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Diagnostic retrieval monitoring in patients with frontal lobe lesions: Further exploration of the distinctiveness heuristic

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Abstract

The distinctiveness heuristic is a diagnostic monitoring strategy whereby a subject expects a vivid recollection if a test item has been seen during the study session; the absence of a vivid recollection suggests the test item is novel. Consistent with the hypothesis that memory monitoring is dependent upon the frontal lobes, previous work using a repetition-lag paradigm found that patients with frontal lobe lesions were unable to use the distinctiveness heuristic. Evidence from recent neuroimaging studies, however, has suggested that use of the distinctiveness heuristic decreases the need for frontal processing. The present study used the criterial recollection task to revisit the question of whether patients with frontal lobe lesions are able to use a distinctiveness heuristic. Subjects studied black words paired with the same word in red font, a corresponding picture of the word, or both. They then took three memory tests designed to elicit false recognition of presented items. Both frontal lesion patients and matched control subjects showed intact ability to use the distinctiveness heuristic to reduce false recognition when tested on whether items were previously presented as pictures compared to red words. This use of the distinctiveness heuristic is evidence that patients with frontal lesions can use certain diagnostic monitoring strategies during recognition memory tasks when given guidance in coordinating their decision-making processes. This result suggests that the frontal lobes are necessary for self-initiation of this strategy during recognition memory tasks.
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Keywords: Memory; Metacognition; Metamemory; Frontal lobes; Retrieval monitoring; False memory

Distortions and failures of memory occur frequently in everyday life (Schacter, 1996). One common form of memory distortion, false recognition, has recently received greater attention in the laboratory (Schacter & Slotnick, 2004). False recognition occurs when a person mistakenly claims to have encountered a novel item or event previously. Healthy people employ a variety of cognitive monitoring strategies to prevent false recognition from happening (Dodson, Koutstaal, & Schacter, 2000). For example, in some situations, the specific recollection of certain detailed information can prevent a person from incorrectly "recognizing" a new event, even if that new event seems familiar (Gallo, 2004; Yonelinas, 2002). This strategy, known as a "recall-to-reject" phenomenon, is an example of a disqualifying memory monitoring process. That is, the *presence* of a particular recollected memory disqualifies a mutually exclusive but seemingly familiar event from actually having occurred (i.e., "This event seems familiar but could not have possibly happened because I definitely remember something different").

A different class of strategies that people employ to reduce false recognition involves using the *absence* of an expected recollection as a rule of thumb for correctly deciding that a novel

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event is indeed "new" (i.e., "This event could not have possibly happened because I definitely would have remembered more details about it"). This assessment of one's memory based on one's recollective expectations can be broadly classified under the category of diagnostic memory monitoring processes (Anderson, 1984; Foley, Johnson, & Raye, 1983; Hashtroudi, Johnson, & Chrosniak, 1989; Johnson, Hashtroudi, & Lindsay, 1993; Hicks & Marsh, 1999; Johnson, Raye, Foley, & Foley, 1981; Kelley, Jacoby, & Hollinghead, 1989).

In certain diagnostic monitoring situations, the type of memory that one expects to have in order to be confident that an event actually happened is a vivid perceptual recollection of the event itself. Schacter and colleagues have referred to this expectation for distinctive recollections as a distinctiveness heuristic (Israel & Schacter, 1997; Schacter, Israel, & Racine, 1999; for review, see Schacter & Wiseman, 2006). In their examination of the distinctiveness heuristic, Dodson and Schacter (2002b) used a variation of the repetition-lag paradigm (Jennings & Jacoby, 1997; Underwood & Freund, 1970) to induce familiarity-based false recognition. All participants studied an auditory list of unrelated words, but while one group of participants also saw corresponding pictures on a computer screen, a different group also saw the words on a computer screen. At test, participants were asked to make old-new recognition judgments about previously studied items and new words. To induce false recognition, each new word was repeated on the test with a variable number of intervening items (i.e., "lags") between the first and second occurrence. Dodson and Schacter (2002b) found that those subjects who studied pictures showed lower rates of false recognition compared to those who studied words, suggesting use of the distinctiveness heuristic.

Gallo, Weiss, and Schacter (2004) introduced another method for exploring the distinctiveness heuristic, the *criterial recollection task*. Subjects studied unrelated words in black font followed by the same word in a larger red font, a corresponding color picture, or both. Their memory was then assessed by three different types of criterial tests during which they were presented black words as memory cues. During the "Standard Test," participants were instructed to respond "yes" to any test word that corresponded to a previously studied item. During the "Red Word Test" and the "Picture Test," participants were to respond "yes" to any test word for which they could recollect the item as a red word or, respectively, as a picture. Importantly, all participants were explicitly reminded before taking the criterial tests that some items had been studied in both formats (i.e., as both a red word and a picture); therefore, memory that an item had been presented in one format was irrelevant to whether it had been presented in the other as well. Consistent with the participants' use of the distinctiveness heuristic, results from the criterial recollection task showed that false recognition rates to studied lures (i.e., items presented in the format other than the one in question for a given test type) and unstudied lures were lower on the Picture Test as compared to the Red Word Test.

