

The impact of left and right intracranial tumors on picture and word recognition memory

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Accepted 21 October 2002

Abstract

This study investigated the effects of left and right intracranial tumors on picture and word recognition memory. We hypothesized that left hemispheric (LH) patients would exhibit greater word recognition memory impairment than right hemispheric (RH) patients, with no significant hemispheric group picture recognition memory differences. The LH patient group obtained a significantly slower mean picture recognition reaction time than the RH group. The LH group had a higher proportion of tumors extending into the temporal lobes, possibly accounting for their greater pictorial processing impairments. Dual coding and enhanced visual imagery may have contributed to the patient groups' similar performance on the remainder of the measures.

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Keywords: Brain tumors; Laterality; Recognition memory

1. Introduction

Primary brain tumors can compromise neurological systems integral to information processing because of their capacity to invade normal brain tissue (Ojemann, Miller, & Silbergeld, 1996; Skirboll, Ojemann, Berger, Lettich, & Winn, 1996) causing neuronal death, mass effect, or edema (Anderson, Damasio, & Tranel, 1990). Neuropsychological research has provided evidence of these tumor effects on attention, memory, and intellectual processing (Armstrong, Mollman, Corn, & Alavi, 1993; Fisk & Del Dotto, 1990; Mattis, 1995; Meadows & Butler, 1995; Taphoorn et al., 1994). However, the laterality effects of pervasive tumors on cognition have not been extensively investigated. Therefore, examining the impact of hemispheric tumor presence on cognitive

factors in a patient population prior to irradiation or chemotherapy may elucidate some of the uncertainty. Picture and word recognition memory are intriguing cognitive factors to study because the hemispheric specialization required to process them is inconclusive.

Several cognitive theories have attempted to explain recognition memory effects through various semantically based picture and word recognition studies. One theory posits that visual (e.g., pictures) recognition tests appear to engage dual hemispheric processing (Gainotto, Capella, Perri, & Silveri, 1994), whereas verbal recognition tests often use real words that appear to be predominantly processed by the left hemisphere (Lieury & Le Nouveau, 1987). Similarly, Gainotto et al. (1994) examined word and picture recognition memory in a right and left neurologically mixed group of patients, requiring them to recognize a previously presented stimulus. They reported a left hemispheric superiority on the verbal memory test with no significant group differences on the picture memory test. Grady, McIntosh, Rajah, Beig, and Craik (1999) presented pictures

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or words to a normal control group during different encoding conditions and measured their regional blood flow using PET.

During the multiple conditions, there was bilateral activation throughout the presentations of pictures, although it was more pronounced in the right hemisphere. Although visual field studies by Lupker and Sanders (1982) have suggested that the right and left hemispheres are nearly equal in capacity for processing pictorial stimuli, there have also been specific hemispheric differences illustrated in word and picture recognition studies.

Whitehouse (1981) demonstrated that left hemisphere brain-damaged patients were impaired on verbal memory and right hemisphere patients were impaired on pictorial memory tasks. Additional studies have found greater right hemisphere activation associated with picture, but not word, encoding in the medial temporal lobe (Kohler, Moscovitch, Winocurm, & McIntosh, 2000; Martin, Wiggs, & Weisberg, 1997). These studies suggest that verbal recognition memory is almost exclusively associated with the left hemisphere because of its association with linguistic processing, whereas picture memory is processed bilaterally.

Based on the findings of prior research, our study attempted to address the primary question: Can we identify specific hemispheric processing differences for pictures and words? From this, we have formulated two hypotheses: (1) since picture encoding may require bilateral processing (both verbal and visual), there will be no hemispheric differences on picture recognition memory in brain tumor patients; (2) since word recognition requires greater linguistic encoding (verbal or lexical representation), left hemispheric lesions will disrupt word recognition memory more than right hemispheric lesions.

