Journal of Anxiety Disorders, Vol. 5, pp. 1-20, 1991
Printed in the USA.

0887-6185/91 $3.00 + .00

RESEARCH PAPERS

Memory Functioning in Panic Disorder: A Neuropsychological Perspective

JOHN A. LUCAS*†, MICHAEL J. TELCH*, AND ERIN D. BIGLER*†

**The University of Texas at Austin; †The Austin Neurological Clinic*

Abstract – Subjects with panic disorder and normal controls were administered a battery of neuropsychological measures of memory functioning, as well as several self-report measures. Subjects with panic disorder demonstrated overall visual memory impairment compared to normal controls, but were no different from control subjects in overall verbal memory or ability to concentrate. Analyses of learning versus recall variables yielded significant differences between groups on measures of visual learning, visual recall, and verbal recall, with panic disorder subjects performing worse than controls. No group difference was found in verbal learning. Results provide a neuropsychological correlate to panic disorder with implications for temporal lobe involvement.

Gray (1982) has suggested that the neuroanatomical substrate to anxiety is the septo-hippocampal system (SHS). The SHS is a brain system comprised of limbic structures, including the septal nuclei and hippocampal formation, which lie medially in the brain. The hippocampal formation consists of the hippocampus proper and dentate gyrus, as well as its associated cortices, including the subiculum and parahippocampal gyrus. The hippocampal formation is located in the medial temporal lobes and, in addition to its proposed role in anxiety, is considered essential to new learning and memory (Butters & Cermak, 1975; Nadel & Morris, 1982; O'Keefe, 1983; Squire, 1983).

Neuro-imaging studies of patients with panic disorder provide evidence for temporal-limbic involvement in panic. A recent published case study reported that "autonomic and experiential phenomena consistent with a diagnosis of panic disorder" were the only symptoms experienced by a patient with a neoplasm involving the right medial temporal lobe (Drubach & Kelly, 1989). Panic episodes have also been reported in patients with focal right temporal lobe meningioma (Ghardian, Gauthier, & Bertrand, 1986) and arteriovenous malformation (Wall, Tuchman, & Mielke, 1985). A magnetic resonance imaging (MRI) study reported a higher incidence of right medial temporal

The authors would like to thank Drs. Clarke Burnham, Gerald Metalsky, Mark Shermis, and Renee Dupont for their suggestions on earlier drafts of this manuscript, and T. LaNae Schoonover and Terry P. Smith for their assistance in data collection. Address reprint requests to John A. Lucas, VAMC, Psychology Service (116B), 3350 La Jolla Village Dr., San Diego, CA, 92161.

lobe abnormalities in panic disorder patients than normal controls (Ontiveros et al., 1989). Furthermore, patients with these MRI hyperintensities had an earlier age of onset of their panic disorder, longer duration of illness, and greater number of spontaneous attacks than patients with normal brain scans.

Studies using positron emission tomography (PET) have found metabolic abnormalities in the medial temporal lobe (i.e., parahippocampal gyrus) of panic disorder patients who panic in response to lactate infusion. While at rest, these patients display abnormally high regional cerebral blood flow (rCBF) in the right medial temporal lobe (Reiman, Raichle, Butler, Herscovitch, & Robins, 1984; Reiman et al., 1986). During a panic attack, however, abnormal rCBF elevations were found bilaterally (Reiman et al., 1989). To date, PET studies have failed to show such involvement in patients with phobic disorder, generalized anxiety disorder, obsessive-compulsive disorder, or major depression (Mindus et al., 1986; Baxter et al., 1985, 1987, 1988, 1989; Mathew et al., 1980; Phelps, Mazziotta, Baxter, & Gerner, 1984).

Temporal lobe abnormalities may interfere significantly with learning and recall of new information. It is generally accepted that the left cerebral hemisphere subserves verbal functions, while the right hemisphere subserves nonverbal functions (Geschwind & Galaburda, 1985). Although the presence of extensive connections between cerebral hemispheres makes it unlikely that memory functioning is completely lateralized, the finding of predominantly right temporal lobe involvement in panic disorder patients at rest, suggests that visual memory may be impaired to a greater extent than verbal memory. The present study examined this hypothesis by evaluating the performance of subjects with panic disorder and normal controls on neuropsychological tests of verbal and visual learning and recall.

METHOD

Subjects

Patients with Panic Disorder (PD). Twenty-five right-handed subjects (4 males, 21 females), ranging in age from 20 to 60 years (X = 34.7, *SD*=10.2), were recruited through local media as part of an ongoing panic disorder treatment study at The University of Texas at Austin. Potential subjects were administered a brief telephone screening interview. Those reporting panic attacks as their primary problem were invited for a face-to-face structured clinical interview (Spitzer et al., 1989). Subjects with current mood disorder (e.g., Major Depression, Bipolar Mood Disorder, etc.), psychotic disorder, substance abuse, or other DSM III-R anxiety disorder were excluded from the study. In addition, subjects with a history of bipolar illness, psychosis, or substance dependence were also excluded. All subjects in the final sample met DSM III-R criteria for current panic disorder with or without agoraphobia as their primary Axis I condition.

Normal Controls. Twenty-five right-handed subjects (4 males, 21 females), ranging in age from 20 to 56 years (X = 35.0, SD=9.1), were recruited from

the staff of the Austin Neurological Clinic and its associated facilities to serve as normal controls. Resources precluded a full clinical evaluation of control subjects. Rather, screening of controls was accomplished using the SCL-90 Revised and the Anxiety Questionnaire (AQ), a brief self-report panic disorder assessment instrument (Telch, Lucas, & Nelson, 1989). Those with current psychopathology, as measured by elevations on any of the SCL-90 clinical scales, as well as those with a history of panic attacks, as determined by the AQ, were excluded from the study.

All subjects reported a negative history of significant central neurological illness, birth stress, learning disability, and previous neuropsychological evaluation. Subjects taking prescribed medications were included in the study only if they had been maintained on their medication for at least one month.

MATERIALS

Neuropsychological Memory Tests

Wechsler Memory Scale (WMS; Wechsler, 1945). Form I of the WMS was employed in this study. It consists of seven subtests designed to assess various aspects of memory functioning. The subtests are as follows:

a) Personal and Current Information. This subtest consists of questions regarding the subject's age and date of birth, as well as the names of current public figures.

b) Orientation. This subtest assesses orientation to time (i.e., the date) and place.

c) Mental Control. Subjects are asked to count backwards, recite the alphabet, and perform serial calculations, all under time pressure.

d) Logical Memory (LM). Two brief passages are read to the subject. After each passage is presented, the subject is asked to recall as much information from the passage as possible.

e) Memory Span. Subjects are asked to repeat digits forward or backward.

f) Visual Reproduction (VR). Subjects study cards containing two-dimensional geometric figures, and are asked to draw the figures from memory. Cards are presented one at a time. Two cards contain one figure each, while the third contains two designs presented side by side.

g) Paired Associate Learning (PAL). A list of word-pairs is read to subjects over three trials. After each presentation of the list, the examiner states the first word of a pair, and the subject must respond with its associate.