As a tool for investigating the distinctiveness heuristic, the criterial recollection task has several advantages. First, by presenting some items at study as both a red word and a picture, the criterial recollection task discourages participants from using a disqualifying monitoring or recall-to-reject strategy; that is, recollection of the item in one format does not exclude the possibility that it was also presented in the other (the recall-to-reject strategy may be used in the repetition-lag paradigm [Dodson & Schacter, 2002; Jennings & Jacoby, 1997]). Second and most important, because subjects are verbally reminded when taking the criterial tests that they should base their decisions on their memory of the format in question, they are explicitly guided into having an expectation for vivid recollections when deciding to answer "yes" to items on the Picture Test. This aspect of the task helps to isolate the use of a diagnostic monitoring strategy, specifically that of the distinctiveness heuristic. Third, rates of true recognition for pictures and red words can be closely matched, by repeating the red words at study. Matching rates of true recognition for pictures and red words removes the potential criticism that effects of the distinctiveness heuristic are instead attributable to the picture superiority effect or familiarity-based processes. Lastly, the criterial recollection task uses a within-subjects design that eliminates between-subject variables from the interpretation of the results.

While many improvements have been made in the methodology for investigating the diagnostic monitoring processes involved in using the distinctiveness heuristic, the neural substrates of the strategy have been more difficult to elucidate (Schacter & Wiseman, 2006). In general, the metacognitive processes that evaluate and regulate memory for accuracy are thought to be dependent upon the frontal lobes (Fernandez-Duque, Baird, & Posner, 2000; Fletcher & Henson, 2001; Shimamura, 2000; Simons & Spiers, 2003; Thaiss & Petrides, 2003). In particular, the dorsolateral prefrontal cortex (DLPFC, roughly defined as Brodmann's areas 9 and 46) is believed to be critical for monitoring and verification of those memories for which only a feeling of familiarity initially exists (Burgess & Shallice, 1996; Dobbins, Foley, Schacter, & Wagner, 2002; Rugg, 2004). Thus, the frontal lobes and the DLPFC in particular seem to be logical *a priori* candidates for the neural correlates of the distinctiveness heuristic.

Gallo, Kensinger, and Schacter (2006) noted that the studies examining the frontal lobes and the distinctiveness heuristic have produced conflicting results. In a behavioral study using the repetition-lag paradigm, Budson, Dodson, et al. (2005) found that a group of patients with frontal lobe damage was unable to use the distinctiveness heuristic to reduce false recognition of repeated lures after studying pictures relative to a similar group who studied words. However, when Budson, Droller, et al. (2005) conducted an event-related potential (ERP) study of the repetition-lag task in healthy subjects, they discovered that it was the word group that showed the greatest ERP differences between studied and unstudied items in a frontally based component (from 1000 to 2000 ms), while the picture group instead showed the greatest differences in a parietally based component (from 550 to 1000 ms). Budson, Droller, et al. (2005) argued that only the word group needed to use frontally based post-retrieval verification and monitoring processing; the picture group simply used recollection of the studied picture (or lack thereof) as diagnostic of whether the item was studied. Gallo et al. (2006) obtained a similar finding in an functional magnetic resonance imaging study of healthy subjects using the criterial recollection task: DLPFC activity was reduced when rejecting familiar lures on the Picture Test relative to the Red Word Test. Given that the results of these imaging studies suggest that the distinctiveness heuristic decreases the recruitment of frontal lobes, the inability of patients with frontal lobe lesions to reduce their false recognition after studying pictures relative to words during performance of the repetition-lag paradigm (Budson, Dodson, et al., 2005) warrants further investigation.

The purpose of the present study is to better understand the role of the frontal lobes in diagnostic monitoring strategies such as the distinctiveness heuristic. We theorized that the reason for the frontal lesion patients' failure to use the distinctiveness heuristic after studying pictures during the repetition-lag paradigm was not because the distinctiveness heuristic itself is dependent upon the frontal lobes, but rather because the application of the heuristic in the repetition-lag paradigm required a level of "self-guidance" that the patients were unable to implement independently. That is, patients with frontal lobe lesions may have some intact diagnostic monitoring processes but may have difficulty selecting an effective strategy to accomplish a given task (Bechara & Van Der Linden, 2005; Damasio, 1985; Elliott, 2003; Godefroy, 2003; Stuss & Levine, 2002). Without an effective strategy, these patients may instead rely upon familiarity. Based on the results of the imaging studies above, we hypothesized that these patients should be able to use the distinctiveness heuristic to suppress false recognition, provided that they receive explicit instructions to do so. The criterial recollection task is designed such that subjects are explicitly guided into a diagnostic monitoring strategy demanding vivid recollections on the Picture Test.