2. Method

2.1. Participants

All subjects (males = 14, females = 15) were right-handed adults, who were being treated for primary low-grade gliomas at the University of Pennsylvania Cancer Center or the Thomas Jefferson University Bodine Cancer Center. Patients were administered both recognition memory tests approximately 6 weeks post-surgery (although not all patients had surgery) and prior to irradiation and chemotherapy. The extent of edema is less pronounced in low-grade brain tumors compared to malignant brain tumors (Greenberg, Chandler, & Sandier, 1999), so the impact from edema was presumably mitigated by delaying the testing 6 weeks to accommodate post-surgical recovery. Surgery consisted of gross total resection (42%), partial resection (0%),

biopsy (16%), or none (42%) for the left hemisphere group and gross total resection (76%), partial resection (12%), biopsy (6%), or none (6%) for the right hemisphere group. None of the patients had tumor growth for at least 6 months following their evaluation, as demonstrated by MRI. The mean age of the patients was 41.20 years ($SD = 12.85$) and mean educational attainment was 16.10 years ($SD = 2.38$). Twenty-two normal controls (NC; males = 8, females = 14) were compared to the patient population. The NC consisted of patient's family members and volunteers from the two hospitals. They were grouped together and used throughout all of the analyses. The mean age of the NC group was 39.45 ($SD = 16.29$) and mean educational attainment was 16.23 ($SD = 2.49$). On major demographic variables (education and age), the two samples appear to be similar.

The tumor characteristics of the patients are illustrated in Table 1. Inclusion criteria were age between 18 and 69 years, low tumor grade, and supratentorial location. Tumor grading was based on pathology reports or neuroradiologic findings. Exclusionary criteria were extensive neuropsychological impairment, major

Table 1
Clinical characteristics of brain tumor patients

Tumor location	Tumor type
<i>Left hemispheric tumors (n = 12)</i>	
Temporal	Non-specific glioma
Temporal	Astrocytoma
Temporo-parietal	Astrocytoma
Temporo-parietal	Non-specific glioma
Frontal	Mixed glioma
Frontal	Astrocytoma
Fronto-temporal	Astrocytoma
Fronto-temporal	Oligodendroglioma
Parietal	Astrocytoma
Parietal	Non-specific glioma
Parietal	Ependymoma
Parieto-occipital	Oligodendroglioma
<i>Right hemispheric tumors (n = 17)</i>	
Temporal	Ganglioglioma
Temporal	Non-specific glioma
Temporo-parietal	Pleomorphic
	Xanthoastrocytoma
Temporo-parietal	Pleomorphic
	Xanthoastrocytoma
Frontal	Astrocytoma
Frontal	Astrocytoma
Frontal	Astrocytoma
Frontal	Astrocytoma
Frontal	Oligodendroglioma
Frontal	Non-specific glioma
Frontal	Oligodendroglioma
Frontal	Oligodendroglioma
Fronto-parietal	Oligodendroglioma
Parietal	Oligodendroglioma
Parietal	Astrocytoma
Parietal	Ependymoma
Parietal	Astrocytoma

psychiatric diagnosis, history of traumatic brain injury, learning disability, amnesia (i.e., inability to learn new material), aphasia (i.e., inability to understand task instructions or express thoughts fluently), neurological co-morbidity (e.g., encephalitis, meningitis, multiple tumors, or stroke), and history of coronary artery disease, hypertension, diabetes, pulmonary disease, kidney disease, other cancer, and immunosuppressive disease. These exclusions were determined by an initial neurodiagnostic interview, neurological examination, and neuropsychological assessment.

2.2. Tumor location

The patients were grouped according to their tumor location, which was identified by MRI as part of the patients' clinical evaluation. Tumors were confined to two categories: right hemisphere (RH) ($n = 17$) and left hemisphere (LH) ($n = 12$). The categories were created using the superior longitudinal fissure for the left/right hemispheric boundaries. Brain tumor loci are characteristically heterogeneous and have non-structured boundaries, therefore no further effort was made to limit tumor boundaries.