In addition to Wechsler's (1945) immediate recall procedures, recall of LM passages, VR designs, and PAL word-pairs was assessed after a 15- and 45-minute delay period.

Several studies suggest that several factors underlie the structure of the WMS. In most studies, LM, VR, and PAL load on a "memory" or "retention" factor, while Mental Control and Memory Span load together on a separate factor, often labelled "freedom-from-distractibility" or "attention/concentration" (c.f. Erickson & Scott, 1977; Prigatano, 1978). When Information and

Orientation subtests are included in the analyses, these subtests hold primary loadings on a separate "orientation" factor.

Larrabee, Kane, and Schuck (1983) factor analyzed the WMS together with subtests from the Wechsler Adult Intelligence Scale (WAIS), and found that the WMS PAL and LM subtests loaded together on a factor which they labelled "verbal learning and recall." Others have also reported evidence that these subtests are valid measures of verbal learning and memory (e.g., Macartney-Filgate & Vriezen, 1988). Studies examining the construct underlying the WMS VR subtest, however, have been somewhat controversial. Some have argued that VR is too sensitive to verbal encoding, (e.g., Trahan & Larrabee, 1984; Trahan, Quintana, Willingham, & Goethe, 1988) and that it assesses visual-perceptual-constructional ability, rather than visual mnestic functioning (Larrabee et al., 1983; Larrabee, Kane, Schuck, & Francis, 1985). Most investigators agree, however, that use of a delayed recall procedure substantially mitigates these confounding effects (Larrabee et al., 1985, Trahan et al., 1988). Moreover, delayed recall of the VR subtest has been shown to be more sensitive to the effects of lateralized involvement than immediate recall (Cullum & Bigler, 1986; Lezak, 1983).

Larrabee et al.'s (1983) factor analysis of the WMS and WAIS subtests yielded a separate factor containing the Memory Span and Mental Control subtests of the WMS and the WAIS Arithmetic subtest (to avoid redundancy, WAIS Digit Span was not included). Consistent with previous research, this factor was labelled "attention/concentration" (c.f. Erickson & Scott, 1977; Lezak, 1983; Prigatano, 1978).

Selective Reminding (SR; Buschke, 1973). SR is a procedure developed by Buschke and his colleagues to evaluate memory within the context of information processing theory. The procedure has found widespread appeal because it allows one to parcel "memory" into several components, such as long-term storage and long-term recall. Consequently, this technique has been implemented to assess both verbal (e.g., Ruff, Light, & Quayhagen, 1988) and visual (e.g., Fletcher, 1985) learning and memory among a variety of clinical and nonclinical populations.

In verbal SR, subjects are asked to learn a list of 12 common words. The entire list is read aloud to the subject at a rate of one word every two seconds, and the subject is then asked to recall the words in any order. Subjects are reminded only of the words they failed to recall on the preceding trial. The reminding procedure continues until the subject recalls all 12 words on three consecutive trials or until 12 trials have been administered. The word list employed by this study was one of four lists (List 2) developed by Hannay and Levin (1985). In addition to learning the word list, delayed recall was also assessed. Verbal SR has been shown to be a valid measure of verbal learning and memory (Macartney-Filgate & Vriezen, 1988). Measures from the verbal SR test correlate modestly with the LM and PAL subtests of the WMS, suggesting that these tests are related but not redundant (Macartney-Filgate & Vriezen, 1988).

The visual SR test follows the same procedure and offers evaluation of the same memory variables as the verbal SR test. In this procedure, the subject is

presented a card with eight squares, each of which contains five dots in random positions. One dot in each square is pointed out to the subject at a rate of one every two seconds. After all dots have been designated, the subject is asked to recall each target dot in any order employing the selective reminding procedure described above. A delayed recall of the target stimuli was also elicited. The stimulus card used by this study is an 8.5 x 11" enlargement of Fletcher's (1985) stimulus figure (Figure 1, p. 251). Target dots in each square were chosen randomly. Although visual SR is believed to be analogous to verbal SR (Fletcher, 1985), little research has been conducted in this measure.

Benton Visual Retention Test (BVRT; Benton, 1974). The BVRT is a test of immediate memory for geometric designs similar to the VR subtest of the WMS. It consists of 10 cards, most of which contain three figures each: two large "main" figures and one small "peripheral" figure. Subjects are given 10 seconds to study each card, and are then asked to reproduce the figures from memory. The BVRT is scored for the number of cards correctly reproduced and the number and type of errors made.

Benton (1967, 1968) examined the psychometric properties of the BVRT and found that poor performances on immediate recall were associated with right-hemisphere lesions. Larrabee et al. (1985) reported that BVRT immediate recall loaded primarily on a visual-perceptual motor factor, and only secondarily on a memory factor; however, Moses (1986) demonstrated that copying BVRT figures (a task of "pure" visual-perceptual motor ability) loaded on a factor distinct from immediate recall of the figures, arguing that construct underlying the BVRT immediate recall is distinct from pure motor ability.

Intellectual Tests

Wechsler Adult Intelligence Scale—Revised (WAIS-R; Wechsler, 1981). Four subtests of the WAIS-R were included in the test battery: a) Picture Completion, b) Vocabulary, c) Block Design, and d) Similarities. These subtests were chosen because they each correlate highly with their respective (Verbal vs. Performance) IQ measures, as well as with Full Scale IQ (FSIQ).

a) Picture Completion is a measure of visuoperceptual discrimination. The subject is presented a stimulus card in which an important part is missing, and is asked to state the missing part under time pressure. This subtest correlates .79 with Performance IQ (PIQ) and .73 with FSIQ.

b) Vocabulary has the highest loading of all subtests on the Verbal Comprehension factor of the WAIS-R, and it has the highest correlation with both Verbal IQ (VIQ; .90) and FSIQ (.85) of all subtests.

c) Block Design is a measure of visuospatial constructional ability. Subjects must manipulate blocks to reproduce designs similar to models presented by the examiner. Block Design has the highest correlation of all subtests with PIQ (.82), and correlates .74 with FSIQ.

d) The Similarities subtest measures verbal abstract reasoning ability by

asking subjects to think of similarities between different concepts. It correlates .83 with VIQ and .80 with FSIQ.