To evaluate this hypothesis, we thus tested patients with a wide variety of frontal lobe lesions, within-subjects, using the criterial recollection task modeled after Gallo et al. (2004), Experiment 2. We predicted that false recognition of both studied and unstudied lures would be lower on the Picture Test as compared to the Red Word Test for all patients with lesions of the frontal lobes, reflecting use of the distinctiveness heuristic. Alternatively, if the patients were unable to use the distinctiveness heuristic and instead relied upon familiarity to make their recognition decisions, we would expect that false recognition of studied and unstudied lures would be similar on the Red Word and Picture Tests.

1. Methods

1.1. Participants

Twelve patients with various unilateral lesions in the frontal cortex participated in the experiment. The patients were all recruited from the neurosurgery services at Brigham and Women's Hospital (BWH), Boston, MA, USA. All 12 patients were status post-tumor resection and had stable lesions for at least 1 year prior to testing. Five patients had right-sided lesions, while seven had left-sided damage (see Table 1 for specific lesion localizations and patient handedness). Twelve control participants were matched to the patients on the basis of age (patient mean = 45.0 years, range 30–56 years; control mean = 46.1 years, range 29–61 years), education (patient mean = 17.3 years, range = 14–24 years; control mean = 17.4, range 12–26 years), and gender (7 male patients and 5 male controls). Control subjects were recruited by online postings on craigslist.org, by flyers placed in and around Boston, and by word of mouth. Written informed consent was obtained from all participants. The study was approved by the Human Subjects Committee of BWH. Participants were paid US $10 per hour for their participation. Participants were excluded if English was not their primary language or if they had a clinically significant history of psychiatric illness, alcoholism, or drug use. Controls were also excluded if they had suffered traumatic brain damage or cerebrovascular disease. Standard neuropsychological tests were performed to obtain quantitative measures of the participants' cognitive functions (Table 2).

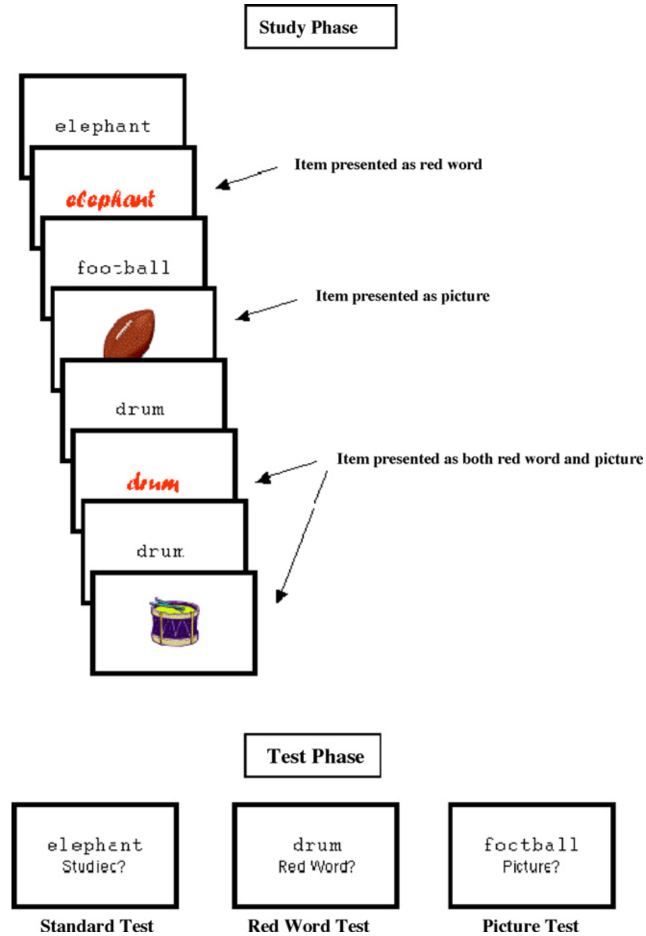


Fig. 1. Schematic representation of the criterial recollection task, modeled after Gallo et al. (2004), Experiment 2. At study, all items presented as red words were repeated three times. Each test consisted of four item types: (1) items studied as red words, (2) items studied as pictures, (3) items studied as both red words and pictures, and (4) non-studied items. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

1.2. Study design and procedure

The criterial recollection task used was a within-subjects paradigm similar to that of Gallo et al. (2004), Experiment 2 and Gallo et al. (2006); Fig. 1 presents a schematic overview of the task. Stimuli were 360 common nouns (e.g., football, drum) and corresponding colored pictures obtained from the Internet, divided into four groups of 90. During the study phase of the experiment, 90 stimuli were presented as red words, 90 were presented as pictures, 90 were presented as both, and 90 were set aside as unstudied lures during the test phase. For the test phase, the items in these four groups were evenly divided among three different types of criterial tests (i.e., the Standard Test, Red Word Test, and Picture Test). Twelve counterbalancing conditions were created to rotate the stimuli across subjects through the studied groups (i.e., studied as red word, picture, both, or neither) and criterial test types.

