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Homotopy and heterotopy and the bilateral field advantage in the Dimond paradigm

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Abstract

Pairs of homotopic and heterotopic visual bilateral stimuli and pairs of unilateral visual stimuli were presented to 12 normal right-handed university students requiring a key press if they were of the same form. As predicted from the known histology of the corpus callosum (massive preponderance of homotopic fibers), homotopic presentations yielded significantly faster reaction times than heterotopic stimulations. Bilateral pairs of stimuli were also advantaged in comparison with unilateral trials, replicating Sereno and Kosslyn [Sereno, A. B., & Kosslyn, S. M. (1991). Discrimination within and between hemifields: a new constraint on theories of attention. *Neuropsychologia*, *29*, 659–675]. Moreover, certain attentional processes have never been investigated in the Dimond paradigm and this study provides evidence to the effect that discriminative reaction times to stimulus pairs are strongly influenced by their proximity to the fixation point. In similar previous experiments, the homotopy/heterotopy observation and the bilateral field advantage may have been distorted by that particular confound, as well as several others.

Keywords: Dimond paradigm; Bilateral field advantage; Simple reaction time; Heterotopy; Homotopy

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1. Introduction

1.1. Major paradigms of behavioral investigation of interhemispheric dynamics

Poffenberger (1912) introduced behavioral investigation of interhemispheric dynamics by inferring and demonstrating that stimuli presented to a visual field and responded to with the contralateral hand ought to produce RTs a few ms longer than stimuli responded to with the ipsilateral hand—due to the cost of interhemispheric relay. This difference in RT has been termed the crossed–uncrossed difference (CUD), and by extension, "interhemispheric transfer time" or IHT. This elegant prediction remains one of the rare instances where a simple brain circuit has yielded highly constrained and precise predictions at the level of RT. Over a hundred RT investigations have since confirmed Poffenberger's prediction. A second simple circuit-based prediction would state that cross-field stimulus pairs should entail the same cost (relative to within-field pairs) as in the Poffenberger paradigm, for the same reason (the necessity of interhemispheric relay should entail additional time for relay along an extra neuronal distance). In other words, unilateral stimulus arrays (at least those in the advantaged field, if such were to be the case) should entail shorter RTs than bilateral stimulus arrays. After several dozens of experimental investigations, this simple inference has been rejected because it is the cross-field situation (bilateral field) which generally yields the *shortest* RTs, even shorter than the shortest within field condition (unilateral stimulation) (Banich & Belger, 1990; Brown & Jeeves, 1993; Dimond & Beaumont, 1972; Jeeves & Lamb, 1988; Ludwig, Jeeves, Norman, & DeWitt, 1993; Norman, Jeeves, Milne, & Ludwig, 1992; Sereno & Kosslyn, 1991; Taroyan, Myamlin, & Genkina, 1992). Hatta and Tuji (1993) obtained less errors from bilateral presentations than from unilateral ones. Complex neurocognitive models have been posited to explain this surprising phenomenon (Merola & Liederman, 1990) termed the bilateral field advantage (BFA), but none of these models is constrained by simple non-controversial anatomical facts about specific circuits. Still, there is no doubt that the callosal fibers contribute to cross-field integration: (1) the BFA correlates negatively with the CUD (Braun, Collin, & Mailloux, 1997) and (2) bilateral stimuli cannot be discriminated by persons without callosi (Brown, Jeeves, Dietrich, & Burnison, 1999). The present paper addresses two questions: (1) Do homotopic displays yield faster RTs than heterotopic presentations? (2) Are homotopy/heterotopy and BFA effects influenced by their position relative to the fixation point?

1.2. Homotopy and heterotopy interhemispheric exchange

However, as the paradigm has become more sophisticated and various modulations and correlates of the CUD have been reported, few behavioral inferences have been made based on other specific neural circuit properties of the interhemispheric commissures. One simple and specific circuit property of the mammalian interhemispheric commissures is that they are composed of a much greater number of homotopic than heterotopic connections (Heimer, Ebner, & Nauta, 1967; Innocenti & Bressoud, 2000; Miller & Vogt, 1984; Rosenquist, 1985; Springer & Deutsch, 1985).