Self-Report Measures:

Subjective Memory Questionnaire—Revised (SMQ—R). The SMQ-R is a brief, three-part questionnaire derived from the SMQ (Bennett-Levy & Powell, 1980) by the authors. Items with the highest reliability coefficients were taken from the original SMQ (Bennett-Levy & Powell, 1980), and the language was changed to replace British jargon with American equivalents. Part I elicits the subject's perception of his/her memory ability for various things (e.g., names of people, telephone numbers, etc.) on a Likert-type scale ranging from "Very Bad" to "Very Good." Part II assesses the subject's perception of how often certain memory failures occur (e.g., forgetting to turn off the stove, etc.) on a scale from "Very Often" to "Rarely or Never." Parts I and II are summed to obtain a total subjective memory score. Part III consists of a single question which asks the subject to rate his/her memory ability relative to age-related peers on a Likert-type scale ranging from "Much Worse" to "Much Better."

The SMQ-R was administered to 415 college students at the University of Texas at Austin in partial fulfillment of their introductory psychology course requirement. The measure yielded adequate internal consistency, with alpha equal to .81.

State Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1968). The STAI is a 40-item measure developed to assess the level of anxiety experienced at the moment, as well as in general.

Beck Depression Inventory (BDI; Beck, 1978). The BDI is a widely-used questionnaire consisting of 21 items which reflect depressive symptomatology. The subject is presented a series of grouped statements, and asked to select the statement which best describes how he/she has been feeling during the past week.

Neurological History Interview (NHI). The NHI is an author-constructed compilation of questions that elicit neurologically-relevant information such as history of head injury, neurological illness, learning disability, etc.

PROCEDURE

Subjects were first asked to complete the (SMQ—R), and were then administered the Wechsler Memory Scale (WMS). Standard procedures were followed in the administration of the WMS, with one exception. The order of subtest administration was changed, with the Memory Span subtest preceding, rather than following, the Logical Memory (LM) subtest. Thus, the three WMS subtests from which delayed recall measures were obtained (LM stories, Visual Reproduction (VR) drawings, and Paired Associate Learning (PAL) word-pairs) were administered in succession. The State-Trait Anxiety Inventory, Beck Depression Inventory, and Neurological History Interview were administered next, followed by a 15-minute delayed recall of the WMS

subtests. The Picture Completion, Vocabulary, Block Design, and Similarities subtests of the WAIS-R were administered next, followed by a 45-minute delayed recall of the WMS subtests. The Verbal and Visual Selective Reminding (SR) procedures and the Benton Visual Retention Test (BVRT) were then administered in that order, followed by a 15-minute delayed recall of the Verbal SR word-list and a 10-minute delayed recall of the Visual SR stimuli. Testing required approximately 1-½ hours to complete.

DATA ANALYSIS

Memory variables were divided into those that reflect learning, recall, and attention. Learning variables included PAL scores from the WMS, Long Term Storage (LTS) scores of the SR procedures, and the number of learning trials required to meet criterion on the selective reminding procedures. Recall variables included 15-minute delayed recall[1] of LM stories, VR drawings, and PAL word-pairs of the WMS, Long Term Retrieval (LTR) and Delayed Recall scores of the SR procedures, and BVRT error scores[2]. Scores from the Mental Control and Memory Span (number of digits forward and backward) subtests of the WMS were analyzed separately as measures of concentration.

Group differences in learning, recall, and concentration were evaluated using multivariate analyses of variance (MANOVA), with group status (panic vs. control) as the independent variable, and test scores as dependent variables. Learning and recall variables were further divided along the verbal-visual dimension. Because anxiety at the time of testing and level of depressive symptomatology may have affected cognitive functioning, analyses were repeated holding state anxiety scores and BDI scores as covariates. Additional MANOVAs were conducted excluding all subjects reportedly receiving benzodiazepine treatment at the time of testing.

Normative data for several of the memory measures used in this study were obtained from the literature in order to determine the clinical significance of findings. Because norms were in different forms, cutoff scores for impaired performances were determined by various procedures. Trahan et al.'s (1988) norms and recommended cutoff scores were used for delayed recall of the WMS VR subtest; "impaired" scores were all below the 10th percentile for the individual's age cohort. Benton's (1974) "expected" scores for number of errors were used to determine impaired performances on the BVRT; subjects who produced more errors than expected, given their age and estimated IQ, were considered impaired on this test. Abikoff, Alivar, and Hong's (1987) norms were used to determine impaired performance on delayed recall of the WMS LM subtest. Unfortunately, these norms contain extremely large stan-

---

[1] Logical Memory, Visual Reproduction, and Associate Learning showed high correlations between 15- and 45-minute recall conditions (Logical Memory $r = 0.93$; Visual Reproduction $r = 0.92$; Associate Learning $r = 0.80$), therefore only 15-minute delay was included in the analyses.

[2] Scoring of the BVRT for both number correct and number of errors has been shown to be statistically redundant (Moses, 1986). Error scores were included in the analysis because they offer greater discrimination between performance.

dard deviations, making it virtually impossible to obtain a score greater than two standard deviations below the mean (e.g., the mean score for individuals aged 50 to 59 is 8.07, with a standard deviation of 4.45). Consequently, scores were considered impaired if they were greater than one standard deviation below the mean. PAL norms were obtained from desRosiers and Ivison (1988); performances greater than two standard deviations below the mean were considered impaired. Finally, normative data for LTS and Consistent Long Term Retrieval (CLTR) scores of verbal SR were obtained from Ruff, Light, and Quayhagen (1988); no normative data could be found for LTR scores or visual SR. Although CLTR scores were not used in the multivariate analyses, they correlate highly ($r = .92$ in the present study) with LTR scores (a measure included in our analyses). Subjects with scores two standard deviations below the mean or greater on these SR measures were considered impaired.

RESULTS

Demographic, self-report, and medical history information are presented in Table 1. Two subjects with panic disorder failed to complete the "trait" side of the State-Trait Anxiety Inventory. Also, one subject with panic disorder had previous experience administering the WAIS-R; therefore, the Army Beta Examination—Revised (Kellogg & Morton, 1935) was administered in place of the WAIS-R subtests in order to obtain an estimate FSIQ.

Panic disorder subjects and normal controls did not differ significantly in age [F (1,48) = 0.01, NS] or education [F (1, 48) = 0.40, NS]. Scores from the WAIS-R subtests were pro-rated to obtain estimates of VIQ, PIQ, and FSIQ. No differences were found between groups on pro-rated FSIQ [F (1, 48) = 3.18, NS] or pro-rated VIQ [F (1, 47) = 0.56, NS]. A group difference was found, however, on pro-rated PIQ, with panic disorder patients scoring significantly lower than normals [F (1,48) = 6.97, $p < .01$]. This difference appears to be due to performance on the Picture Completion subtest of the WAIS-R [F (1, 47) = 8.65, $p < .01$] rather than the Block Design subtest [F (1, 47) = 1.02, NS].

