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Bilateral field advantage and evoked potential interhemispheric transmission in commissurotomy and callosal agenesis

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Abstract

The role of the corpus callosum versus other cerebral commissures in the interhemispheric integration of visual information was studied in four individuals with complete agenesis of the corpus callosum, two individuals with partial agenesis, one total commissurotomy patient, and normal individuals. Evoked potential (EP) indices of interhemispheric transmission of visual sensory responses were observed during matching of unilateral and bilateral visual field letters and patterns. Neither the commissurotomy nor any of the acallosal patients had ipsilateral hemisphere visual EPs (P1 and N1), demonstrating that the posterior callosum is necessary for interhemispheric transmission of these components of visual evoked potentials. While the commissurotomy patient could not compare bilaterally presented letters, the anterior commissure of the acallosal patients appeared to be sufficient for interhemispheric comparison of single letters. However, bilateral comparison of more complex visual patterns resulted in considerable difficulty for complete agenesis patients, while comparison of patterns was more nearly normal when anterior callosal fibers were present (partial agenesis). © 1999 Published by Elsevier Science Ltd. All rights reserved.

1. Introduction

Although a large portion of the posterior corpus callosum is made up of fibers crossing between the extrastriate visual processing areas of the two hemispheres, the specific role of the corpus callosum in the integration of information from the two visual fields is as yet uncertain. Numerous reports have appeared of behavioral studies of visual cross integration in commissurotomized patients. The majority of experiments with commissurotomy patients suggest that surgical cutting of all the cerebral commissures leaves the patient unable to integrate or compare bilaterally presented visual stimulus information [73,75–78]. Nevertheless, a few studies have reported that split-brain subjects may be able to accurately compare simple, easily encoded properties of visual stimuli across the midline [34,50,70]. However these results remain controversial [15] since it is not clear whether information might have been cross-signaled by the subjects in some bodily form.

Studies of individuals with total agenesis of the corpus callosum (acallosals) provide additional evidence for the role of the corpus callosum in bilateral integration of visual information [37]. This research generally indicates that acallosal subjects can perform bilateral comparisons of visual stimuli in experimental tasks in which a commissurotomy patient would show no evidence of interhemispheric transfer [27,31,36,38,49,67]. However, this same research shows that the performance of acallosal subjects on interhemispheric comparisons of bilaterally presented visual information may be in some circumstances deficient compared to normals [27,38]. These data suggest that,

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whereas the corpus callosum is not necessary for comparing certain stimuli presented to the two visual fields, the callosum contributes to accuracy and efficiency.

An important dimension mediating the success of interhemispheric comparisons of information may be the complexity of the information to be transferred [27,38]. An example of the importance of complexity in the adequacy of callosal transfer can be found in studies of interhand transfer of tactile learning in the Tactile Performance Test (Form Board). The standard administration of this test is to have subjects put all of the blocks in the appropriate locations on the board (while blindfolded) using the dominant hand, then to do the same with the nondominant hand on a second attempt at the same board. Normal individuals show considerable saving when shifting to the nondominant hand. Early reports had suggested that individuals with complete agenesis of the corpus callosum have difficulty transferring the tactile-spatial learning between hands [22,29,30,57,63,71]. However, Sauerwein and her colleagues reported no deficits in interhand transfer of tactile memories in a test using the 6-block form of the puzzle. A subsequent study using an 8-block version of the TPT [23] indicated mild deficits in acallosals. Finally, Sauerwein and Lassonde [68] reported a marked deficit in interhand transfer on the TPT using the same ACC subjects previously tested, only this time using the 12-block version. Thus, while interhand transfer of simple tactile-spatial information (6-block patterns) was possible in acallosals, increasingly significant deficits were apparent as the complexity of the information to be transferred increased from 6 to 8 to 10-block patterns. It is possible that the same is true of the interhemispheric transfer of visual information. In normal individuals, Jeeves and Lamb [32] demonstrated an effect on interhemispheric transmission rate of complexity defined as the amount of distortion in bilaterally presented visual patterns that subjects were asked to compare.

1.1. Bilateral field advantage

The bilateral field advantage (BFA) is an index of the speed and accuracy in comparing two visual stimuli when presented simultaneously one stimulus to each visual field, compared to performance when both stimuli are presented to the same visual field. Specifically, there is an advantage in both reaction time and the percentage of correct trials when two visual stimuli to be compared are presented bilaterally (one to each visual field) rather than unilaterally [3,5,6,11,18,19,32,40,42]. There is some evidence that in normals this advantage for bilateral trials increases as the difficulty of the task increases [3,48,51]. Because the stimuli in the two hemispheres must be compared before a decision is made, it is reasonable to assume that the BFA relies in some manner on callosally mediated interhemispheric interactions. It is clear that commissurotomy patients would not be able to make the bilateral matches on the specific tasks in which normals manifest a bilateral advantage [15,16,34,77,78]. However, to the degree that the corpus callosum (vs other cerebral commissures or subcortical pathways) is critical to the BFA, the bilateral advantage should diminish or disappear in acallosal patients, suggesting a decreased ability to compare bilaterally presented visual information.

1.2. Evoked potential indices of interhemispheric transfer

An increasing number of studies have used visual evoked potentials (EPs) as an electrophysiological probe of the transfer of stimulus-locked neural activity between the hemispheres in normals [10,11,12,41,59–61,65], acallosals [10,62], and commissurotomy patients [10,43]. In normals, the early P1 (approximately 100 ms post stimulus) and the N1 (approximately 150 ms) components of the cross-callosal evoked potential are consistently found to be smaller in amplitude and delayed in latency in comparison to the response recorded over the directly stimulated hemisphere. The latency delay (between approximately 10 and 15 ms) has consistently been interpreted as an index of interhemispheric transfer time (IHTT) (see Brown et al. [12] for a meta-analysis of EP-IHTT). This EP method has been demonstrated to be a reliable method of measuring IHTT [65].

Converging evidence suggests that EP-IHTT is sensitive to the development and integrity of the corpus callosum. Salamy [64] studied somatosensory EPs and found that EP-IHTT was significantly negatively correlated with age in the 3.75–13 year range, but not significantly correlated in the 10–20 year range (when the callosum is already mature). Similarly, Thompson et al. [79] have recently reported that both visual EP interhemispheric transfer time and the BFA manifest a developmental progression that reaches asymtote between 6 and 12 years of age, suggestive of the developmental progression of myelinization of the corpus callosum [2,80]. Thus, EP-IHTT is sufficiently sensitive to reflect developmental changes in the corpus callosum.

Rugg et al. [60] have presented data demonstrating that the cross-callosal P1 and N1 is absent in individuals with agenesis of the corpus callosum, despite normal appearing waveforms over the directly stimulated hemisphere. Similarly, one abstract has been published suggesting the possibility of a similar EP pattern in commissurotomy patients [43]. To our knowledge, replications of these studies have not been reported,