

ENHANCED DUAL TASK PERFORMANCE FOLLOWING CORPUS COMMISSUROTOMY IN HUMANS*

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Abstract—A commissurotomy patient and two neurologically intact control observers were required to encode spatial patterns presented concurrently to the two hemifields. Under conditions of maximal perceptual load, in which different patterns appeared in the two fields, the commissurotomy patient encoded more information than the control observers. Based on these findings, it is concluded that competition for common internal processing mechanisms interferes with overall processing efficiency.

INTRODUCTION

WHAT FACTORS determine how well a particular task is performed? One popular theoretical distinction has been between task-independent factors, such as how much “effort” or “resource” is committed to a particular task, and task-dependent factors, which include the input and output modalities that are utilized in the performance of the task, as well as the requisite internal cognitive operations. When the former factors are manipulated, it is generally termed a “resource” manipulation; when the latter are manipulated, it is generally termed a “structural” manipulation [9].

One major theoretical goal has been the specification of individual processing structures. The componential analysis of task performance derives in large part from the results of selective interference paradigms, in which observers are required to perform two tasks concurrently. The guiding assumption of this approach is that the less two tasks interfere with one another, the less they compete for common processing structures. For example, with regard to sensory systems, TREISMAN and DAVIES [18] found that two shadowing tasks were performed better when presented to different modalities (e.g. auditory/visual) than when they shared the same modality (e.g. auditory/auditory). With regard to motor systems, MCLEOD [12] found that a manual tracking task was performed better when paired with a vocal reaction-time task than when paired with a manual reaction-time task. On the basis of these results, it has been argued that the processing of auditory and visual stimuli, and the generation of vocal and manual responses, are subserved, at least in part, by different processing structures (for discussion, see WICKENS [19]).

One inherent problem with this approach is that individual processing structures can only be inferred indirectly based on performance under various constellations of *different* dual-task pairings. Such an analysis implicitly assumes that any additional demands created by

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pairing tasks (termed "emergent processes" by DUNCAN [2]) are directly related to the shared components of the tasks. There is no reason to assume this is necessarily the case. Moreover, the selective interference approach to specifying processing structures—i.e. if two tasks fail to compete, they must rely on different processing structures—is tautological. This presents significant problems when processing structures are unknown in advance and inferred *post hoc* on the basis of dual-task performance, such as whether two tasks rely on different kinds of memory [11].

The motivation for the present experiments was to provide direct evidence that the less two tasks rely on common internal processing mechanisms, the better they are performed. The subject for this study has undergone surgical transection of the corpus callosum for the control of intractable epilepsy. As a consequence of this surgery, visual information lateralized to the left visual field is almost exclusively processed by the right hemisphere; visual information lateralized to the right visual field is processed by the left hemisphere [7]. Thus, for this subject, it was assumed that the separated hemispheres function as independent processors, an assumption that has been verified in other experimental contexts [5, 14]. It was reasoned that, if competition for common processing structures is detrimental to overall performance, then the performance of commissurotomy patients at two concurrent tasks, one of which is lateralized to each visual field and thereby isolated to a single hemisphere, should exceed that of neurologically intact observers, in whom visual information is transferred between the hemispheres via the corpus callosum. In general, the present findings confirm this hypothesis, and imply that competition for common internal processing mechanisms interferes with overall processing efficiency.

METHODS

Subjects

One commissurotomy patient, J.W., and two neurologically intact control observers participated in this study. A detailed neurological history of J.W. is provided elsewhere [15]. Briefly, J.W. is a 30-yr-old right-handed male who suffered from intractable epilepsy since age 19 yr that could not be controlled with anti-epileptic drugs. Over the summer and fall of 1979, he underwent a two-stage microneurosurgical section of his corpus callosum [20] with the anterior commissure left intact. The posterior portion of the callosum and splenium were sectioned first, with the remaining anterior portion sectioned 10 weeks later because of a recurrence of seizures.

Both of the control observers are right-handed female members of the laboratory in their early thirties who were naive to the purposes of the experiment.

Apparatus

During the experiment the observer, seated 0.5 m from a video monitor, viewed stimuli generated by an Apple II microprocessor. Two manual response keys were situated in front of the subject and connected to the computer, which recorded observers' responses and response latencies, and stored the data on magnetic disk for subsequent analysis. Displays were viewed binocularly under normal daylight illumination. In order to confirm that trials in which central fixation was disrupted occurred infrequently, a video camera equipped with a 10:1 zoom lens recorded the observers' eye movements throughout the experiment.