As expected, significant differences were found between panic subjects and controls on measures of state anxiety [F (1, 48) = 14.47, p < .001], trait anxiety [F (1, 46) = 19.61, $p < .001$], and BDI scores [F (1, 48) = 17.59, $p < .001$], with panic subjects scoring higher than controls on each measure. Surprisingly, panic and controls did not differ in their assessment of the specific types, or frequency of memory failures they experience, as reflected by sum scores of Parts I and II of the SMQ—R [F (1, 48) = 0.90, NS]. However, panic subjects demonstrated a nonsignificant trend toward rating their overall memory ability (SMQ—R Part III) as worse than age-related peers [F (1, 48) = 3.24, $p < .08$].

Chi-square analyses were performed to compare groups on medical history variables. In the present sample, a greater proportion of subjects with panic disorder than controls have sought neurological consultation ($\chi^2 = 4.37$, p < .05) and report current use of prescription medication ($\chi^2 = 16.10$, $p < .001$).

A multivariate analysis of variance (MANOVA) revealed a significant dif-

ference between groups on overall performance on memory tests [F (13, 36) = 2.66, $p < .01$], with panic disorder subjects performing worse than controls. Similar results were obtained from multivariate analyses of covariance (MANCOVAs), except when state anxiety scores were held alone as a covariate. In that analysis, the effect was reduced to a nonsignificant trend [F (13, 35) = 1.88, $p < .06$].

Separate analyses were performed on verbal and visual memory variables. These results are presented in Tables 2 and 3, respectively. A MANOVA of verbal memory variables yielded no significant difference between groups overall [F (7, 42) = 1.46, NS]. Similar results were obtained from MANCOVAs. Dividing variables into learning and recall yielded no difference between groups on verbal learning [F (3, 46) = 1.98, NS]; however, a

TABLE 1
DEMOGRAPHIC AND SELF-REPORT DATA OF PANIC DISORDER AND NONPANIC SUBJECTS

	Panic Disorder (N = 25)		Control (N = 25)		
	Mean	(*SD*)	Mean	(*SD*)	F
Age	34.7	(10.2)	35.0	(9.1)	0.14
Education	14.3	(2.3)	14.6	(1.7)	0.40
WAIS-R Subtests:					
Vocabulary	10.9	(1.6)	10.9	(2.2)	0.01
Similarities	9.8	(1.9)	10.5	(2.0)	1.67
Picture Completion	8.9	(1.8)	10.6	(2.1)	8.64*
Block Design	9.5	(2.7)	10.3	(2.4)	1.02
Pro-rated Full Scale IQ	100.4	(8.7)	106.1	(13.3)	3.18
Pro-rated Verbal IQ	102.1	(10.3)	104.6	(12.4)	0.56
Pro-rated Performance IQ	98.3	(10.4)	107.4	(13.5)	6.97*
Beck Depression Inventory	14.4	(9.1)	5.7	(5.1)	17.59**
State Anxiety (Spielberger STAI)	25.7	(8.0)	16.8	(8.6)	14.47**
Trait Anxiety (Spielberger STAI)	29.6	(11.4)	17.4	(7.5)	19.61**
Subjective Memory Questionnaire:					
Total (Parts I and II)	70.4	(13.5)	73.3	(7.4)	0.90
Part III	3.9	(1.3)	4.5	(0.9)	3.24
	N	(%)	N	(%)	χ^2
Head Injury [a]	1	(4%)	4	(16%)	2.00
Neurological Consultation	12	(48%)	5	(20%)	4.37*
Current Medication	14	(56%)	1	(4%)	16.10**

[a]All subjects who responded positively rated their experience as "mild" on a scale of "none, mild, moderate, severe" (i.e., no loss of consciousness or symptoms of postconcussion syndrome)

*$p < .05$
**$p < .01$
***$p < .001$

group difference was found on verbal recall [F (4, 45) = 2.67, $p < .04$], with panic disorder subjects performing worse than normal controls. Surprisingly, a MANCOVA with BDI scores as a covariate yielded a significant difference in verbal learning [F (3, 45) = 2.88, $p < .04$]; however, all other MANCOVAs yielded results similar to those above.

A significant difference in overall visual memory was found between groups, with panic disorder subjects again performing worse than controls [F (6, 43) = 4.55, $p < .01$; See Table 3]. Further analyses revealed group differences in both visual learning [F (2, 47) = 5.00, $p < .01$] and visual recall [F (4, 45) = 7.10, $p < .01$]. MANCOVAs yielded similar results, except when state anxiety scores were used as a covariate. Under such conditions, the group difference on visual learning became a nonsignificant trend [F (2, 46) = 2.90, $p < .06$].

Results of the multivariate analyses of concentration variables are presented in Table 4. No difference was found between groups on measures of attention [F (3, 46) = 0.50, NS] under any condition.

Impaired versus unimpaired performances were determined for several memory measures, and rates of impairment between panic disorder subjects and controls were compared using Chi-square analyses with correction for continuity. Results of these analyses are presented in Table 5. A significantly greater number of panic disorder subjects than controls were impaired on the BVRT and delayed VR; however, the proportions of panic disorder subjects with impaired performances on PAL, verbal SR LTS, delayed LM, and verbal SR CLTR were not significantly greater than that of controls.

Multivariate analyses of variance were performed on the subsample of subjects not receiving treatment with benzodiazepines at the time of testing (n = 38). Results were essentially identical to those of the full sample. Significant differences were found between panic disorder subjects and controls on visual learning [F(2, 35) = 4.73, $p < .01$], visual recall [F (4, 33) = 4.87, $p < .01$], and verbal recall [F (4, 33) = 3.04, $p < .05$]. Groups did not differ on measures of verbal learning [F (3, 34) = 2.25, NS] or concentration [F (3, 34) = 0.44, NS].

DISCUSSION

In the present study, subjects with panic disorder demonstrated greater impairment of memory functioning than normal controls. Panic disorder subjects performed significantly worse than controls on overall visual memory, but not on measures of overall verbal memory or concentration. Analyses of learning versus recall variables revealed significant group differences on measures of visual learning, visual recall, and verbal recall, but not verbal learning. The presence and pattern of memory deficits is consistent with studies that have reported structural (Ontiveros et al., 1989) and metabolic (Reiman et al., 1984; 1986) abnormalities in the medial temporal lobe.