Table 1
Patients with frontal lobe lesions

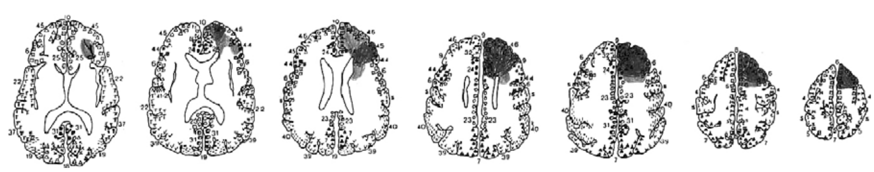
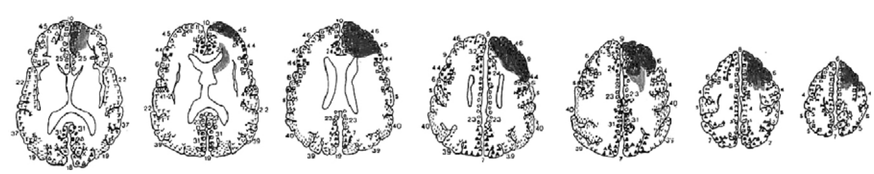
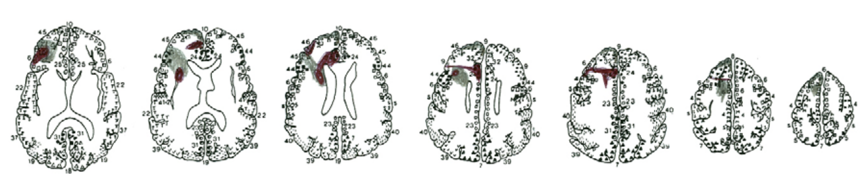
Patient	Gender/age handedness	Lesion site		
A	M/45 LH	R 4 6 8 9 10 11 12	24 25 32 44 45 46 47	
B	M/56 RH	R 6 8 9 10 11 45	46	
C	M/53 LH	R 6 8 9 10 11 25	32 44 45 46 47	
D	F/45 RH	L 4 6 8 9 10 24	32 44 45 46	
E	F/46 RH	L 4 6 8 9 10 24	25 32 44 45 46	
F	F/56 RH	L 6 8 9 10 32 45	46	
G	M/30 RH	R 6 8 9 10 24 32	44 45 46	
H	M/39 RH	L 6 9 11 12 44 45	46 47	

Table 1 (*Continued*)

Patient	Gender/age handedness	Lesion site	
I	M/54 LH	L 6 8 9 24 32	
J	F/48 RH	L 6 9 46	
K	M/38 RH	R 4 6	
L	F/30 RH	L 4	

Note: Schematic diagrams of lesion locations are drawn on standardized templates (Damasio & Damasio, 1989). Images are in radiologic convention with the right hemisphere on the left side of the template. Black areas represent regions where brain tissue has been replaced by cerebral spinal fluid. Grey areas represent regions where brain tissue has been severly damaged as indicated by increased signal on T2-weighted MRI. Lesion site numbers correspond to Brodmann's areas.

An Apple G4 (Cupertino, CA) computer presented all stimuli on a white background in the center of the screen. At study, each of the 270 items to be studied was first presented in lowercase black Courier font for 250 ms. Afterwards, each item was followed either by the same word in larger red Sand font (1 s) or the corresponding picture (1.5 s). The next black word followed after a 400 ms interstimulus interval. Of note, those items presented as red words (regardless of whether they were also presented as pictures) were repeated three times throughout the study phase. The study phase of the experiment was divided into three sections, separated by two self-paced breaks. All of the items, including the repetitions of red words, were randomly mixed and divided throughout the study sections.

At test, each of the three criterial test types (i.e., the Standard Test, Red Word Test, and Picture Test, each with 120 test items total) was divided into three blocks; the test phase was administered in three runs, with each run comprised of one block of each criterial test type. Thus, each of the nine individual criterial test blocks consisted of 40 items (10 studied as red words, 10 studied as a picture, 10 studied as both, and 10 unstudied lures) presented in random order. The order of the blocks was varied across the three runs and counterbalanced across subjects. An equal number of stimuli from the first, second, and third section of the study phase was tested in each of the three test runs.

Each individual criterial test block was first introduced with a title screen. Test items were presented as black words, under which an appropriate test prompt for the format in question was given in black capital letters (e.g., "STUDIED?" for the Standard Test, "RED WORD?" for the Red Word Test, "PICTURE?" for the Picture Test). Subjects responded to each prompt by pressing appropriate buttons on the computer (labeled "yes" and "no") that corresponded to whether they remembered the test item in the requested format (for the Standard Test, subjects were instructed to respond "yes" to any item previously studied, regardless of presentation format). The test phase was self-paced. All participants were explicitly reminded before beginning the test phase of the experiment that some items had been studied in both formats (e.g., as a red word and a picture); thus, responses on Red Word Test and Picture Test in particular should be based on actual recollections for the format in question and not be influenced by memories of items in non-criterial format.