Conditions

For all trials the observers fixated a central dot, 5° on either side of which a 3 × 3 cell grid was continuously displayed (see Fig. 1). Each cell subtended approximately 4° of visual angle. On each trial, a bilaterally displayed 2° "X" moved among four cells in the two grids. Each "X" was displayed for 150 msec, with a 500 msec interstimulus interval. After presentation of the bilateral "target" sequences, 1.5 sec elapsed, a tone sounded, and a unilateral "probe" sequence of four "X"s was presented. The probe sequence either moved among the same four cells in the same order as the probed field's target sequence, or one of the cells differed. The observer was instructed to indicate with the appropriate key press whether the probe sequence matched the probed field's target sequence.

The experiment consisted of two conditions. For the Redundant condition depicted in Fig. 1, the same target sequence was initially presented to the two fields. It was anticipated that this condition would impose minimal

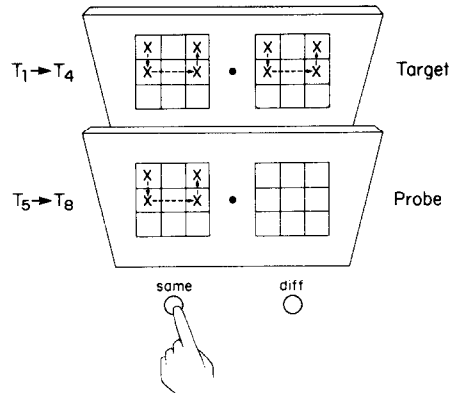


FIG. 1. Example of Redundant condition trial. On each trial, a bilaterally displayed target "X" moved among four homologous cells in the two matrices. A tone sounded, and unilateral probe sequence was presented. The observer indicated whether the probe sequence matched the probed field's target sequence. In this example, the bilateral target sequences began at time T_1 in the upper left corners of the two matrices and concluded at T_4 in the upper right corners, and the unilateral probe sequence was presented from T_5 to T_8 . All "X"s appeared for 150 msec with a 500 msec interstimulus interval, and the target and probe sequences were separated by 1.5 sec. Hence, the total time for each display was 5.7 sec, 2.1 sec for the target and probe sequences plus the 1.5 sec intersequence interval.

perceptual load on control observers, because accurate performance would require encoding of a single target sequence. In contrast, for the Mixed condition depicted in Fig. 2, different target sequences were initially presented to the two fields, a condition that should produce maximal perceptual load because two sequences had to be encoded. Trials were run in blocks of 48, with approximately 3 min rests between blocks. Each block consisted of an equal number of Redundant and Mixed trials, an equal number of trials in which the probe sequence appeared in the left and right visual fields, and an equal number of positive and negative trials. Trials were randomized within blocks, and response hand was varied across blocks in a counterbalanced order. A total of 288 trials was collected for J.W.; 192 trials for each of the control observers.

RESULTS

Correct responses as a function of condition and visual field are summarized graphically in Fig. 3. Each value represents the proportion of correct responses based on 72 replications for

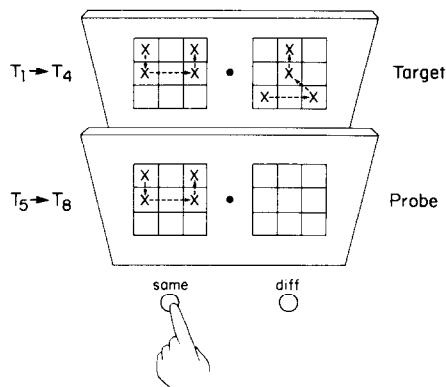


FIG. 2. Example of Mixed condition trial. Mixed condition trials differed from Redundant condition trials only in that different target sequences were presented to the two visual fields.

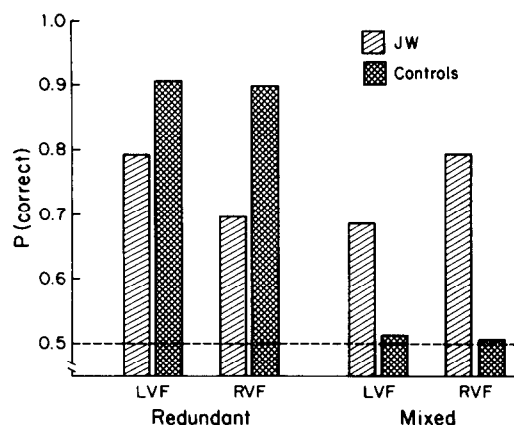


FIG. 3. Proportion of correct responses for left visual field (LVF) and right visual field (RVF) trials in the Redundant and Mixed conditions. Data are presented separately for commissurotomy patient J.W. and the average performance of the control observers.