2.3. Recognition tests

The testing information for this study was originally accumulated as part of a larger scale study examining the effects of radiation therapy on cognitive functioning. In this more extensive study, participants were individually administered a comprehensive battery of standardized neuropsychological tests prior to any irradiation or chemotherapy. The tests were administered under the direct supervision of a licensed clinical neuropsychologist. In this present study, two recognition memory measures were selected for analysis.

Word recognition and picture recognition test stimuli were selected from a list of high frequency nouns that had strong word association (Carroll, Davies, & Richman, 1971; Paivio et al., 1968). The pictures were controlled in order to constrain familiarity and bring parity to the accuracy and reaction time for recognition (Snodgrass & Vanderwart, 1980) that have been rated for their concreteness, imagery, and meaningfulness. The 172 words and 260 pictures selected were tested in two different pilot studies involving different sets of control subjects screened for neurological abnormalities. Words or pictures that fell outside one standard deviation of the mean for the meaningfulness and frequency ratings were eliminated. Words or pictures were also eliminated if they overlapped during the free recall section of the two tests.

We selected 175 pictures and tested their robustness as measures of memory in a pilot study of 16 healthy normal individuals. The mean age of the picture recog-

nition memory control group was 35.08 years and the mean average number of years of education was 16.50. The variability of the individual stimuli of both tests was tested with a coefficient of variance, which was calculated by dividing the item's mean by the standard deviation. The words from the list that attained a coefficient greater than .249 were eliminated, resulting in 60 pictures that were used as targets, and 60 pictures that were used as foils. The mean age of the word recognition memory control group was 36.45 years and the average number of years of education was 16.09. Words that produced too much variability among the 14 controls subjects were also eliminated. This resulted in the final selection of 60 words that were targets, and 60 words that were foils.

The word recognition and picture recognition tests consist of a study portion and then a test portion, which together takes approximately 5 min. During the study phase, 60 words or pictures of familiar living and non-living objects were individually presented at 2-s intervals in the center of a 12 in. Macintosh Powerbook G3 OS 8.5 laptop computer screen. Words were in lower case and approximate .5 in. in height. The test phase immediately ensued, and after viewing the target stimuli from the study phase, the subject was asked to view a set of 120 words or pictures presented singly, and to press the space bar when the subject recalls that the word or picture appeared in the previous study list. The 60 study pictures were randomly distributed in the 120 test stimuli. Hit rate, reaction time, discrimination, and response bias indices were used for measurement of both picture and word recognition.

2.4. Statistical analysis

All statistical analyses were carried out using the Statistical Package for the Social Sciences (SPSS version 10.0 for Windows). An α level of .05 was used to determine significance. To analyze overall performance differences, group scores were compared by means of separate one-way analyses of variance (ANOVAs). In case of a significant effect, post hoc Tukey tests were used to determine the significant group differences.

3. Results

A total of 51 subjects, 12 with left hemispheric tumors, 17 with right hemispheric tumors, and 22 normal controls were tested on two different memory tests comprised of word and picture recognition memory tasks. One-way ANOVAs were conducted on each of the four recall indices. In the sample of all brain tumor patients, all of the eight measures were normally distributed. Tukey HSD was used for post hoc analyses.

3.1. Hit rate

Hit rate and reaction time indices were derived by Balota and Spieler (1999) and Snodgrass and Corwin (1988) for picture and word recognition. The results indicate a significant difference by group ($F(2, 48) = 3.35$, $p < .05$) on picture recognition hit rate (see Table 2). A Tukey test indicated that the significant difference was between the LH and NC group for picture (mean difference = -0.10 , $p < .05$) recognition hit rate. There were no individual patient group differences found on picture recognition hit rate.