Imaging studies further suggest that cerebral involvement in panic disorder may be lateralized to the right temporal lobe. Our results demonstrate greater visual learning and recall deficits in panic disorder subjects than controls, and thus lend support to these findings. However, we also found significant (albeit

TABLE 2

VERBAL MEMORY VARIABLES BY GROUP STATUS

	Panic Disorder ($N = 25$)		Control ($N = 25$)		Unadjusted	Adj. for BDI	Adj. for State Anxiety	Adj. for BDI & State Anxiety
Verbal Learning	$\bar{X}$	(*SD*)	$\bar{X}$	(*SD*)	*F*	*F*	*F*	*F*
Paired Associate Learning	17.3	(2.8)	18.5	(1.7)	3.51	3.16	1.33	1.85
Verbal Selective Reminding:								
Long term storage	116.6	(19.4)	125.4	(9.6)	4.23*	7.76**	3.98*	6.37*
Trials to criterion	9.6	(3.0)	8.2	(3.3)	2.37	2.70	1.88	2.24
Overall Verbal Learning[a]					1.98	2.88*	1.40	2.23
Verbal Recall	$\bar{X}$	(*SD*)	$\bar{X}$	(*SD*)	*F*	*F*	*F*	*F*
Logical Memory:								
Delayed recall	4.6	(2.6)	6.1	(2.4)	4.50*	3.25	2.56	2.50
Associate Learning:								
Delayed Recall	9.6	(0.8)	9.8	(0.6)	1.62	0.49	0.03	0.03
Verbal Selective Reminding:								
Delayed recall	10.2	(1.8)	11.5	(0.9)	10.21**	13.28**	9.50**	11.77**
Long term retrieval	109.3	(22.5)	120.6	(12.7)	4.84*	7.36**	4.36*	6.15*
Overall Verbal Recall[a]					2.67*	3.30**	2.49*	3.05*
Overall Verbal Memory[a]					1.46	2.01	1.35	1.80

[a] Multivariate Analyses

*$p < .05$

**$p < .01$

TABLE 3
VISUAL MEMORY VARIABLES BY GROUP STATUS

	Panic Disorder ($N = 25$)		Control ($N = 25$)		Unadjusted	Adj. for BDI	Adj. for State Anxiety	Adj. for BDI & State Anxiety
Visual Learning	$\bar{X}$	(*SD*)	$\bar{X}$	(*SD*)	*F*	*F*	*F*	*F*
Visual Selective Reminding:								
Long term storage	79.8	(13.2)	88.3	(5.4)	8.92**	11.50**	5.69*	8.56**
Trials to criterion	7.8	(3.4)	5.4	(3.0)	7.36**	8.06**	3.31	5.22*
Overall Visual Learning[a]					5.00**	6.14**	2.90#	4.45**
Visual Recall	$\bar{X}$	(*SD*)	$\bar{X}$	(*SD*)	*F*	*F*	*F*	*F*
Visual Reproduction:								
Delayed recall	8.1	(2.4)	10.2	(2.3)	10.09**	6.30*	7.79**	6.15*
Visual Selective Reminding:								
Delayed recall	6.7	(1.4)	7.8	(0.4)	13.46**	9.17**	7.61**	7.05**
Long term retrieval	75.5	(16.6)	86.7	(6.7)	9.78**	11.87**	6.06*	8.80**
Benton VRT Errors	4.2	(1.6)	2.3	(1.9)	14.78**	8.59**	9.52*	7.49**
Overall Visual Recall[a]					7.10**	5.16**	4.60**	4.24**
Overall Visual Memory[a]					5.44**	3.34**	2.96**	2.73*

[a] Multivariate Analysis

#$p < .06$

*$p < .05$

**$p < .01$

TABLE 4

CONCENTRATION VARIABLES BY GROUP STATUS

	Panic Disorder ($N = 25$)		Control ($N = 25$)		Unadjusted	Adj. for BDI	Adj. for State Anxiety	Adj. for BDI & State Anxiety
	$\bar{X}$	(SD)	$\bar{X}$	(SD)	F	F	F	F
Mental Control	7.5	(1.5)	7.8	(1.3)	0.81	0.54	0.41	0.38
Digits Forward	6.8	(1.1)	6.7	(1.2)	0.24	0.42	2.92	1.96
Digits Backward	5.0	(1.3)	5.0	(1.2)	0.05	0.05	1.29	0.92
Overall Concentration[a]					0.50	0.41	1.38	1.00

[a]Multivariate Analysis

TABLE 5
PERCENTAGE OF SUBJECTS WITH IMPAIRED PERFORMANCE ON SELECTED MEMORY MEASURES

	Panic Disorder ($N = 25$)		Control ($N = 25$)		
	N		N		χ^2
Visual Memory					
Visual Reproduction:					
Delayed Recall	6	(24%)	0	(0%)	4.74*
Benton VRT Errors[a]	15	(60%)	6	(24%)	5.26*
Verbal Memory					
Associate Learning	0	(0%)	0	(0%)	--
Logical Memory:					
Delayed Recall[b]	12	(48%)	5	(20%)	3.21
Verbal Selective Reminding:					
Long Term Storage	4	(16%)	0	(0%)	2.45
Consistent Long Term Retrieval	3	(12%)	0	(0%)	1.42

[a]Percent of subjects displaying a greater number of errors than expected for their age and IQ using Benton (1974) norms.
[b]Percent of subjects scoring one standard deviation below the mean based on Abikoff et al. (1984) norms.
*$p < .05$

relatively weaker) between-group differences on measures of verbal recall, a result that is inconsistent with lateralized, right temporal lobe involvement. This finding may be explained by the observation that panic disorder subjects demonstrate abnormal rCBF elevations bilaterally during a panic attack (Reiman et al., 1989). It is possible that some panic disorder subjects were actually experiencing panic episodes during testing. If so, these subjects may have had difficulty with both verbal and visual memory tasks, due to bilateral temporal lobe involvement. It should be noted that the differences between the PD and control group on verbal memory performance disappear when one applies a more stringent criterion of memory dysfunction, namely the proportion of subjects displaying clinically significant deficits in neuropsychological testing. Such was not the case for visual memory, where a significantly greater proportion of the PD group, compared to controls, displayed clinically significant deficits based on available normative data.

Factors other than cerebral dysfunction may contribute to poor performance on neuropsychological tests. It has long been recognized that age, gender, education, fatigue, anxiety, and depression, among other factors, can influence neurocognitive functioning. In the present study, group differences were not found for age or education, and subjects were matched for gender; therefore, it is unlikely that these variables were responsible for the observed

findings. Depression and anxiety were controlled statistically, with results remaining essentially the same (see below for discussion). Moreover, it is unlikely that other factors (e.g., fatigue) would cause greater difficulty in one memory modality compared to another, as was found in the present study. Taken together, these findings strengthen the temporal lobe deficit hypothesis.