J.W. and a combined total of 96 replications for the control observers. The average latencies of correct responses as a function of condition and visual field appear in Table 1. Data from the control observers are combined, with each observer given equal weight.

Overall, J.W.'s performance was very similar for the Redundant and Mixed conditions. Analysis of the accuracy data [21] revealed non-significant differences between conditions and between visual fields ($\chi^2_{(1)} = 0.01$ and 0.15 , respectively; n.s.), and a marginally significant condition by hemifield interaction ($\chi^2_{(1)} = 3.98$; $P < 0.05$). This interaction was not evident when the latency data were analyzed, however: A 2×2 analysis of variance revealed non-significant differences between conditions [$F(1, 207) = 0.17$; n.s.], visual fields [$F(1, 207) = 0.21$; n.s.] and condition by field interaction [$F(1, 207) = 0.03$; n.s.]. This latter result, and the additional finding that no significant differences between visual fields were noted for either the Redundant or Mixed conditions ($\chi^2_{(1)} = 1.29$ and 2.85 ; n.s.) suggests that the significant condition by hemifield interaction that was obtained probably arose due to chance variation. The results of an interfield comparison task also imply that J.W. was not combining information from the two hemifields. Here, when the same bilateral target

Table 1. Average response latencies in msec on correct trials for control subjects and J.W. (S.E. = standard error). Control subjects are averaged with each subject given equal weight

	Redundant		Mixed	
	LVF	RVF	LVF	RVF
Control				
X	1175	1227	1973	1990
(S.E.)	(175)	(167)	(271)	(314)
N	89	86	51	50
JW				
X	1220	1275	1260	1435
(S.E.)	(244)	(265)	(271)	(285)
N	56	50	48	57

sequences were repeated and J.W. was required to indicate whether they were the same (Redundant) or different (Mixed), his performance did not exceed chance levels (51/96; $z=0.61$; n.s.). Control observers performed this task without error.

It would appear, then, that J.W. found the Redundant and Mixed condition trials to be of comparable difficulty, presumably because each target sequence was encoded by a single hemisphere. This was not the case for either of the control observers. Both observers were significantly more accurate in the Redundant condition than in the Mixed condition ($\chi^2_{(1)} = 44.44$ and 28.02 ; $P < 0.001$), whereas no significant effects of visual field ($\chi^2_{(1)} = 1$ and 0.09 ; n.s.) or condition by hemifield interaction ($\chi^2_{(1)} = 0.11$ and 0 ; n.s.) were noted for either observer. The same general pattern of results also was evident when response latencies were analyzed. Both control observers responded significantly faster on correct Redundant condition trials than on correct Mixed condition trials [$F(1, 139) = 5.75$ and $F(1, 128) = 23.57$; $P < 0.05$ and $P < 0.001$, respectively]. Moreover, no significant effects of visual field [$F(1, 139) = 0.69$ and $F(1, 128) = 2.28$; n.s.] or condition by hemifield interaction [$F(1, 139) = 0.33$ and $F(1, 128) = 0.26$; n.s.] were noted for either observer. Thus, unlike J.W., each control observer had significantly more difficulty with the Mixed condition than with the Redundant condition.

The most interesting aspect of these data is J.W.'s performance relative to that of the control observers. In the Redundant condition, both control observers were significantly more accurate than J.W. ($\chi^2_{(1)} = 19.70$ and 5.68 ; $P < 0.001$ and $P < 0.05$, respectively), although the response latencies on correct trials were similar for J.W. and the control subjects [$t(196) = -0.74$ and $t(187) = 1.28$; n.s.]. In the Mixed condition, however, J.W. performed significantly *better* than both control observers ($\chi^2_{(1)} = 8.95$ and 11.98 ; $P < 0.01$ and $P < 0.001$, respectively), and also responded faster on correct trials, although this difference did not achieve significance when J.W. was compared to one of the control observers [$t(154) = -2.21$ and $t(152) = -1.78$; $P < 0.05$ and $P < 0.10$ respectively]. Moreover, J.W.'s performance in the Mixed condition did not differ for the first and second halves of the experiment ($P_{\text{correct}} = 0.76$ and 0.69 , respectively; $\chi^2_{(1)} = 0.88$; n.s.). Hence, his superior performance in the Mixed condition can not be attributed simply to increased practice relative to the control observers.