3.2. Reaction time

Reaction time analyses indicated a significant difference on word ($F(2, 48) = 3.35$, $p < .05$) and picture ($F(2, 48) = 14.83$, $p < .01$) recognition reaction time. A Tukey test indicated that the significant differences were between the LH and RH groups (mean difference = 101.17 , $p < .05$) and the LH and NC groups (mean difference = 172.91 , $p < .01$) on picture recognition reaction time, with the LH group exhibiting the longest reaction times (see Table 3). For word recognition reaction time, the significant difference was between the LH and NC group (mean difference = 137.61 , $p < .05$).

3.3. Discrimination

Corwin (1994) discusses the measurement of discrimination and response bias. On discrimination, there were no significant patient or normal control differences found on picture ($F(2, 48) = 3.14$, $p = .053$) or word ($F(2, 48) = 2.18$, $p = .12$) recognition.

3.4. Response bias

On response bias, there were no significant patient or normal control group differences for picture ($F(2, 48) = 2.05$, $p = .14$) or word ($F(2, 48) = 2.45$, $p = .10$) recognition.

3.5. The effects of surgery and tumor location

Group test score performance differences were analyzed in terms of surgical intervention, and tumor location. While there were some group differences found for tumor location (word recognition response bias ($F(10, 18) = 2.45$, $p < .05$)), with the Bonferroni correction, nearly all of them failed to achieve significance. There was also a significant effect for surgery type (e.g., biopsy, partial resection, gross total resection, or none) on picture recognition reaction time ($F(4, 46) = 7.37$,

Table 2
Picture recognition means and standard deviations for left and right hemisphere lesioned and normal control groups

Measures	Regions						F	p
	Left (n = 12)		Right (n = 17)		Controls (n = 22)			
	M	SD	M	SD	M	SD		
PRHR ^a	0.76	0.13	0.81	0.11	0.86	0.10	3.35	.04*
PRRT ^b	969.97	81.03	868.80	99.65	797.07	83.61	14.83	.00*
D ^c	0.68	0.15	0.75	0.11	0.80	0.13	3.14	.053
Br ^d	0.10	0.54	0.28	0.19	0.31	0.18	2.05	.14

^a Picture recognition hit rate.

^b Picture recognition reaction time.

^c Picture recognition discrimination.

^d Picture recognition response bias.

* <.05 significance level.

Table 3
Word recognition means and standard deviations for left and right hemisphere lesioned and normal control groups

Measures	Regions						F	p
	Left (n = 12)		Right (n = 17)		Controls (n = 22)			
	M	SD	M	SD	M	SD		
WRHR ^a	0.54	0.21	0.58	0.22	0.70	0.15	3.35	.04*
WRRT ^b	943.82	78.94	866.01	217.46	806.21	95.59	3.50	.04*
D ^c	0.45	0.20	0.50	0.21	0.58	0.16	2.18	.12
Br ^d	0.18	0.12	0.19	0.19	0.30	0.19	2.45	.10

^a Word recognition hit rate.

^b Word recognition reaction time.

^c Word recognition discrimination.

^d Word recognition response bias.

* <.05 significance level.

$p < .01$). However, small group size precluded any further analysis.

4. Discussion

This study examined the laterality effects of brain tumors on picture recognition and word recognition memory. We initially contended that there would be no hemispheric group differences on picture recognition memory due to bi-hemispheric involvement. However, there were significant patient group differences on picture recognition. The LH patients had significantly slower mean reaction times than the RH group. The LH group also had a slower hit rate and longer reaction times than the NC group on both tests. It is possible that picture recognition requires significantly greater left hemispheric involvement. One could also attribute the group differences to the higher concentration of left hemispheric (50%) compared to right hemispheric (24%) tumors invading the temporal lobe, which may have significantly impacted the LH group's picture recognition memory reaction time performance.

