni, Buchtel, and Rizzolatti (1977) performed a seminal study that provided robust evidence in favor of the

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anatomical, callosal relay, interpretation of the CUD. They had subjects respond with uncrossed arms (that is, left arm on the left side and right arm on the right side) and with crossed arms (that is, left arm on the right side and right arm on the left side) in the standard Poffenberger paradigm as well as in a choice reaction time task to lateralized stimuli. Their results yielded no effect of arms crossing in the Poffenberger paradigm but a reliable effect of arms crossing in the choice task, lending support to the callosal relay interpretation of the CUD in the Poffenberger paradigm (Anzola et al., 1977). Findings from several other studies seem compatible with the anatomical model (Berlucchi, Crea, di Stefano, & Tassinari, 1977; Clarke & Zaidel, 1989; Iacoboni & Zaidel, 1995; Marzi, 1999).

Some more recent studies, however, have provided evidence not entirely compatible with the hypothesis that the CUD reflects callosal relay. For instance, Hommel (1996) used a modified version of the Poffenberger paradigm. The response hand could vary every 8 trials (high-frequency blocks) or 80 trials (low-frequency blocks). The results revealed a reaction time advantage for uncrossed trials, compared to crossed trials, that was larger for the high-frequency compared to the low-frequency condition. By itself, this result does not rule out an anatomical basis for the larger CUD in the high-frequency condition. For example, the high- and low-frequency conditions may be associated with transfer through different callosal channels. However, an additional experiment demonstrated the same effect with responses from either the index or middle finger of the same hand. The within-hemisphere control of the responses rules out an anatomical (callosal) interpretation of the result (Hommel, 1996). Braun, Larocque, and Achim (2004) suggested that the result with alternating fingers may be attributable to a reprogramming of the response code. Indeed, again using a modified SRT task, they demonstrated that the CUD is largest immediately after a shift in response preparation from one hand to the other and decreased as the interval since the last change in response hand increased (Braun et al., 2004). Weber et al. (2005) recently examined the role of spatial attention in measures of the CUD during SRT by varying the proportions of crossed and uncrossed trials. They reasoned that subjects are more likely to attend to the hemifield where the stimulus is likely to occur. Using this paradigm, Weber and colleagues demonstrated that the size of the CUD varied from −2.5 ms with predominantly crossed trials to 6.5 ms with predominantly uncrossed trials. Equal proportions of crossed and uncrossed trials resulted in a CUD of 4.4 ms, in line with the meta-analytic estimate of the CUD (Marzi et al., 1991). Thus, allocation of attention for action preferentially to one hemifield or the other, or more precisely, the probability of a crossed versus an uncrossed trial, was enough to change the size and direction of the CUD. The simple anatomical model of the CUD as interhemispheric transfer time has also been challenged with electrophysiological evidence revealing bilateral activity even for simple uncrossed responses (Saron, Foxe, Schroeder, & Vaughan, 2003; Saron, Foxe, Simpson, & Vaughan, 2003).

How can one reconcile these findings? We believe that an often-neglected source of variance across studies is task history. Anzola and colleagues manipulated arms crossing between-subjects, whereas the more recent studies showing experimental modulation of the CUD (Braun et al., 2004; Hommel, 1996; Weber et al., 2005) all used within-subjects manipulations, thus affecting changes in 'task history' more than the design adopted by Anzola and colleagues. In principle, then, the inconsistency between studies supporting the purely callosal relay interpretation of the CUD and studies supporting a more complex nature of the CUD may be explained by differences in task history. Experimental designs that do not vary spatial attention may be more likely to yield results compatible with a pure callosal relay interpretation of the CUD, whereas designs that do vary spatial attention are more likely to yield results compatible with the view that the CUD reflects both callosal relay and attentional factors.

To test this hypothesis, we first replicated the between-subjects experimental design of Anzola et al. (1977) (Experiment 1) followed by a second experiment in which arms crossing was varied within subjects. If our working hypothesis is correct, the first experiment should yield results consistent with the anatomical model, similar to Anzola et al., whereas the second experiment should yield results consistent with spatial attentional effects, more in line with the results of Hommel, Braun et al., and Weber et al. Unlike Hommel, Braun and Weber who used modified SRT paradigms and manipulated spatial attention by changing stimulus–response assignments, we used a classic SRT (Poffenberger) task and manipulated spatial attention with arms crossing.

2. Experiment 1

2.1. Materials and methods

We performed this experiment to replicate Anzola et al. (1977). Twenty-eight subjects participated in the experiment (19 female, 9 male). All subjects were strongly right-handed as determined by a modified version of the Edinburgh handedness Inventory (Oldfield, 1971). Subjects were undergraduate students at the University of California, Los Angeles. Each subject was paid a small fee or received course credit for their participation in the study.

Subjects were tested using a Macintosh IIsi computer with an RGB monitor. Subjects were seated 57 cm from the monitor with their chins in a chin rest and their eyes aligned with a fixation cross in the middle of the screen. Index fingers were placed on response switches mounted vertically on wood panels with the hands positioned comfortably with thumbs up and palms toward the body. The response switches were placed ∼6.5 in. on either side of the midline, approximately 12–14 in. from the body, and approximately 14 in. from the screen. The experiment was run using the software package MacProbe (Hunt, 1994).

Subjects responded to lateralized light stimuli with unimanual index finger presses on response microswitches. For all trials, the subject's task was to make a response to stimulus presentation regardless of stimulus location. A fixation cross was displayed during the entire experiment. For each trial, the stimulus appeared after a random interval (500–2500 ms) following a warning tone. Stimuli were presented for 45 ms and were white squares against a black background. Stimuli subtended 2.0° of visual angle and were 4.0° (=4 cm) from the fixation cross to the center of the stimulus. Subjects' eyes were visually monitored throughout the experiment to verify fixation. There is a great deal of evidence to show that participants rarely move their eyes in tasks of covert attention (Corbetta, Kincade, & Shulman, 2002; Corbetta, Miezin, Shulman, & Petersen, 1993). The subjects participated in one practice block of 10 trials in the same arms position – response hand – visual field condition as their first test block. There were 16 test blocks consisting of 40 trials each. In half of the blocks stimuli were presented in the left visual field (LVF) and in the other half, stimuli were presented in the right visual field (RVF). Blocked visual field presentation was used instead of the more prevalent random visual field presentation in order