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NOTE

HEMISPHERIC DIFFERENCES IN MNEMONIC PROCESSING: THE EFFECTS OF LEFT HEMISPHERE INTERPRETATION

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Abstract—Several studies suggest that the abilities to make inferences and interpret events are stronger in the left hemisphere than the right hemisphere [6] (GAZZANIGA, M. S., *The Social Brain.* Basic Books, New York, 1985). Given that inference and interpretation are important aspects of normal memory functioning [1] (BARTLETT, F. C., *Remembering: A Study in Experimental and Social Psychology*, Cambridge University Press, 1932), one would expect this hemispheric difference to extend to mnemonic processing. Two split brain subjects were shown a series of pictures representing a common scene. Their memory for these pictures was later tested with a lateralized Yes–No recognition test where the distractor pictures were either consistent or inconsistent with the scene. The left hemisphere performed below chance on consistent distractor pictures whereas the right hemisphere was above chance on these pictures and performed at the same level of accuracy as the pictures originally presented. These results suggest that recognition performance in the left hemisphere was more strongly influenced by the expectations for actions common to a scene than the right hemisphere and provide evidence that the left hemisphere superiority in interpretation and inference effect memory performance.

INTRODUCTION

RESEARCH WITH split-brain patients has led support to the idea that there is modularity of function in the brain by showing that some cognitive functions are lateralized on the left and others on the right. The most striking example of this is language. When the callosum is severed, the left hemisphere has the ability for normal verbal communication while the right has only rudimentary language ability. This laterality extends to other functions, that are not so dramatic or immediately apparent. One of these more subtle distinctions is the ability of the left brain to make inferences and interpret events [6]. In a series of studies GAZZANIGA and SMYLIE [7] found that the left hemisphere could accurately identify an event whose occurrence is dependent upon two elements (e.g. boiling water can be inferred from the presence of water and a pan) while the right hemisphere seemed incapable of inferring any combined meaning to the elements. The left hemisphere ability to interpret can be seen when patients were asked to explain actions that the right hemisphere has performed. For instance, if the command "walk" is flashed to the right hemisphere, the patient might respond by getting up and leaving the testing room. If asked to explain this action, the patient might respond that he or she is going to get a soda [6]. In this case, the left hemisphere easily comes up with a plausible (but wrong) explanation for the subject's behavior. These results and others have led GAZZANIGA [4] to hypothesize a "left brain interpreter". The interpreter is a system unique to the human that elaborates on data presented to it and makes inferences about the meaning of the data.

Over the years, it has become clear that inference and interpretation are important elements of normal mnemonic functioning. The earliest example of this is a study conducted by BARTLETT [1]. He told subjects a literal interpretation of an Indian story that was difficult for most English-speakers to comprehend. When he asked his subjects to recall this story, they all made errors that reflected their attempts to make sense of the story. He hypothesized that when remembering, we do not have access to a literal transcript of the to-be-remembered story, but rather we have bits and pieces that we "reconstruct" into a story using our world knowledge. Thus our knowledge and expectations for an event are reflected in our memory of that event. Later studies have gone on to show that our tendency to elaborate, organize and interpret events can lead to both improved or impaired memory performance, depending on the situation. BRANSFORD and JOHNSON [2] have shown that improving comprehension of a confusing story by providing a picture improves our ability to remember this story. On the other hand, LOFTUS [9] and others who work on eye-witness testimony present evidence that our expectations for a sequence of events can lead us to falsely recognize events that did not occur.

If the ability to interpret and infer are primarily the responsibility of the left hemisphere, one might expect this difference to be reflected in the memory performance of the two separate hemispheres. The present research on the laterality of memory functioning has not directly addressed this issue, although MOSCOVITCH [11] found some evidence that the left hemisphere may be more sensitive to the organization of the to-be-remembered stimuli in a study examining the phenomenon of release from proactive interference in patients with either right or left temporal lobe damage or right or left frontal lobe damage. MOSCOVITCH [11] found that all the patients he examined demonstrated release from proactive interference except for those with damage to the left frontal lobe (patients with damage to the right frontal lobe performed normally). Frontal lobe damage is often thought to lead to difficulty in aspects of memory functioning that are more sensitive to organization and elaboration (i.e. metamemory [13]; source memory [8]), so it is not surprising that patients with frontal lobe damage show an impairment in release from proactive interference. What is surprising is that this deficit would be confined to patients with damage to the left frontal lobe. This study suggests that there may be hemispheric differences on memory tasks sensitive to elaboration or organization.