Of note, before beginning the experiment, all subjects first completed a complete practice version of the task; thus, all encoding during the main experiment was presumably intentional. The practice paradigm used 24 stimuli that were not recycled in the main experiment.

2. Results

The results of the standard neuropsychological tests are shown in Table 2. As expected, the patients with frontal lobe lesions showed impairment on tests of frontal lobe function compared to control subjects. Most other tests of cognitive function did not differ significantly from controls, with the exception of the Logical Memory and Digit Span subtests of the Wechsler Memory Scales Third Edition. These findings are consistent with previous evidence showing that verbal working memory and memory for complex narratives are impaired with patients with frontal lobe lesions. (Zalla, Phipps, & Grafman, 2002).

Table 3 presents recognition data from the criterial recollection task for all of the individual patients as well as the means and standard deviations for both the patient and control groups. First we examine the overall performance of the two groups by analyzing the data from the Standard Test. However, because we are primarily interested in whether patients with frontal lobe lesions are able to use a distinctiveness heuristic appropriately, the critical analysis is whether patients have a lower rate of false recognition when they are asked to recollect items studied as pictures compared to when they are asked to recollect items studied as red words. To evaluate this hypothesis, we examine for both groups the two types of false recognition responses in

Table 2
Results of standard neuropsychological measures in patients with frontal lobe lesions and controls

Test	Patient												Frontal mean (S.D.)	Control mean (S.D.)	*F* 1,22	*p*
	A	B	C	D	E	F	G	H	1	J	K	L				
Global cognitive score																
MMSE (Folstein, Folstein, & McHugh, 1975)	30	29	30	29	30	28	28	29	28	30	30	30	29.25 (.86)	29.83 (.39)	4.53	.05
Intelligence																
ANART (Blair & Spreen, 1989)	35	41	40	46	45	46	41	43	47	45	40	42	42.58 (3.45)	44.58(3.70)	1.87	ns
Naming																
Boston naming test (Kaplan, Goodglass, & Weintraub, 1983)	60	60	60	58	60	60	60	60	60	60	58	60	59.67 (.78)	59.75 (.87)	<1	ns
Attention/Working Memory																
Verbal																
Arithmetic (Wechsler, 1997)	13	15	17	11	12	14	14	20	15	16	18	19	15.33 (2.78)	16.75 (2.26)	1.89	ns
Mental control (Wechsler, 1997)	26	21	37	25	21	24	39	40	25	34	30	32	29.50 (6.82)	33.75 (4.81)	3.12	.09
Digit span (Wechsler, 1997)	14	23	25	17	16	20	15	18	13	22	24	24	19.25 (4.23)	23.33 (3.23)	6.95	.02
Visual (Weintraub & Mesulam, 1988)																
Target Cancellation																
Left	0	0	0	0	0	1	0	0	0	0	0	0	.08 (.29)	.08 (.29)	<1	ns
Right	0	0	0	0	0	0	0	0	1	0	0	0	.08 (.29)	.33 {.65)	1.48	ns
Spatial span (Wechsler, 1997)	14	23	25	17	16	20	15	18	13	22	24	24	16.83 (1.59)	18.58 (3.70)	2.26	ns
Executive																
Trail Making B (Adjutant General's Office, 1944)	82	105	52	114	79	61	60	57	83	63	33	54	70.25 (23.16)	56.16 (22.97)	2.24	ns
Modified Wisconsin Card Sort (Nelson, 1976)																
Correct	36	40	36	36	37	33	36	40	20	37	36	43	35.83 (5.62)	37.50 (2.23)	<1	ns
Errors	25	26	15	24	14	39	31	15	52	22	8	19	24.17 (12.10)	13.17 (5.67)	8.14	01
Perseverative Errors	9	7	0	5	4	17	9	3	12	4	0	4	6.17 (4.95)	2.33 (3.28)	5.00	.04
Letter Fluency (Monsch et al., 1992)	35	34	41	34	30	30	50	46	44	44	37	49	39.50 (7.09)	52.75 (10.38)	13.30	<01
Category fluency (Monsch et al., 1992)	41	40	46	37	55	41	39	45	30	58	5:5	55	45.16 (8.80)	58.75 (7.24)	17.10	<.01
Memory (Wechsler, 1997)																
Verbal																
Logical memory																
I	38	37	51	3S	52	46	58	54	26	56	55	42	46.17 (9.82)	55.00 (6.15)	6.98	02
II	20	23	29	31	37	30	36	28	16	33	40	32	29.58 (7.05)	39.50 (4.81)	7.88	.01
Recognition	23	25	29	27	26	25	25	29	24	29	28	26	26.33 (2.06)	28.42 (.90)	10.31	<.01
CERAD word list (Morris et al., 1989)																
Encoding	21	19	19	25	27	22	23	27	22	29	28	24	23.83 (3.41)	25.83 (1.95)	3.12	.09
Recall	5	5	8	8	10	8	8	10	7	B	10	9	8.00 (1.71)	8.67 (1.30)	1.16	ns
Recognition	10	10	9	9	10	9	10	10	10	10	10	10	9.75 (.45)	9.67 (.65)	<1	ns
Visual																
Rey O (Meyers & Meyers, 1995)																
Immediate	20	14	26	27	19	17	25	33	21	24	25	26	22.87 (5.19)	23.75 (4.74)	<1	ns
Delay	19	13	25	28	15	18	26	30	21	25	24	22	22.00 (5.16)	23.38 (4.33)	<1	ns
Recognition	19	18	20	22	20	22	22	22	20	29	20	18	21.00 (2.92)	19.92 (1.73)	1.22	ns
Family Pictures (Wechsler, 1997)																
I	31	32	50	51	51	38	56	64	31	60	52	60	48.00 (11.98)	49.67 (7.90}	<1	ns
II	30	25	44	50	48	37	57	64	25	60	52	60	46.00 (13.86)	48.17 (9.28)	<1	ns
Visuospatial																
Line Bisection (Goodglass & Kaplan, 1983)	−3.7	−4.7	0	−0.2	−1.8	−1.2	10	2.5	2.5	1	−1.5	1.7	0.39 (3.77)	−1.84 (4.67)	1.66	ns
Rey O Copy (Meyers & Meyers, 1995)	36	34	36	34	35	35	34	35	36	36	36	36	35.25 (87)	35.67 (.78)	1.54	ns

