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Bilateral field interactions, hemispheric specialization and evoked potential interhemispheric transmission time

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Abstract—The interrelationship between bilateral visual field processing, hemispheric specialization and interhemispheric transmission time (IHTT) was examined in two experiments in order to test two theories regarding callosal function and lateralized visual processing. Contrary to both theoretical speculations [Braun, *Neuropsychology Review*, Vol. 3, pp. 321–365, 1992] and a recent report [Nowicka *et al*., *Neuropsychologia*, Vol. 34, pp. 147–151, 1996], the directional asymmetry in evoked potential measures of IHTT did not vary with task differences in indices of hemispheric specialization. IHTT was faster from right to left hemispheres regardless of visual field advantage for the task. Similarly, patterns of correlation between IHTT and bilateral field advantage did not change between verbal and spatial matching tasks, despite differences in visual field advantage. Since the latter data did not consistently support the Brown and Jeeves [*Neuropsychologia*, Vol. 31. pp. 1267–1281, 1993] hypothesis, an alternative hypothesis involving hemispheric asymmetries in attention rather than processing specialization was proposed. © 1997 Elsevier Science Ltd.

Key Words: corpus callosum; hemispheric asymmetry.

Introduction

Recent research concerning the corpus callosum has focused attention on asymmetry in transmission speed and the functional significance of this asymmetry for interhemispheric interactions and hemispheric specialization. Faster transmission has been noted from the right hemisphere to the left hemisphere (compared to left-to-right transmission) in both crossed–uncrossed differences (CUD) in RTs [5–7, 17] and visual evoked potentials [9]. One area of debate concerns reports that the asymmetry in speed of callosal transmission may be dynamically related to task specific differences in hemispheric dominance [5–7, 22]. Another area of debate concerns how IHTT affects performance on bilateral information matching tasks. Brown and Jeeves [8] proposed that the performance advantage for bilateral (vs unilateral) visual matching is related to faster IHTT from the hemisphere that is specialized for the task to the nonspecialized hemisphere, resulting in enhancement of processing in the less able hemisphere. This paper presents data which address both of these areas of debate.

Interhemispheric transmission time

Early efforts to analyze the speed of interhemispheric transmission relied on behavioral data. These studies of the crossed–uncrossed difference (CUD) were modeled on Poffenberger's [23] classic experiment in which he used RTs to estimate the time it takes information to cross the corpus callosum. Subjects were presented with visual stimuli lateralized to one visual field (and consequently to one cerebral hemisphere). Interhemispheric transmission time (IHTT) was thought to be indexed by the difference between crossed and uncrossed manual response times. Poffenberger's experiment has been replicated and modified by others who have consistently found a crossed–uncrossed difference of 2–3 msec (reviewed by Bashore [3]).

Saron and Davidson [30] suggested that such RT studies have several limitations, the most important of which

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is the fact that the evidence of interhemispheric transfer provided by such a methodology is indirect. It is possible that noncallosal neural paths mediate the crossed motor response. After finding a crossed motor response in acallosal patients, Jeeves [13] suggested that, at least for these subjects, CUDs involve neural pathways other than the corpus callosum. CUDs in patients with callosal agenesis are consistently longer than normal subjects [13, 14, 19]. Berlucchi, *et al*. [4, 32] have recently replicated the prolonged CUDs in patients with callosal agenesis or complete callosotomies, but report normal CUDs in patients with partial callosotomies, whether anterior or posterior. Thus, many portions of the corpus callosum can mediate rapid crossed manual reaction time. Estimates of IHTT based on CUDs are thus complicated by the fact that they may reflect transmission via several different callosal and non-callosal pathways, each of which may have a different speed of transmission.