The present study examines hemispheric differences in recognition memory for stimuli that are common to a particular scene. Several studies have shown that our expectations for an event can lead us to falsely remember events one would expect to occur, but did not occur [12, 14]. CHANDLER [3] extended this to picture recognition by showing that subjects are more likely to falsely recognize pictures that "fit" in a particular scene than those that are not similar. Both of these results would be expected if the subject were to elaborate on or draw inferences from the to-be-remembered stimuli. If the ability to infer and interpret are stronger in the left hemisphere, one would expect the left hemisphere to falsely recognize pictures that "fit" in a scene more often than the right hemisphere.

Two fully sectioned split-brain patients were shown a series of pictures representing the chronological sequence of events common to a scene. After a retention interval, the subjects were given a lateralized Yes–No recognition test containing the original pictures, within-scene distractor pictures and out-of-scene distractor pictures. If the left hemisphere is more likely to infer actions that might occur in a scene, than one would expect the left hemisphere to falsely recognize more of the within-scene distractor pictures than the right hemisphere. If, however, both hemispheres show similar patterns of responses, one might argue that the influence of the left-brain interpreter does not extend to mnemonic processing.

METHOD

Subjects

Cases J.W. and V.P. are fully sectioned callosal patients with an MRI confirmed lesion. J.W.'s lesion was complete while V.P. has fibers remaining in the splenium and rostrum. Both J.W. and V.P. have been studied extensively over the past 9 years on a variety of perceptual, cognitive and attentional tests [5].

Materials

The stimuli were three sets of 80 pictures. Each set consisted of pictures containing the same characters in the same setting. Within each set, 60 of the pictures, when placed in the correct order, represented a sequence of events that are common to a particular scene. The additional 20 pictures were of the same characters and setting, but were not consistent with the action of the scene. Of the 60 within-scene pictures, 40 were presented in the acquisition stage of the experiment and 20 were used as distractors in the test stage. All 20 of the out-of-scene pictures were used as distractors. The three scenes represented were: (1) a man getting up in the morning and getting ready for work, (2) two women going bowling, and (3) a woman making cookies. Examples of the within-scene pictures are: picture (1) a man is sleeping in bed, picture (2) he is looking at his alarm clock, picture (3) he is turning off the alarm clock, and picture (4) he is sitting up in bed. Pictures 5–60 go on to show the same man brushing his teeth, shaving, choosing clothes for the day, getting dressed, having breakfast and finishing his morning coffee. Examples of out-of-scene pictures include: the same man smoking a cigar, reading a book, fixing a TV, and opening a beer.

Procedure

The procedure was the same for each set of pictures and each set was presented on a different day. Subjects were told that they are going to see a series of pictures and that they should pay attention to the pictures because they will be asked to remember them later. They were told that the pictures represent a sequence of events common to a particular scene and that knowing this might help them remember the pictures. Finally they were told the scene that would be represented (e.g. "these pictures are about a man getting up in the morning and getting ready for work"). The subjects then saw 40 of the within-scene pictures presented in the correct chronological sequence. Each picture was presented for 3 sec.

After presentation of the pictures, the 40 within-scene pictures presented during acquisition were rearranged so that they were not in chronological sequence and were mixed in with the additional 20 within-scene pictures (also not in sequence) and the 20 out-of-scene pictures. These 80 pictures were used in a lateralized Yes–No recognition test.The recognition test was given approx. $1\frac{1}{2}$ hr after the initial presentation. During this retention interval, the subjects participated in other experiments. After $1\frac{1}{2}$ hr, the subjects were told that they were going to see a series of pictures and for each picture they had to decide if they had seen it earlier. The subjects were shown each picture in central view and were allowed to look at each picture as long as was needed in order to decide if they had seen it previously (this decision time did not exceed 5 sec for any subject or picture). When the subjects were ready to indicate their decision (i.e. Yes or No) they were instructed to look at the computer screen where they were told to fixate on the middle of the screen. A fixation point appeared in the middle of the screen for 500 msec. This was immediately followed by the words "Yes" and "No" flashed for 150 msec to the upper and lower quadrants on either the right or left side of the fixation point (150 msec is long enough for the subjects to read the words, but not long enough to move their eyes). On half of the recognition trials the word "Yes" was in the upper quadrant and for the other half the word "No" was in the upper quadrant. For half of the recognition trials, the words "Yes" and "No" appeared to the right of the fixation point and for the other half they appeared on the left. The subjects did not know in advance for any recognition trial on which side the words would appear and in which quadrant a particular word would appear. If the words "Yes" and "No" were flashed to the left of the fixation point (i.e. the right hemisphere), the subjects were told to use their left hand to point to the correct answer. If the words were flashed to the right of the fixation point (i.e. the left hemisphere), the subjects were told to use their right hand to point to the correct answer. This procedure was repeated for all 80 pictures. The 80 pictures were divided up so that each hemisphere responded to 40 pictures: 20 within-scene pictures presented in the acquisition phase, 10 within-scene distractor pictures, and 10 out-of-scene distractor pictures. The particular set of 40 pictures for which the right or left hemisphere was required to make a response was counterbalanced across subjects.