F and *p* values are from one-way ANOVAs, ns = non-significant ($p > .10$).

Table 3
Mean proportion of items recognized in patients with frontal lobe lesions and controls for each memory test

Test	Control mean (S.D.)	Patient mean (S.D.)	Individual patient data											
			A	B	C	D	E	F	G	H	I	J	K	L
Standard test														
Both hit	.83 (.14)	.85 (.17)	.80	.47	.83	.90	1.0	.97	.87	.83	.57	.93	1.0	1.0
Word hit	.72 (.17)	.72 (.22)	.50	.57	.43	.87	.87	1.0	.60	.73	.37	.83	.93	.97
Picture hit	.65 (.13)	.66 (.20)	.57	.53	.47	.60	.83	.90	.90	.67	.30	.63	.97	.60
New false alarms	.10 (.07)	.13 (.12)	.00	.13	.23	.17	.00	.37	.13	.07	.00	.00	.33	.10
Red word test														
Both hit	.77 (.16)	.85 (.15)	.80	.50	.67	.93	.87	.97	.77	.93	.80	.97	.97	.97
Word hit	.67 (.22)	.75 (.20)	.63	.30	.57	.93	.93	.93	.73	.77	.63	.97	.77	.93
Picture false alarms	.42 (.21)	.51 (.18)	.73	.17	.40	.60	.43	.70	.57	.57	.43	.43	.80	.33
New false alarms	.14 (.11)	.11 (.09)	.13	.07	.13	.07	.07	.17	.23	.17	.03	.00	.30	.00
Picture test														
Both hit	.74 (.14)	.74 (.19)	.53	.33	.70	.77	.93	.77	.77	.67	.67	1.0	.77	.97
Picture hit	.58 (.15)	.63 (.19)	.57	.53	.63	.67	.77	.80	.60	.37	.27	.77	.70	.93
Word false alarms	.12 (.11)	.11 (.06)	.07	.13	.20	.13	.00	.17	.13	.07	.07	.07	.13	.10
New false alarms	.05 (.06)	.04 (.03)	.03	.10	.03	.00	.03	.07	.03	.07	.07	.00	.00	.07

this experiment: (1) responses to studied lures on the Red Word Test and the Picture Test (i.e., items studied only as pictures presented on the Red Word Test and items studied only as red words presented on the Picture Test), and (2) responses to unstudied lures on the Red Word Test and the Picture Test.

2.1. Overall performance: standard test

An ANOVA for the Standard Test with the between-subjects variable of Group (patients versus controls) and the within-subjects variable of Item Type (both hits, red word hits, picture hits, false alarms) showed an effect of Item Type [$F(3,66) = 209.76$, $p < .0005$, $\eta^2 = .91$], no effect of Group [$F(1,22) < 0.1$, $\eta^2 < .01$], and no Item Type × Group interaction [$F(3,66) < 0.1$, $\eta^2 < .01$]. Thus, there was no difference between the groups in their overall memory performance. Paired sample *t*-tests showed that the effect of Item Type was present because both hits were greater than red word hits [$t(23) = 4.35$, $p < .0005$], red word hits in turn were greater than picture hits [$t(23) = 2.33$, $p = .029$], and picture hits in turn were greater than false alarms [$t(23) = 17.22$, $p < .0005$].