Multivariate analyses of covariance controlling for state anxiety and level of depressive symptomatology generally yielded results commensurate with MANOVAs. When state anxiety was held alone as a covariate, however, the group difference on visual learning was reduced to a nonsignificant trend. Conversely, when BDI scores were held alone as a covariate, the group difference on verbal learning improved to a statistically significant level. These results suggest that state anxiety and depression may differentially or selectively mediate visual and verbal learning. While the overlap between depression and panic has been well documented (e.g., Lesser et al., 1988), these results may suggest an important area of distinction between the two disorders.

The loss of the group difference in visual learning and the persistence of group difference in visual recall when state anxiety was controlled statistically is of particular interest. It would appear, based on these findings, that visual learning is mediated by processes related to state anxiety, while recall of visual information is independent of such processes. Studies of amnesic patients suggest that the hippocampus may play a role specifically in consolidation and storage of information, whereas other temporal lobe regions may be more important to retrieval (c.f., Butters & Miliotis, 1985). The hippocampus has also been implicated as a neuroanatomical substrate of anxiety (Gray, 1982). It may be that the role of the hippocampus in learning is secondary to its role in anxiety, and that learning is sacrificed during anxious activation. This is consistent with observations of decreased cognitive efficiency associated with severe anxiety (e.g., Yerkes & Dobson, 1908).

Similar effects were not found for verbal learning. Panic disorder subjects performed as well as controls on overall verbal learning with and without controlling for state anxiety. This, again, may indicate lateralization of function. It has been suggested that dysphoric mood is a function of the right cerebral hemisphere, while the euthymic mood is a function of the left hemisphere (c.f., Heilman, Bowers, & Valenstein, 1985). Given the dysphoric nature of anxiety, it is possible that anxiety is mediated primarily by the right hippocampus, thus accounting for the relationship between state anxiety and visual learning, but not verbal learning.

Unlike the effect for visual learning, the effect for visual recall remained after controlling for state anxiety. This supports the findings of studies of amnesics that retrieval of information relies on processes distinct from those underlying learning (Butters & Miliotis, 1985). Squire (1987) has suggested that memory storage is widely distributed in the brain, with different loci storing different aspects of the whole. Extensive connections from the neocortex converge on the parahippocampal gyrus, which may be important to long term retrieval of information. Studies of metabolic functioning in patients with panic disorder have reported abnormalities in the parahippocampal gyrus

(Reiman et al., 1984; 1986). If the parahippocampal gyrus is indeed important to retrieval of information, abnormalities in that region should affect recall regardless of mood state. Clearly, the absence of imaging techniques in the present study precludes firm conclusions regarding memory processes and involved brain regions. Moreover, as Butters and Miliotis (1985) point out, application of information processing models to neuropsychological studies of memory functioning is a relatively new venture, and has proven quite complex. Considerable research is therefore necessary to clarify the relationship between anxiety and neural mechanisms.

The present study failed to find group differences on tests traditionally believed to measure attentional activity. While this underscores the specific nature of panic disorder with regard to memory, it is inconsistent with the literature, which contains compelling evidence supporting differences in attention between subjects with anxiety disorders and controls. Barlow (1988) has proposed that attentional shifts toward self-evaluation are central to all anxiety disorders, and studies exploring the role of attentional processes in anxiety have suggested that anxious subjects shift attention toward threat-related stimuli (e.g., MacLeod, Mathews, & Tata, 1986; Mathews & MacLeod, 1985; Watts, McKenna, Sharrock, & Trezise, 1986). In neuropsychology, attentional activity is generally conceptualized in terms of three related constructs:

1) Attention, which refers to the capacity for selective perception,
2) Concentration, which is characterized as an effortful state of attention in which irrelevant stimuli are inhibited from awareness, and
3) Conceptual tracking, which involves concentrating on a line of thought over a period of time (Lezak, 1983).

While the tests of attentional activity used in the present study are often casually referred to as measures of attention (e.g., Erickson & Scott, 1977; Larrabee et al., 1983; Prigatano, 1978), it may be more accurate to conceptualize these tasks as measures of "concentration" and/or "conceptual tracking." This separation of concepts may reconcile the discrepancy between the present findings and those of the studies cited above, which appear to have examined perceptual selectivity (i.e., attention), rather than concentration or conceptual tracking.

The role of medication use among the panic disorder subjects and its potential effects on memory functioning deserves comment. Forty-four percent (n = 11) of the panic disorder subjects in the present study were taking benzodiazepines (ten alprazolam, one lorazepam) at the time of testing. In addition, one subject was taking an MAO inhibitor, and two others were taking tricyclic antidepressants (one of the subjects taking tricyclic medication was also taking a benzodiazepine). Overall, studies of the effects of benzodiazepines on memory functioning have yielded fairly consistent results. Several studies have suggested that acute administration of benzodiazepines may impair learning and memory significantly (Lister, 1985; Block & Berchou, 1984; Wolkowitz, et al., 1987). Studies of chronic use of benzodiazepines, however, have failed to show a similar

effect. Bornstein, Watson, and Pawluck (1985) administered the WMS LM and VR subtests, as well as other neuropsychological measures, to subjects who had taken either benzodiazepine or placebo for seven days. Results showed no differences between groups on any measure. Similarly, Lucki, Rickels, and Geller (1986) found that patients who had been taking a benzodiazepine for a mean of 60 months performed as well on a list-learning task while taking their medication as they did after their medication was terminated.

In contrast, studies of the effects of antidepressant medication on neuropsychological performance have yielded inconsistent results. Some have reported impaired performance on memory tests following treatment with imipramine (Legg & Stiff, 1976), while others have found no significant impairment in neuropsychological functioning (Heimann, Reed, & Witt, 1968; Kendrick & Post, 1967). Still others have reported that tricyclic medication actually improved performance of depressed patients on tests of learning and memory (Sternberg & Jarvik, 1976). Given the low frequency of antidepressant medication use in this study, any memory effects attributable to use of such medication is likely to be negligible.

Subjects taking psychotropic medications were included in the present study only if they had been maintained on their current dosage for at least one month, thus reducing the likelihood that results were due to acute benzodiazepine effects. Results of analyses excluding subjects treated with benzodiazepines were quite similar to those found using the entire sample, suggesting that the observed memory effects were not strongly influenced by subjects' medication status.

In addition to those previously mentioned, several other limitations of the present study should be addressed. First, the lack of a psychiatric control group makes it impossible to conclude unequivocally that the memory deficits observed in this study are specific to panic disorder. A controlled study including patients with other anxiety disorders would help clarify whether the observed memory dysfunction is specific to panic disorder. Second, the presence of neuropsychological deficits in panic disorder patients in no way confirms that temporal lobe dysfunction is of etiological significance in panic disorder. It is quite possible that the temporal lobe abnormalities detected in the PET studies and the memory deficits suggesting temporal lobe dysfunction observed in the present study, are concomitants or consequences of panic disorder. Prospective studies are needed to clarify whether neuropsychological deficits are present prior to the onset of panic disorder. Finally, although several widely-used memory tests were included in the battery, additional aspects of memory functioning, such as remote memory and implicit memory (e.g., priming effects), were not assessed. Also, our test battery did not include other measures of neuropsychological functions, such as language, psychomotor speed, or cognitive flexibility. Use of a comprehensive neuropsychological battery is needed to determine if memory is selectively affected in patients with panic disorder, or if impaired memory is just one facet of a constellation of neuropsychological deficits.