Studies have discussed the association between the temporal lobes and reaction time (Nicholls, Schier, Stough, & Box, 1999; Wassermann et al., 1999). Wassermann et al. (1999) examined visual naming in temporal lobe epilepsy patients with transcranial magnetic stimulation, reporting impaired visual (but not word) naming with the left temporal patients. Subjects were asked to name pictures or words presented to them on a computer screen. The left temporal patients produced significantly more picture naming errors and had slower mean reaction times than the right temporal patients. Nicholls et al. (1999) examined temporal lobe asymmetries via projecting unilateral white noise into subjects' ears using electrophysiological and psychophysical measures. They found that the subjects produced faster response times and lower levels of error when the noise was projected to the right ear, concluding that there is a left hemispheric specialization for the detection of brief temporal events. Thus, the study interval may have presented inadequate time to complete lexical, linguistic, and semantic processing.

Temporal lobe lesion studies have also supported the left hemisphere's contribution to memory. Researchers have reported that left temporal lesions impair name and picture recall (Incisa della Rocchetta, Gadian, Connelly, & Polkey, 1995; Smith & Milner, 1984). These results suggest that left temporal lesions can disrupt visual memory performance because of the left temporal lobe's contribution to visual characteristic retention and encoding. However, these deficits have been reported in right temporal lesioned patients, who also demonstrated impaired picture memory performance (Nunn, Graydon, Polkey, & Morris, 1999; Pigott & Milner, 1993).

Milner (1968) in particular, found delayed visual recall deficits in right hemisphere lesioned patients, suggesting that the right temporal lobe contributes to material specific retention and picture encoding. We considered analyzing the right and left temporal lobe patients exclusively, but the small group sizes precluded further stratification for statistical testing.

We also hypothesized that LH patients would be impaired on word recognition memory due to its heavy reliance on left hemispheric functioning. We also expected LH patients would exhibit slower mean reaction times than the RH patients on word recognition. Surprisingly, there were no patient group differences in terms of word accuracy and reaction time, contrary to our hypothesis that such differences would be evident on this verbally mediated measure. In other words, RH patients performed similarly to LH patients on this verbal task. One explanation for the patient groups' similar performances on both picture and word recognition memory is due to enhanced visual imagery, evoked during the long stimulus onset intervals on both sets of measures. Therefore, when the subjects were presented a picture or a word, a common strategy may have been to associate a corresponding visual or verbal image, facilitated by the sufficient time permitted between the consecutive stimuli. This may have induced greater recognition regardless of tumor location or stimulus type.

The remainder of the non-significant patient group findings may be explained by dual coding theory (DCT), which addresses the idea of cross-modal processing and representation (Paivio, 1995; Paivio, Clark, Digdon, & Bons, 1989; Sadoski & Paivio, 1994). DCT suggests that comprehension of language and construction of meaning requires bilateral involvement, precluding specific hemispheric dominance for word or picture processing. Thus, the encoding of information may be facilitated through patients' strategic verbal labeling of a pictorial stimulus or mental visualization of a word stimulus at the time of presentation (Sadoski, Kealy, Goetz, & Paivio, 1997; Sadoski, Paivio, & Goetz, 1991).

We interpret the results from this study with caution given the small group size, composition, and uneven tumor distribution. While we did find group performance differences related to tumor location and type of surgery, the group sizes limited any conclusions based upon these results. In spite of these limitations, we believe that the focal and discrete nature of low-grade brain lesions provides a more concise description of the relationship between brain damage and behavior.

Future studies may want to consider testing patients prior to surgery to avoid complicating factors associated with a craniotomy and post-surgical changes. Furthermore, a larger sample size with a more homogeneous group of uniform left and right hemispheric loci may bring the non-patient group differences noted here

to statistical significance. Finally, varying the length of the stimulus onset interval could modulate the left hemispheric findings, such that longer periods of study might significantly improve hit rate and/or reaction time.

Acknowledgments

This study was supported by a grant by the National Cancer Institute, RO1 CA 65438.

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