RESULTS

The overall level of recognition (i.e. the percentage of trials the subject responded correctly whether the correct answer is Yes or No) for J.W. was 70% for the right hemisphere ($\bar{X}=28$ of 40 possible) and 65% ($\bar{X}=26$ of 40) for the left hemisphere. V.P. correctly recognized 69% ($\bar{X}=27.7$ of 40) of the pictures with the right hemisphere and 64% ($\bar{X}=25.7$ of 40) with the left hemisphere. Both subjects performed better than chance (50% or $\bar{X}=20$ of 40) with both hemispheres.

More important is how the subjects responded to the different types of stimuli (see Fig. 1). The percentage of "hits" (saying "Yes" to a picture that was seen before) was: for J.W.—70% with the right hemisphere ($\bar{X}=14$ of 20) and 68% ($\bar{X}=13.7$ of 20) for the left hemisphere; for V.P.—68% ($\bar{X}=13.7$ of 20) for the right hemisphere and 62% ($\bar{X}=12.3$ of 20) for the left. A sign test comparing the right and left hemispheres found no significant difference although the right hemisphere performed slightly better than the left ($P<0.11$, $N=6$). The percentage of correct rejections (saying "No" to a picture that was not seen before) for the out-of-scene distractors was: for J.W.—93% ($\bar{X}=9.3$ of 10) for the right hemisphere and 90% ($\bar{X}=9$ of 10) for the left hemisphere; for V.P.—77% ($\bar{X}=7.7$ of 10) for the right hemisphere and 93% ($\bar{X}=9.3$ of 10) for the left hemisphere. No significant difference was found between the right and left hemispheres using a sign test ($P>0.05$, $N=6$). Thus, it appears the right and left hemispheres performed similarly for both the original pictures and out-of-scene distractors.

The accuracy for the within-scene distractor pictures, however, differed between hemispheres. The percentage of correct rejections for within-scene distractors was: for J.W.—63% ($\bar{X}=6.3$ of 10) for the right hemisphere and 33% ($\bar{X}=3.3$ of 10) for the left hemisphere; for V.P.—63% ($\bar{X}=6.3$ of 10) for the right hemisphere and 40% ($\bar{X}=4.0$ of 10) for the left hemisphere. This difference was found to be significant using a sign test ($P<0.05$). Both hemispheres performed worse on the within-scene distractors than the out-of-scene distractors, however for the left hemisphere, performance on the within-scene distractors fell below chance. The right hemisphere was able to correctly respond (whether the answer was "Yes" or "No") to both the original pictures and within-scene distractors at about the same level of accuracy (the mean for both subjects—69% for the original pictures and 63% for the within-scene distractors), indicating that it could distinguish between the two. This is not the case for the left hemisphere (the mean for both subjects—66% for the original pictures and 37% for the within-scene distractors). In fact if we look at the percentage of "Yes" responses to all types of stimuli (see Fig. 2) we see that for the left hemisphere, the pattern of responding to the within-scene distractors is very similar to the pattern of responding to the original pictures. The percentage of "Yes" responses with the left hemisphere was: for J.W.—62% ($\bar{X}=12.3$ of 20) for the original pictures and 60% ($\bar{X}=6.0$ of 10) for the within-scene distractors; for V.P.—68% ($\bar{X}=13.7$ of 20) for the original pictures and 67% ($\bar{X}=6.7$ of 10) for the within-scene distractors. These data indicate that the left hemisphere had a difficult time distinguishing between previously seen and new pictures that are consistent with the events common to a particular scene.

