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CEREBRAL SPECIALIZATION AND HEMISPHERIC PERFORMANCE ASYMMETRIES IN NARRATIVE MEMORY[1]

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Summary.—Data on cerebral specialization derived from studies of human head-injuries have long implicated the left hemisphere's critical role in speech processing and verbal memory. We report a relatively simple paradigm which demonstrates an analogous asymmetry in narrative recall performance in normal subjects when either one hemisphere or the other is concurrently engaged with control of a secondary motor task. Caution in generalizing these data to performance asymmetries in brain-injured patients is nevertheless required.

There are upper limits to human attentional capacity which become dramatically apparent in performance decrements as one engages in more than one task at a time. There is, however, little agreement on why this is so, or on how to characterize those tasks which, when performed concurrently, yield the greatest interference. The amount of interference between any two tasks could depend on their information complexity (2), their degree of "automaticity" (11), whether they draw on the same cognitive structures (4), or whether they involve the same sensory or response modalities (10).

More recent speculation has focused more directly on known or presumed functional organization within the brain; the "closeness" of the cerebral areas of functional control of the tasks in question. For example, the amount of interference might differ if a speech task (controlled by the left hemisphere in right-handed individuals) is performed concurrently with a manual task using the left hand (controlled by the right hemisphere) than if the manual task is done with the right hand (both tasks competing for processing capacity within the same left hemisphere) (3, 6, 8). Similarly, monitoring concurrent messages would be difficult because both must compete for the same speech areas in the left hemisphere. While intuitively appealing, "functional distance" and its expected consequences have remained ill-defined and the motor and speech tasks used to test this hypothesis have not been amenable to precise measurement of the amount of interference (7, 8).

The importance of establishing methods to allow generalization from studies of brain lesions to normal brain specialization, however, prompted us to use a so-called dual-task paradigm in a slightly novel way. Twelve right-handed male undergraduates were required to engage in a visual tracking task using a hand-held stylus to track a

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moving spot of light through a 30-rpm triangular pattern on a visual display. The stylus tip held a photo-cell in circuit with a timer which gave an accurate record of the subject's total time-on-target over a series of preset 15-sec. tracking time periods. Subjects tracked either with the right hand (left hemisphere control) or with the left hand (right hemisphere control) in counterbalanced order.

In the dual-task conditions, subjects concurrently heard prerecorded 60-word narratives through earphones for immediate spoken recall. As a narrative was presented to one ear, irrelevant masking speech was delivered to the other ear. Such "dichotic" conditions are usually assumed to give analytic priority to the opposite (contralateral) hemisphere from the ear being stimulated (5), although right ear advantages for speech are ordinarily small and their interpretation is complex (12). In our procedures, subjects always tracked with the hand contralateral to the ear in which the narrative was presented; if the narrative was presented to the right ear (left hemisphere), tracking was always performed with the left hand (right hemisphere) or vice versa. Our interest was to compare performance at recall for speech delivered to the left hemisphere, while the right hemisphere was engaged by the tracking task, with recall under the reverse conditions. (Accepting contralateral priority, of course, does not assume that auditory information is accessible only to, or remains confined in, the hemisphere contralateral to the ear of stimulation. Neither the anatomy of the auditory system nor the presence of the *corpus callosum* suggests this would be so.)

To the extent that these procedures would reflect verbal performance with either one hemisphere or the other diminished in effectiveness through interference, one might expect results analogous to those produced by right- or left-hemisphere lesions. Our narratives were taken from the Wechsler Logical Memory Scale, which elicits greater memory deficits in patients with unilateral left than right hemisphere lesions (1). Our question was whether we could simulate such effects using this paradigm with normal subjects.

Fig. 1 shows mean tracking accuracy for the two hands in terms of the percentage of total time-on-target in (A) a control condition where subjects tracked alone without concurrent speech, (B) tracking while listening quietly to the narrative for later recall, and (C) tracking while in the act of spoken recall.

Fig. 1 shows an over-all right-hand superiority in tracking accuracy ($F_{1,11} = 14.72$, $p < .01$), a decline in accuracy across the three conditions ($F_{2,22} = 12.90$, $p < .001$), and an approximately equal superiority of right-hand over left-hand tracking in all three conditions (interaction of conditions × hands, $F < 1.00$). Supplementary analyses showed that the significant effect of conditions was primarily attributable to the decline in tracking accuracy during recall as compared with tracking accuracy alone ($p < .001$), or tracking while listening ($p < .05$). The reduction in tracking accuracy while listening as compared with tracking alone was not significant. That is, active recall of a narrative has an effect on concurrent tracking accuracy that simply listening to a narrative for later recall does not. The effect, however, is one of general interference, the depressed tracking accuracy being approximately equal for both hands.