2.2. Criterial performance: false alarms on red word test versus picture test

An ANOVA with the between-subjects variable of Group (patients versus controls) and within-subjects variables of Test (Red Word versus Picture) and False Alarm Type (Studied versus Unstudied) revealed effects of Test [$F(1,22) = 61.15$, $p < .0005$, $\eta^2 = .74$] and False Alarm Type [$F(1,22) = 140.01$, $p < .0005$, $\eta^2 = .86$], and an interaction of Test × False Alarm Type [$F(1,22) = 66.27$, $p < .0005$, $\eta^2 = .75$]. There was no effect of Group [$F(1,22) < 1$, $\eta^2 < .01$] and no reliable interactions with group [Test × Group: $F(1,22) < 1$, $\eta^2 = .03$; False Alarm Type × Group: $F(1,22) = 2.62$, $p = .119$, $\eta^2 = .11$; Test × False Alarm Type × Group: $F(1,22) = 2.47$, $p = .131$, $\eta^2 = .10$]. As expected the effect of Test is present because studied and unstudied false alarms were much greater on the Red Word Test than on the Picture Test, suggesting use of the distinctiveness heuristic. The lack of a Test × Group interaction indicates that the effect of Test was present equally in the patients and controls (Fig. 2). The effect of False Alarm Type is present because studied false alarms were greater than unstudied false alarms. The interaction between Test and False Alarm Type is likely present because the difference between studied and unstudied false alarms was greater for the Red Word Test (.469–.125 = .344) than the Picture Test (.111–.048 = .063) [$t(23) = 7.89$, $p < .0005$].

2.3. False alarm rates for individual patients

The individual patterns of response rates to studied and unstudied lures on the Picture and Red Word Tests for each frontal patient mirrored the patterns of the group as a whole (Table 3). Of particular interest, every patient tested had a lower rate of false recognition of items studied only as red words on

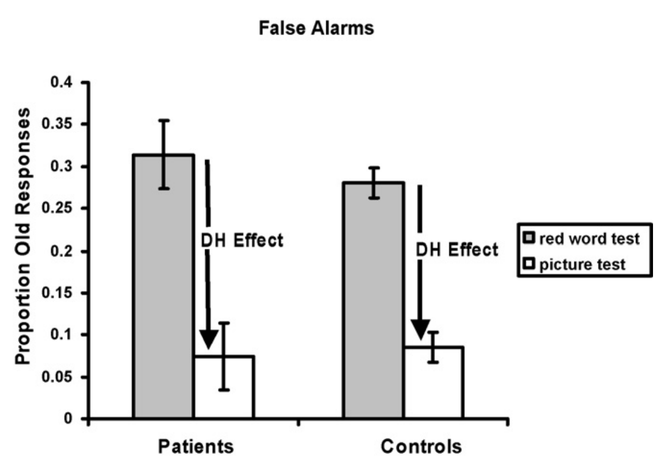


Fig. 2. Total false alarms on red word and picture tests in patients with frontal lobe lesions and controls. The difference in false alarms represents the effect of the distinctiveness heuristic (DH).

the Picture Test compared to items studied only as pictures on the Red Word Test. This finding suggests the use of a distinctiveness heuristic for each patient, regardless of the laterality of the patient's lesion or its specific Brodmann's areas.

3. Discussion

When performing the criterial recollection task, patients with frontal lobe lesions and matched control subjects showed lower false recognition rates to studied and unstudied lures when performing the Picture Test compared to the Red Word test. This was despite the fact that on the Standard Test the hit rate was slightly higher for items studied as red words compared to items studied as pictures. The degree to which the false recognition rate was lower for items on the Picture Test compared to the Red Word Test was the same for both patients and controls (Table 3 and Fig. 2). Furthermore, all of the individual patients tested showed a pattern of results that mirrored the group as a whole. Based on prior work with the criterial recollection task (Gallo et al., 2004, 2006), these data suggest that patients with frontal lobe lesions are able to use the distinctiveness heuristic to suppress false recognition, regardless of the laterality, region, or extent of their respective lesions.

It is notable that the ability of these patients to employ a diagnostic monitoring strategy such as the distinctiveness heuristic to reduce false recognition was preserved despite the fact that the patients were impaired on standard neuropsychological tests relative to control subjects in multiple cognitive functions attributed to the frontal lobes (Monsch et al., 1992; Nelson, 1976) (Table 2). This neuropsychological impairment suggests that the patients indeed possess deficits in executive function that correlate with their known frontal lobe lesions (Berman et al., 1995). Our results show that these patients are able to use a diagnostic monitoring strategy, despite their impairments in task switching and coordinating cognitive subprocesses to achieve a specific goal (Bechara & Van Der Linden, 2005; Damasio, 1985; Elliott, 2003; Godefroy, 2003; Stuss & Levine, 2002).