DISCUSSION

The data suggest that the right and left hemispheres perform differently when recognizing previously seen pictures. This is not surprising given that research with unilateral temporal lobectomy patients has shown that damage to the right temporal lobe impairs visual memory more than verbal memory while damage to the left

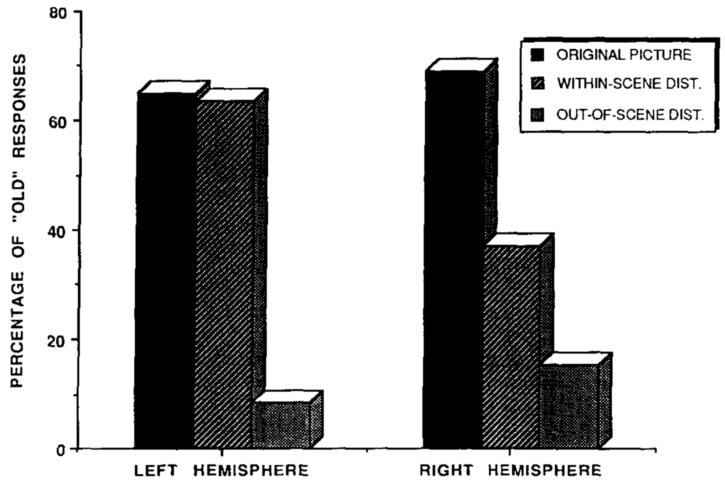

Fig. 1. Mean percentage of "Old" responses on original pictures, within-scene distractors, and out-of-scene distractors for the left and right hemispheres.

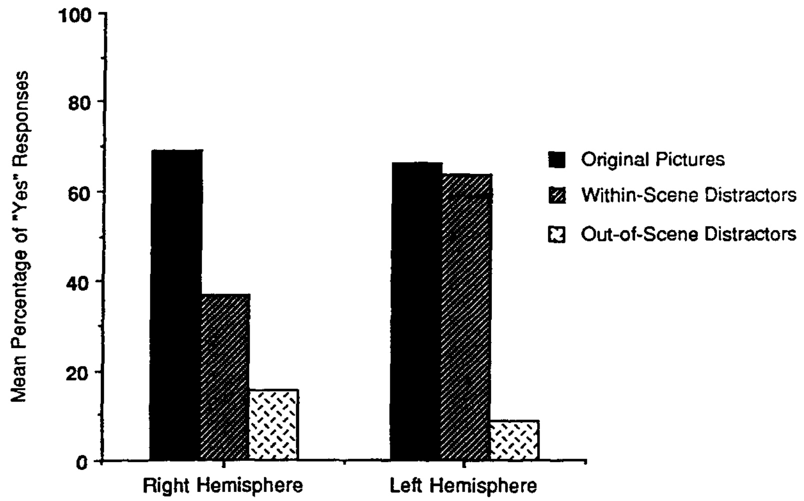

Fig. 2. Mean percentage of "Yes" responses by the right and left hemispheres for orignal pictures, within-scene distractors and out-of-scene distractors.

temporal lobe has the opposite effect [10]. This difference was reflected in our study in that performance for the right hemisphere was slightly better overall. This right hemisphere superiority in visual memory does not, however, explain the below-chance performance of the left hemisphere for the within-scene distractors. The present results suggest that differences in memory performance between the right and left hemispheres extends beyond the physical characteristics of the stimuli to higher-order mnemonic processing. The pattern of responses for the left hemisphere provides a clue as to what aspects of mnemonic processing are more important in the left hemisphere. The poor performance on the within-scene distractors combined with the above-chance performance for the original pictures and out-of-scene distractors indicate that recognition in the left hemisphere was strongly influenced by knowledge and expectations of events (seen or inferred) in the familiar scenes depicted by the pictures. While it is hard to rule out any effect of expectations or inference on mnemonic performance in the right hemisphere, it is clear from the pattern of responses that any influence world knowledge may have had was not nearly as strong.

These results are consistent with findings that the abilities to make inferences and interpret events are stronger in the left hemisphere than the right hemisphere. Furthermore, they suggest that the influence of left-brain interpreter extends to mnemonic functioning. It is hard to know the roles the separate hemispheres play in normal memory functioning, except to say that they play different roles. The current study suggests that one such difference is that the left hemisphere relies more heavily on elaborative processing of mnemonic stimuli than the right hemisphere.

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