DISCUSSION

In general, two main conclusions are supported by these data. First, as anticipated, there is no interaction between visual information lateralized to J.W.'s left visual field and visual information lateralized to his right visual field. In other words, J.W.'s disconnected hemispheres function as independent processors. Thus, when each hemisphere is required to encode the *same* pattern of visual stimulation, overall performance is no better than when different patterns must be encoded. On the other hand, neurologically intact observers, in whom visual information from the two hemifields is not cortically segregated, perform much better when the same pattern is presented to the two hemifields. Second, and presumably as a consequence of independent processing in J.W., the concurrent encoding of bilaterally presented visual information is enhanced relative to control observers. This was noted under conditions in which different patterns were presented to the two hemifields, where J.W.'s performance was superior to that of both control observers. This finding was not obtained simply because J.W. is more skilled at apprehending spatial patterns than are the control observers. If he were, then he also should have performed better than the control subjects in

the Redundant condition, where separate processing systems would provide no advantage, rather than significantly worse. Thus, if anything, J.W. is impaired at encoding spatial patterns relative to the control subjects, a circumstance that makes his superior performance in the Mixed condition even more striking.

It should be emphasized that all subjects were required to perform the same task in this experiment—compare a visual probe to a visual target and generate a manual response. Thus it is probable that any performance differences between subjects are not due simply to different demands on sensory and/or motor systems, but, rather, to limits in how efficiently information is extracted from the visual environment. Under such conditions it was found that when the exchange of information between the cerebral hemispheres is surgically eliminated, the result is an increased capacity to apprehend conflicting visual information from the two hemifields. Thus it would appear that the general finding that the less concurrent tasks compete for common input and output modalities the better they are performed, also holds true with regard to internal processing mechanisms.

However, an alternative explanation of these findings also must be considered. The general pattern of results obtained here also would be expected if J.W.'s attention on any given trial was exclusively directed to one visual field. When the probe sequence appeared in the attended field, J.W. would respond correctly on all of these trials; when it appeared in the unattended field, a guessing strategy would result in a correct response on half of these trials. If such a strategy were used, J.W.'s overall performance should average 0.75 correct, which is very close to the 0.74 and 0.73 correct obtained in the Redundant and Mixed conditions, respectively.

Additional findings from J.W., however, rule out this interpretation. Central to the above explanation is the assumption that J.W. should perform at near-perfect levels when the probe sequence appears in the attended hemifield. In order to determine whether this occurs, 288 additional trials were run in which the test and probe sequences were presented unilaterally. On these trials, J.W. correctly indicated whether the two sequences matched on 0.82 and 0.73 of the left and right visual field trials, respectively. Thus, under conditions of unilateral stimulation, in which there was no ambiguity as to which hemifield would be probed, J.W.'s performance did not improve appreciably from his performance under conditions of bilateral stimulation. If J.W. were simply attending to a single hemifield on bilateral trials, these unilateral scores would predict an overall performance of 0.64 correct. This value is significantly lower than that actually obtained on bilateral trials ($z=3.37$; $P<0.001$). Thus, a strategy to attend to a single hemifield on bilateral trials cannot explain J.W.'s performance in the Redundant and Mixed conditions.

A total of 96 additional unilateral trials also was collected from each of the control observers, who responded correctly on 0.96 and 0.97 of the left and right visual field trials, respectively. These scores are significantly more accurate than the unilateral scores obtained for J.W. ($\chi^2_{(1)}=10.16$ and 32.36 ; $P<0.001$), a finding that provides further confirmation that J.W. was paired with controls who are relatively better at encoding spatial patterns.

In summary, the present results demonstrate that the surgical transection of the corpus callosum can enhance the efficiency with which information is extracted from the visual environment, and thereby confirm the general hypothesis that competition for common internal processing mechanisms is detrimental to overall task performance. It should be pointed out that the enhanced processing capacity obtained here is not generally the rule in commissurotomy patients. Typically, commissurotomy patients show decreased interference between conflicting tasks, but a failure overall to exceed the performance of

neurologically intact observers. In most cases, this diminished performance is attributable either to deficits in alternating responses between the hemispheres [4, 6, 10, 16, 17]; maintaining prolonged activation of a single hemisphere [1, 3]; or generating bimanual responses [13]. Furthermore, the disconnected hemispheres have been shown to rely on a common source of attentional activation [8], a factor that further limits concurrent task performance in these patients. In the present context, an effort was made to minimize those factors that impair the performance of commissurotomy patients (e.g. trials were relatively short, a single hemisphere responded on each trial, and a unimanual response was required), so as to maximize any potential benefit of the functional disconnection of the cerebral hemispheres. Under such circumstances, superior performance by commissurotomy patients can be demonstrated.

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