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NOTE

A LEFT HEMISPHERE BASIS FOR VISUAL MENTAL IMAGERY?*

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Abstract—The lateralization of visual mental imagery was investigated by presenting each hemisphere of a commissurotomy patient with a letter classification task known to require imagery and with a pair of control tasks designed to require all of the same processes as the imagery task except for the imagery processing itself. Whereas both hemispheres performed well on the control tasks, only the left hemisphere performed the imagery task.

INTRODUCTION

Is VISUAL imagery a lateralized function of the brain? If so, which hemisphere is specialized for imaginal thought? The superiority of the right hemisphere in many visual/spatial tasks might suggest a right-hemispheric locus for visual imagery. However in a recent review of the relevant findings, ERLICHMAN and BARRETT [1] found no clear support for this hypothesis. They distinguished between evidence relevant to the neural basis of visual imagery *per se*, and evidence relevant to other aspects of visual/spatial cognition, such as visual recognition and performance on so-called "spatial ability" tasks. They concluded that there is little evidence for the claim that the right hemisphere plays a more central role than the left in visual imagery.

The present study included a simple task that is known to involve imagery, and control tasks that require all of the same cognitive operations as the imagery task except the generation and inspection of the image itself. The imagery task was a letter classification task studied by WEBER *et al.* [10, 11]. In this task, the subject classifies from memory letters of the alphabet according to the relative heights of their lowercase forms. Weber and his colleagues have found reaction-time evidence that subjects perform this task by generating an image of the lowercase letter and examining the image to assess letter height. In the present context, this imagery task was lateralized by presenting uppercase letters to either side of a fixation point, thereby cuing a single hemisphere with the letter whose lowercase form is to be classified.

In order to infer that a failure in this task reflects an imagery deficit *per se*, additional control procedures assessed each hemisphere's ability to perform all other components of the imagery task. A straightforward task analysis of the imagery task shows the required abilities to be: (1) recognizing an uppercase letter, (2) associating a lowercase form with the corresponding uppercase letter, (3) generating an image of the lowercase form, (4) classifying the image as to its height, and (5) responding. The two control tasks together require all of the above processes except

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for image generation and inspection. In the letter association task uppercase letters are presented to a single hemisphere and the subject's task is to select the corresponding lowercase form of the letter from an array of lowercase letters displayed in free vision. Successful performance of this task demonstrates that the hemisphere receiving the uppercase letter is capable of recognizing the uppercase letter and associating the correct lowercase form with the uppercase form of the letter. In the perceptual classification task lowercase letters are presented to a single hemisphere and the subject's task is to classify the letters as to their relative heights and respond. Unlike the imagery task, this task simply requires the subject to classify what he actually sees. Successful performance of this task demonstrates that the hemisphere receiving the lowercase letter is capable of performing the letter height discrimination and responding. It follows that if a hemisphere can perform the two control tasks but fails on the imagery task, then that failure cannot be attributed to a difficulty in perceptual encoding, letter processing, height discrimination or response production.

METHODS

Materials

Letters were generated by an Apple II microcomputer and displayed on a 15 in. display screen. An asterisk at the center of the screen functioned as a fixation point, and letter stimuli were presented for 150 msec at 1.5° to the left or right of the fixation point. The subject viewed the display at a distance of 1 m and rested his response hand on the table between two response buttons. Responses and response latencies were recorded by the Apple II computer. For the letter association control task lowercase letters were displayed in a non-alphabetical order on a sheet of paper located on the table in front of the subject.

Procedure

There were three different tasks: the imagery task, the perceptual classification control task, and the letter association control task. The first task performed by the subject was the perceptual classification control task. The subject was instructed as to the difference between "medium" letters (such as "a" or "s") and "not medium" letters (such as "t" or "g") and given practice pushing the "medium" and "not medium" response buttons. He was then presented with four blocks of 24 trials of the perceptual classification task. On each trial a lowercase letter would appear to the left or right of the fixation point and the subject would decide as quickly as possible whether the letter was medium or not. The "medium" letters were "a", "c", "e", "m", "n", "o", "r", "s", "u", "v", "w" and "z". The "not medium" letters were "b", "d", "f", "g", "h", "j", "k", "l", "p", "q", "t" and "y". The trials were presented in a random order determined in advance to distribute the different experimental conditions evenly throughout the task. Each letter occurred once in each block of 24 trials. Stimuli occurred to the left and to the right of the fixation point equally often in each block, with equal numbers of "medium" and "not medium" letters in each position in each of these blocks. Letters occurring in the left position in the first and third blocks occurred in the right position in the second and fourth blocks, and vice versa. In the first and fourth blocks of trials the subject responded with his left hand and in the second and third blocks he responded with his right hand. Both responses and latencies were recorded.

The second task performed by the subject was the letter association control task. The subject was shown two blocks of 24 trials, each block containing two presentations each of the uppercase forms of the letters used in the previous task arranged in a random order. In each block of trials, each letter was presented once in each position. After each stimulus presentation, the subject looked at the lowercase letters of the alphabet on a sheet of paper and pointed to the lowercase form of the uppercase letter that he had just seen. His pointing response was recorded by the experimenters.

The third task performed by the subject was the imagery task. The subject was asked to make the same judgment as in the first task—to classify lowercase letters as "medium" or "not medium"—using the uppercase forms of the letters as cues. The trials were presented in a random order, counterbalanced for the factors of stimulus position, response category and response hand and their interactions, in the same manner as in the first task. There were 192 trials in the imagery task, presented in four blocks of 48 trials each. As in the first task, the subject responded manually and both responses and response latencies were recorded.