REFERENCES

Abikoff, H., Alivar, J., & Hong, G. (1987). Logical memory subtest of the Wechsler Memory Scale: Age and education norms and alternate-form reliability of two scoring systems. *Journal of Clinical and Experimental Neuropsychology*, **9**, 435-448.

Barlow, D. H. (1988). *Anxiety and its disorders: The nature and treatment of anxiety and panic.* New York: The Guilford Press.

Baxter, L. R., Phelps, M. E., Mazziotta, J. C., Guze, B. H., Schwartz, J. M., & Selin, C. E. (1987). Local cerebral metabolic rates in obsessive-compulsive disorder: A comparison with rates in unipolar depression and in normal controls. *Archives of General Psychiatry*, **44**, 211-218.

Baxter, L. R., Phelps, M. E., Mazziotta, J. C., Schwartz, J. M., Gerner, R. H., Selin, C. E., & Sumida, R. M. (1985). Cerebral metabolic rates for glucose in mood disorders: Studies with positron emission tomography and fluorodeoxyglucose F18. *Archives of General Psychiatry*, **42**, 441-447.

Baxter, L. R., Schwartz, J. M., Mazziotta, J. C., Phelps, M. E., Pahl, J. J., Guze, B. H., & Fairbanks, L. (1988). Cerebral glucose metabolic rates in nondepressed patients with obsessive-compulsive disorder. *American Journal of Psychiatry*, **145**, 1560-1563.

Baxter, L. R., Schwartz, J. M., Phelps, M. E., Mazziotta, J. C., Guze, B. H., Selin, C. E., Gerner, R. H., & Sumida, R. M. (1989). Reduction of prefrontal cortex glucose metabolism common to three types of depression. *Archives of General Psychiatry*, **46**, 243-250.

Beck, A. T. (1978). *Depression inventory.* Philadelphia: Center for Cognitive Therapy.

Bennett-Levy, J., & Powell, G. E. (1980). The subjective memory questionnaire (SMQ): An investigation into the self-reporting of 'real-life' memory skills. *British Journal of Social and Clinical Psychology*, **19**, 177-188.

Benton, A. L. (1967). Constructional apraxia and the minor hemisphere. *Confina Neurologica*, **29**, 1-16.

Benton, A. L. (1968). Differential behavioral effects in frontal lobe disease. *Neuropsychologia*, **6**, 53-60.

Benton, A. L. (1974). *Revised visual retention test: Clinical and experimental applications.* New York: The Psychological Corporation.

Block, R. I., & Berchou, R. (1984). Alprazolam and lorazepam effects on memory acquisition and retrieval processes. *Pharmacology, Biochemistry, & Behavior*, **20**, 233-241.

Bornstein, R. A., Watson, G. D., & Pawluck, L. K. (1985). Effects of chronic benzodiazepine administration on neuropsychological performance. *Clinical Neuropharmacology*, **8**, 357-361.

Buschke, H. (1973). Selective reminding for analysis of memory and learning. Journal of Verbal Learning and Verbal Behavior, **12**, 543-550.

Butters, N, & Cermak, L. S. (1975). Some analyses of amnesic syndromes in brain-damaged patients. In K. Pribram & R. Isaacson (Eds.), *The hippocampus*. New York: Plenum Press.

Butters, N., & Miliotis, P. (1985). Amnesic disorders. In K. M. Heilman & E. Valenstein (Eds.), *Clinical Neuropsychology.* New York: Oxford University Press.

Cullum, C. M., & Bigler, E. D. (1986). Ventricle size, cortical atrophy, and the relationship with neuropsychological status in closed head injury: A quantitative analysis. *Journal of Clinical and Experimental Neuropsychology*, **8**, 437-452.

desRosiers, G., & Ivison, D. (1988). Paired associate learning: Form 1 and Form 2 of the Wechsler Memory Scale. *Archives of Clinical Neuropsychology*, **3**, 47-67.

Drubach, D. A., & Kelly, M. P. (1989). Panic disorder associated with a right paralimbic lesion. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology*, **2**, 282-289.

Erickson, R. C., & Scott, M. L., (1977) Clinical memory testing: A review. *Psychological Bulletin*, **89**, 1130-1149.

Fletcher, J. M. (1985). Memory for verbal and nonverbal stimuli in learning disability groups: Analysis by selective reminding. *Journal of Experimental Child Psychology*, **40**, 244-259.

Geschwind, N. G., & Galaburda, A. M. (1985). Cerebral lateralization: Biological mechanisms, associations, and pathology: I., II., & III. A hypothesis and program for research. *Archives of Neurology*, **42**, 428-458, 521-552, 634-654.

Ghardian, A. M., Gauthier, S., & Bertrand, S. (1986). Anxiety attacks in a patient with right temporal lobe meningioma. *Journal of Clinical Psychiatry*, **47**, 270-271.

Gray, J. A. (1982). *The neuropsychology of anxiety: An enquiry into the functions of the septo-hippocampal system.* Oxford: Oxford University Press.

Hannay, H. J., & Levin, H. S. (1985). Selective reminding test: An examination of the equivalence of four forms. *Journal of Clinical and Experimental Neuropsychology*, **7**, 251-263.

Heilman, K. M., Bowers, D., & Valenstein, E. (1985). Emotional disorders associated with neurological diseases. In K. M. Heilman & E. Valenstein (Eds.), *Clinical Neuropsychology.* New York: Oxford University Press.

Heimann, H., Reed, C. F., & Witt, P. N. (1968). Some observations suggesting preservation of skilled motor acts despite drug-induced stress. *Psychopharmacologia*, **13**, 287-298.

Kellogg, C. E., & Morton, N. W. (1935). *Revised beta examination.* New York: Psychological Corporation.

Kendrick, D. C., & Post, F. (1967). Differences in cognitive status between healthy, psychiatrically ill, and diffusely brain-damaged elderly subjects. *British Journal of Psychiatry*, **113**, 75-81.

Larrabee, G. J., Kane, R. L., & Schuck, J. R. (1983). Factor analysis of the WAIS and Wechsler Memory Scale: An analysis of the construct validity of the Wechsler Memory Scale. *Journal of Clinical Neuropsychology*, **5**, 159-168.