A complementary approach to RT studies of IHTT has been developed using evoked potentials (EPs). This approach involves presenting stimuli to one hemisphere and then recording resulting brain activity from both hemispheres. IHTT is estimated from the latency difference between EP components recorded from the hemisphere contralateral to stimulation (direct projection pathway), vs the latency of EPs from the hemisphere ipsilateral to stimulation (callosal pathway). This method has been used with somatosensory [11, 12, 29], auditory [20], and visual stimuli [1, 8, 9, 15, 16, 25, 27, 28, 31]. Visual evoked potential (EP) studies estimated IHTT to be much longer than RT studies. Andreassi *et al*. [1] and Ledlow *et al*. [15] found that simple visual stimuli yielded EP latency differences (EP-IHTT) of 19.3 msec and 18 msec, respectively, while Rugg and Beaumont [26] observed a difference of 15.2 msec for more complex stimuli. Lines, Rugg and Milner [16] report shorter EP-IHTT for central than for occipital recordings which they suggest represents a unique measurement of transfer across more anterior callosal pathways.

Asymmetry in IHTT

Marzi *et al*. [17] reported asymmetries in IHTT in a metaanalysis of CUD studies. The CUD studies they examined produced a consistent finding of faster IHTT from the right to the left (IHTT R-to-L) than from the left to the right (IHTT L-to-R). They concluded that this asymmetry in IHTT is the result of

> "an asymmetry in callosal connections, with a greater number of neurons projecting from the right hemisphere to the left, than vice versa" [17], p. 1175.

Braun and his colleagues [5–7] reviewed a body of literature and report experimental results suggesting that the direction of the asymmetry in IHTT (as estimated by CUD) is related to task-specific differences in hemispheric dominance as measured by a visual field advantage. They proposed that during processing of a task that is right hemisphere dominant, IHTT would be faster from the right hemisphere to the left than in the other direction, but that this asymmetry reverses for a left hemisphere dominant task (i.e. IHTT is faster L-to-R).

Consistent with Marzi *et al*. [17], Brown, Larson and Jeeves [9] presented a meta-analysis of evoked potential studies demonstrating that IHTT is reported in most studies to be faster from the right hemisphere to the left. These authors also presented additional evidence from their own EP study that IHTT is faster R-to-L. Brown, Larson and Jeeves argued (on the basis of what few studies were available reporting visual field advantages) that the same pattern of directional asymmetry appears to be present regardless of the visual field advantage elicited in the task.

However, Nowicka, Grabowska and Fersten [22] have recently presented data which suggest that hemispheric specialization affects EP-IHTT asymmetry. They found that for a verbal task (for which the left hemisphere was believed to have been dominant) IHTT was faster R-to-L than L-to-R, while for a spatial task (for which the right hemisphere was believed to have been dominant), IHTT was faster L-toR than R-to-L. Like Braun, they concluded that asymmetry in IHTT is a function of hemispheric specialization. However Nowicka *et al*. proposed that IHTT is faster when information is transferred from the hemisphere not specialized for task processing to the specialized hemisphere, an asymmetry opposite in direction to that proposed by Braun on the basis of CUD research.

Callosal function and the bilateral field advantage

To determine the relationship between bilateral field advantage and the speed of callosal transmission, Brown and Jeeves [8] measured EP-IHTT while subjects performed a letter matching task which elicited a bilateral field advantage (BFA). They found that EP-IHTT was negatively correlated with BFA (i.e. faster EP-IHTT is associated with a larger advantage for bilateral processing) and that the correlation with BFA was asymmetric. That is, EP-IHTT calculated for speed of transmission from the left (more verbal) hemisphere to the right (less verbal) hemisphere was significantly correlated with BFA ($r = -0.50$) while transmission in the opposite direction (right to left) was not correlated with BFA ($r = -0.03$).

Based on this finding, Brown and Jeeves proposed a theory of asymmetric homologue enhancement (AHE). That is, bilateral processing was enhanced by the speed with which the left hemisphere transmitted assistance to the right hemisphere to facilitate the less competent verbal processing of the right hemisphere. They suggested that since the right hemisphere does not specialize in the analysis of verbal information (i.e. the letter names), it requires facilitation from the left to refresh the mental