Subject

The subject, J. W., was an alert 29-yr-old right-handed male with a history of staring spells since grade school. After his first grand mal at age 18, siezure frequency increased and became intractable. Midline section of the corpus callosum was performed in two stages by Dr. Donald Wilson of the Dartmouth Medical School. The posterior half of the corpus callosum including the splenium was sectioned first, with the remaining anterior portion sectioned 10 weeks later. The anterior commissure was left intact. Formal testing of the subject after surgery revealed that he could accurately name stimuli presented to the left hemisphere, but was unable to name any stimuli presented only to the right hemisphere. In contrast, comprehension of visual and auditory language was possible in both hemispheres in this subject. Additional patient information is provided elsewhere [3,9].

RESULTS

The percentage of correct responses from each hemisphere in each task is shown in Fig. 1. It is apparent in Fig. 1 that only the left hemisphere could perform the imagery task. The left hemisphere's performance on this task is essentially perfect, 97% correct, whereas the right hemisphere's performance is at chance levels, 43% correct. A Yates-corrected chi-squared test showed this difference to be significant, $\chi^2 = 64.25$; $P < 0.01$. The same trend was apparent in the response latency data. The right hemisphere responded more slowly on both correct trials (mean = 1349 msec; S.E. = 96 msec) and incorrect trials (mean = 2022 msec; S.E. = 141 msec), as compared with the left hemisphere's correct responses (mean = 1118 msec; S.E. = 23 msec). Thus, the greater accuracy of the left hemisphere cannot be accounted for by a speed–accuracy tradeoff. The disproportionate number of incorrect responses from the right hemisphere prevents a strict statistical comparison of the two hemispheres' response latencies.

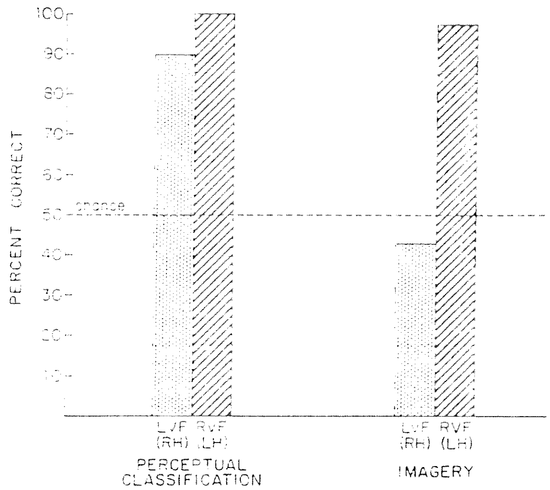

FIG. 1. Percentage of correct responses from each hemisphere in the imagery and perceptual classification tasks.

In contrast to the imagery task, both hemispheres can perform the control tasks quite well. In the letter association task, both hemispheres showed essentially perfect performance, with the left hemisphere responding correctly on 100% of the trials, and the right hemisphere responding correctly on 96% (i.e. all but one) of the trials.

For the perceptual classification task, Fig. 1 shows that the accuracy of the right hemisphere is 90% correct, and the accuracy of the left hemisphere is 100% correct. (A chi-squared test could not be carried out with the data from the two control conditions because of the low number of errors made by both hemispheres.) The possibility that a ceiling effect in the accuracy data from this task masked a larger difference between the two hemispheres' abilities to perform the perceptual height discrimination is dispelled by an examination of the response latencies for correct responses in this task. The left hemisphere did not respond more quickly to the lowercase letters; in fact, it was (nonsignificantly) slower, requiring on average 1057 msec (S.E. = 38 msec) compared to 1048 msec (S.E. = 36 msec) for the right hemisphere, $t < 1$.

DISCUSSION

Whereas both hemispheres performed the control tasks proficiently, their performances diverged sharply on the imagery task, with the left hemisphere performing essentially perfectly and the right hemisphere performing at chance levels. Our interpretation for this pattern of data is that the left hemisphere of this patient is adept at the use of visual imagery and the right hemisphere is not. It is relevant here to note that, to the extent that our subject's right hemisphere is atypical, it is capable of somewhat more varied and demanding tasks that the right hemispheres of most split-brain patients, and his left hemisphere has appeared to be quite normal throughout extensive testing [4, 9]. It remains to be seen whether further studies of imagery in split-brain patients, including imagery for non-verbal materials, will produce the same results.

Alternative interpretations turn on the assumption that the right hemisphere, while possessing all of the same relevant components of processing as the left, failed to integrate them to perform the imagery task. For example, perhaps the right hemisphere understood the nature of the control tasks, but did not understand the nature of the imagery task. Or, perhaps the right hemisphere was simply overloaded by the greater number of components that were required in the imagery task than were required in the control tasks. Indeed, a recent study of lexical knowledge with the same patient showed that the performance of his right hemisphere was highly sensitive to changes in task difficulty [5]. Although any right hemisphere failure is prone to such alternative accounts, the high level of performance of the present patient's right hemisphere on a variety of complex cognitive tasks, such as using a pre-cue to direct eye movements before the onset of a stimulus [6], distinguishing between semantically correct and anomalous sentence completions [5], and judging semantic relatedness among words [5, 9] reduces the plausibility of these alternative interpretations.

Although our result is not in keeping with expectations of a right hemisphere basis for visual imagery, it is consistent with the outcome of FARAH's [2] componential analysis of neurological case reports of imagery deficits, which indicated a left posterior localization for the image generation process. Thus her conclusion, drawn from the study of patients with localized brain damage, and the present conclusion, drawn from the study of a patient with surgically separated but otherwise intact hemispheres, are in agreement.

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