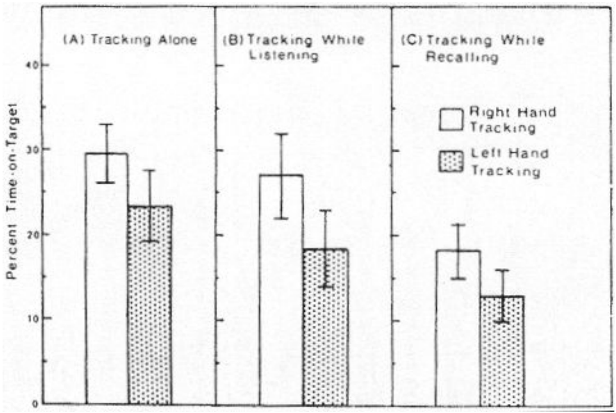

FIG. 1. Mean percentage time-on-target in (A) visual tracking alone, (B) visual tracking while listening to a narrative for later recall, and (C) visual tracking while in the act of spoken recall. Data are shown for right- versus left-hand performance.

Fig. 2 shows the recall performance for speech delivered to the left hemisphere with the right hemisphere engaged by tracking control, and vice versa. Our scoring method, based on narrative structure (13), shows memory performance for the major story elements, or "gist" (Level I), and for three increasingly specific levels of detail (Levels II-IV). There is a significant decline in recall accuracy with increasing levels of narrative detail ($F_{3,33}$ = 53.72, $p < .001$), with narrative recall significantly poorer when the story is presented to the right hemisphere with the left hemisphere occupied, than when the story is presented to the left hemisphere with the right hemisphere occupied ($F_{1,11} = 8.67$, $p < .025$). The effect appears slightly greater for detail than gist, but the interaction of levels × hemispheres was not significant ($F <$ 1.00). The upper curve, where the left hemisphere was not engaged by tracking, was not significantly different from control samples where narratives were simply recalled without concurrent tracking. These effects held for individual subjects and were independent of the particular narratives being heard under each condition.

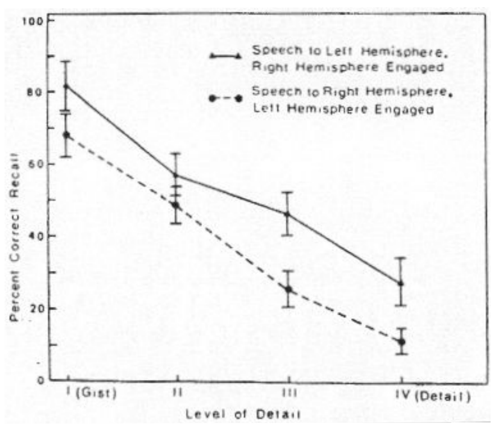

FIG. 2. Percent correct recall of narrative prose for four levels of detail when speech was delivered to the left hemisphere with the right hemisphere engaged by a secondary task and speech delivered to the right hemisphere with the left hemisphere engaged by a secondary task

Our results thus mimic the performance decrements in verbal memory typically associated with unilateral left hemisphere lesions as compared with right hemisphere lesions (1). This is especially dramatic since any attempt to simulate the effects of lowered functioning of one hemisphere or the other in a normal brain with intact *corpus callosum* is bound to be incomplete. This interpretive caution cannot be stressed too highly. As with ordinary data on lesions, decrements could arise either from use of some ordinarily redundant language potential in the right hemisphere or from diminished residual left hemisphere function (9), in this case, the dominant hemisphere working under experimentally induced handicap. It is this latter case of interference that seems most likely for our data.

Parallel experiments in which subjects merely "shadowed" speech (repeating it word-for-word as it was heard) showed only small nonsignificant decrements on the speech task while tracking, and on tracking while speaking, and without the asymmetries we observed for spoken free recall. Nor did dichotic presentation alone without concurrent tracking show a significant difference between ears. While input analyses of the narratives may have been poorer with left-hemisphere interference, the effect appears clearly measureable only when overt recall is required while concurrently tracking. We can therefore tentatively locate the effects on the organization of the verbal materials in recall rather than on perceptual processing or speech activity *per se*.

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