Larrabee, G. J., Kane, R. L., Schuck, J. R., & Francis, D. J. (1985). Construct validity of various memory testing procedures. *Journal of Clinical and Experimental Neuropsychology*, **7**, 239-250.

Legg, J. F., & Stiff, M. P. (1976). Drug-related test patterns of depressed patients. *Psychopharmacology*, **50**, 205-310.

Lesser, I. M., Rubin, R. T., Pecknold, J. C., Rifkin, A., Swinson, R. P., Lydiard, R. B., Burrows, G. D., Noyes, R., Jr., & DuPont, R. L., Jr. (1988). Secondary depression in panic disorder and agoraphobia I: Frequency, severity, and response to treatment. *Archives of General Psychiatry*, **45**, 437-443.

Lezak, M. D. (1983). *Neuropsychological assessment* (2nd ed.). New York: Oxford University Press.

Lister, R. G. (1985). The amnesic action of benzodiazepines in man. *Neuroscience and Biobehavioral Review*, **9**, 87-94.

Lucki, I., Rickels, K., & Geller, A. M. (1986). Chronic use of benzodiazepines and psychomotor and cognitive test performance. *Psychopharmacology*, **88**, 426-433.

Macartney-Filgate, M. S., & Vriezen, E. R. (1988). Intercorrelation of clinical tests of memory. *Archives of Clinical Neuropsychology*, **3**, 121-126.

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology*, **95**, 15-20.

Mathew, R. J., Meyer, J. S., Francis, D. J., Semchuk, K. M., Mortel, K., & Claghorn, J. I. (1980). Cerebral blood flow in depression. *American Journal of Psychiatry*, **137**, 1449-1450.

Mathews, A., & MacLeod, C. (1985). Selective processing of threat cues in anxiety states. *Behavior Research and Therapy*, **23**, 563-569.

Clinical Neurosurgery, **19**, 421-446.

Mindus, P., Ericson, K., Greitz, T., Meyerson, B. A., Nyman, H., & Sjogren, I. (1986). Regional cerebral glucose metabolism in anxiety disorders studied with positron emission tomography before and after psychosurgical intervention: A preliminary report. *Acta Radiologica*, **369 (Suppl.)**, 444-448.

Moses, J. A. (1986). Factor structure of Benton's tests of visual retention, visual construction, and visual form discrimination. *Archives of Clinical Neuropsychology*, **1**, 147-156.

Nadel, L., & Morris, R. (1982). On novelty, places, and the septo-hippocampal system.

Behavioral and Brain Sciences, **5**, 493-494.

O'Keefe, J. (1983). Spatial memory within and without the hippocampal system. In W. Siefert (Ed.), *Neurobiology of the hippocampus* (pp. 375-403). New York: Academic Press.

Ontiveros, A., Fontaine, R., Breton, G., Elie, R., Fontaine, S., and Dery, R. (1989). Correlation of severity of panic disorder and neuroanatomical changes of magnetic resonance imaging. *Clinical and Research Reports*, **1**, 404-408.

Phelps, M., Mazziotta, J., Baxter, L., & Gerner, R. (1984). The PET study of affective disorders: Problems and strategies: NIH PET symposium. *Annals of Neurology*, **15 (Suppl.)**, S149-S156.

Prigatano, G. P. (1978). Wechsler Memory Scale: A selective review of the literature. *Journal of Clinical Psychology*, **34**, 816-832.

Reiman, E. M., Fusselman, M. J., Fox, P. T., & Raichle, M. E. (1989). Neuroanatomical correlates of anticipatory anxiety. *Science*, **243**, 1071-1074.

Reiman, E. M., Raichle, M. E., Butler, F. K., Herscovitch, P., & Robins, E. (1984). A focal brain abnormality in panic disorder, a severe form of anxiety. *Nature*, **310**, 683-685.

Reiman, E. M., Raichle, M. E., Robins, E., Butler, F. K., Herscovitch, P., Fox, P., & Perlmutter, J. (1986). The application of positron emission tomography to the study of panic disorder. *American Journal of Psychiatry*, **143**, 469-477.

Ruff, R. M., Light, R. H., & Quayhagen, M. (1988). Selective reminding tests: A normative study of verbal learning in adults. *Journal of Clinical and Experimental Neuropsychology*, **11**, 539-550.

Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1968). *State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press, Inc.

Spitzer, R. L., Williams, J. B. W., Gibbon, M., & First, M. B. (1989). *Instruction manual for the structured clinical interview for DSM III-R* (SCID, 5/1/89 Revision). New York: Biometrics Research Dept., New York State Psychiatric Institute.

Sternberg, D. E., & Jarvik, M. E. (1976). Memory functions in depression: Improvement with antidepressant medications. *Archives of General Psychiatry*, **33**, 219-224.

Squire, L. R. (1983). The hippocampus and the neuropsychology of memory. In W. Siefert (Ed.), *Neurobiology of the hippocampus* (pp. 492-511). New York: Academic Press.

Squire, L. R. (1987). *Memory and brain*. New York: Oxford University Press.

Telch, M.J., Lucas, J.A., & Nelson, P. (1989). Nonclinical panic in college students: An investigation of prevalence and symptomatology. *Journal of Abnormal Psychology*, **98**, 300-306.

Trahan, D. E., & Larrabee, G. J. (1984). Construct validity and normative data for some recently developed measures of visual and verbal memory. Paper presented at the 12th annual meeting of the International Neuropsychological Society, Houston, Texas.

Trahan, D. E., Quintana, J., Willingham, A. C., Goethe, K. E. (1988). The visual reproduction subtest: Standardization and clinical validation of a delayed recall procedure. *Neuropsychology*, **2**, 29-39.

Wall, M., Tuchman, M., & Mielke, D. (1985). Panic attacks and temporal lobe seizures associated with a right temporal lobe arteriovenous malformation: A case report. *Journal of Clinical Psychiatry*, **46**, 143-145.

Watts, F. N., McKenna, F. P., Sharrock, R., & Trezise, L. (1986). Colour naming and phobia-related words. *British Journal of Psychology*, **77**, 97-108.

Wechsler, D. (1945). A standardized memory scale for clinical use. *Journal of Psychology*, **19**, 87-95.

Wechsler, D. (1981). *Wechsler Adult Intelligence Scale-Revised*. New York: The Psychological Corporation.

Wolkowitz, O. W., Weingartner, H., Thompson, K., Pichar, D., Paul, S. M., & Hommer, D. W. (1987). Diazepam-induced amnesia: A neuropharmacological model of an "organic amnestic syndrome." *American Journal of Psychiatry*, **144**, 25-29.

Yerkes, R. M., & Dobson, J. D. (1908). The relation of strength of stimulus to rapidity of habit formation. *Journal of Comparative Neurology and Psychology*, **18**, 459-482.