Our patients' lesions were specifically selected to encompass the widest range of Brodmann's areas possible within the frontal lobes, some of which are thought to be involved heavily in memory processing (Fletcher & Henson, 2001; Simons & Spiers, 2003). Rather than isolating particular regions of the frontal lobe as neural correlates for the distinctiveness heuristic, our results instead suggest that having an expectation for a vivid recollection when making a recognition memory decision about a test item (i.e., during the Picture Test in the criterial recollection task) may decrease the need for engaging frontal regions during retrieval. The findings of the present study complement recent imaging studies investigating the use of the distinctiveness heuristic in healthy subjects (Budson, Droller, et al., 2005); Gallo et al., 2006). An ERP study of the repetition-lag paradigm (Budson, Droller, et al., 2005), and an fMRI study of the criterial recollection task (Gallo et al., 2006), both in healthy subjects, yielded results consistent with this idea that using a distinctiveness heuristic as a diagnostic monitoring strategy alleviates the burden placed on the frontal lobes for monitoring recognition memory. That is, when a subject at test is deciding whether he or she recognizes a previously studied picture is expecting to remember old images vividly, he or she reduces any internal debate over whether those items that just invoke a feeling of familiarity are old or new. Were the distinctiveness heuristic not in place as a mental "rule of thumb," making decisions on those items that invoke only familiarity would require more frontal processing (Burgess & Shallice, 1996; Dobbins et al., 2002; Rugg, 2004). Although studies using cognitive neuroscience activation techniques such as ERPs and fMRI in healthy subjects can suggest that specific brain regions are not necessary for a given cognitive process, studies using patients with brain lesions provide much stronger evidence.

Why were frontal patients able to use the distinctiveness heuristic in the criterial recollection task, but not in the repetition-lag paradigm of Budson, Dodson, et al. (2005)? One possibility is that there were differences between the groups of subjects in the present study and those of Budson et al. We think that subject difference is unlikely to be the cause, however, since the pattern of results of each and every patient in the present study suggested use of the distinctiveness heuristic. We believe that the answer lies in the differences between the paradigms. Although there are several differences mentioned in the Introduction, the critical difference is likely that in the repetition-lag paradigm subjects need to develop the strategy of the distinctiveness heuristic themselves, whereas the criterial recollection task specifically guides subjects to use the distinctiveness heuristic. On the picture test of the criterial recollection task, subjects are instructed to respond "yes" to a test word only if they can recollect the item as a picture. No such explicit instructions are given in the repetition-lag paradigm; subjects in the picture condition and those in the word condition were given the same test instructions: to respond "old" only to items studied during the syllable-counting study phase. Budson, Dodson, et al. (2005) found that control subject were able to develop and use the diagnostic monitoring strategy of the distinctiveness heuristic to reduce their false recognition, whereas patients with frontal lobe lesions were not, and instead likely relied upon familiarity in their recognition judgments.

The results of the present experiment, in conjunction with that of Budson, Dodson, et al. (2005), suggests that patients with frontal lobe lesions have the ability to recognize whether a test item conjures up a distinct recollection, but are not able to use metamemorial expectations for these recollections as a strategy for reducing false memories unless they receive explicit guidance. This interpretation is consistent with the concept of executive function being dependent on the frontal lobes (Bechara & Van Der Linden, 2005; Damasio, 1985; Elliott, 2003; Godefroy, 2003; Stuss & Levine, 2002). With an impaired ability to self-coordinate otherwise intact mental subprocesses (i.e., the distinctiveness heuristic) to achieve a larger goal (e.g., making correct recognition memory judgments), frontal lobe lesion patients are indeed able to employ certain forms of diagnostic monitoring to evaluate their memory—provided that they receive instructions on exactly when the use of such monitoring strategies are appropriate.

Given that the distinctiveness heuristic itself is not dependent on intact frontal lobes, the question of where the neural substrates for this particular monitoring strategy lie remains unanswered. Recent functional imaging studies have focused on the role that the parietal lobe, normally associated with visuospatial function, plays in recognition memory (Ally & Budson, 2007; Cavanna & Trimble, 2006; Wagner, Shannon, Kahn, & Buckner, 2005). Parietal and precuneus regions are known to be activated during tasks in which subjects are instructed to generate visual imagery for words on which they are subsequently to be tested (Gonsalves et al., 2004). Although the exact meaning of these parietal activations during memory tasks remains very much a subject of debate (Ally & Budson, 2007; Rossi et al., 2006), the potential intersection of visuospatial function and recognition memory at the parietal lobe makes investigation of its role in the distinctiveness heuristic an interesting possibility. Some support for this idea may be found in the ERP study of Budson, Droller, et al. (2005), discussed above. Although one cannot draw reliable neuroanatomical inferences regarding the neural generators of the ERP data, it is interesting to note that those subjects who used the distinctiveness heuristic showed differences between item types in a parietally based component. Additionally, the fMRI study of Gallo et al. (2006) found neighboring fusiform activation when subjects were attempting to recollect pictures. Future studies using the criterial recollection paradigm in patients with parietal lobe lesions could help to determine the importance of the parietal lobes in the distinctiveness heuristic.

In conclusion, we have shown that the distinctiveness heuristic is a diagnostic monitoring strategy that is not dependent upon the frontal lobes. However, the frontal lobes are necessary for self-initiation of this strategy during recognition memory tasks. Lastly, it is worth noting that from a clinical standpoint, the present research suggests that patients (and even healthy older adults) with diminished frontal lobe function may be able to utilize diagnostic monitoring strategies if they are provided with explicit instructions on how to do so.

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