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Metacognition and false recognition in patients with frontal lobe lesions: the distinctiveness heuristic

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Abstract

The distinctiveness heuristic is a response mode in which participants expect to remember vivid details of an experience and make recognition decisions based on this metacognitive expectation. Whereas much is known about the cognitive processes that are involved in using the distinctiveness heuristic, little is known about the corresponding brain processes. Because such metacognitive processes that involve the evaluation and control of one's memory are believed to be dependent upon the frontal lobes, the authors examined whether the distinctiveness heuristic could be engaged to reduce false recognition in a repetition lag paradigm in patients with lesions of their frontal lobes. Half of the participants studied pictures and corresponding auditory words; the other half studied visual and auditory words. Studied and novel items were presented at test as words only, with all novel items repeating after varying lags. Controls who studied pictures were able to reduce their false recognition of repeated lag items relative to those controls who studied words, demonstrating their use of the distinctiveness heuristic. Patients with frontal lobe lesions showed similar levels of false recognition regardless of whether they studied pictures and words or words only, suggesting that they were unable to use the distinctiveness heuristic. The authors suggest that the distinctiveness heuristic is a metacognitive strategy, dependent upon the frontal lobes, that may be engaged by healthy individuals to reduce their false recognition.

Keywords: Memory; Frontal lobes; False memory; Metacognition; Patients

1. Introduction

Although memory is often accurate, memory distortions and false memories frequently occur (Schacter, 1996). False recognition is one type of memory distortion that has been recently studied in the laboratory. False recognition occurs when people incorrectly claim to have previously encountered a novel word or event. During the past several years, there has been growing interest in procedures that reduce the occurrence of false memories (see Dodson, Koutstaal, & Schacter, 2000; Schacter & Wiseman, 2003, for review). For example, a number of experiments have observed reduced false recognition of novel items that are semantically related to previously studied items when the study and test trials are repeated multiple times (Budson, Daffner, Desikan, & Schacter, 2000; Kensinger & Schacter, 1999; McDermott, 1996; Schacter, Verfaellie, Anes, & Racine, 1998a). These studies have contributed to our understanding of the neuropsychology of memory failure in specific brain diseases and the occurrence of clinically relevant memory distortions in certain patient populations, as well as having aided our understanding of normal memory function.

Israel and Schacter (1997) investigated another method to reduce false recognition. They tested the idea that if false recognition of semantically-related words depends upon par-

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ticipants' reliance upon the common semantic features or gist of the study list, then it should be possible to reduce false recognition by use of study conditions that promote encoding of distinctive information about particular items. Israel and Schacter presented one group of young adults with lists of semantic associates in which each word was presented auditorily and was also accompanied by a corresponding picture. A second group heard the same words auditorily, but instead of an accompanying picture, they saw the visual presentation of the word. Israel and Schacter found that pictorial encoding yielded lower levels of false recognition of both semantically related and unrelated lures than did word encoding alone.

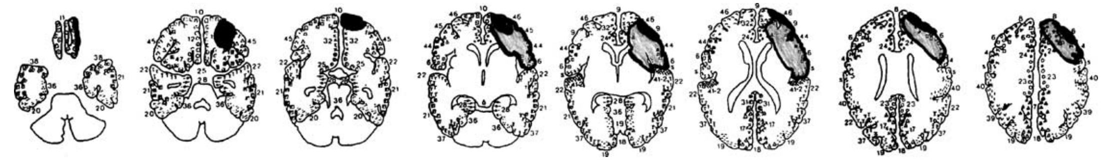
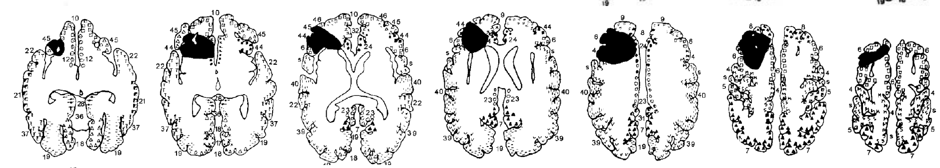
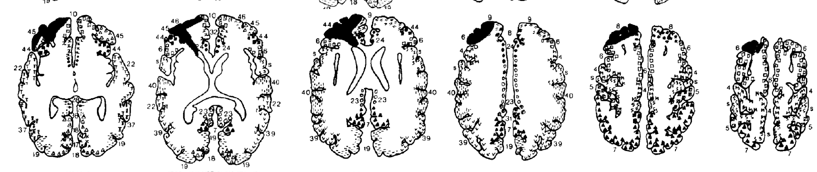
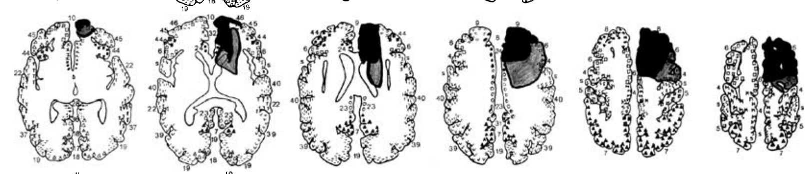
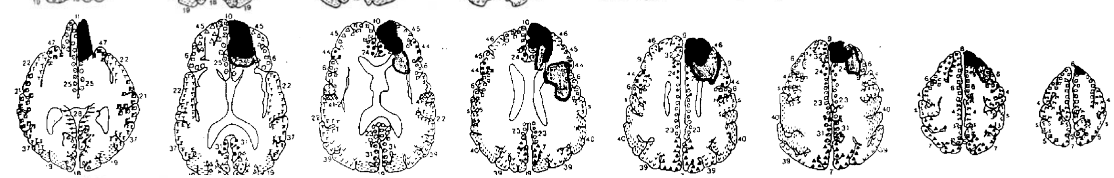
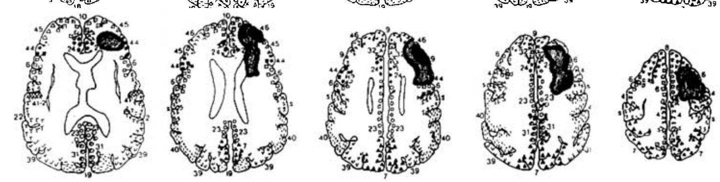
In a follow-up study, Schacter, Israel, and Racine (1999) found that participants showed a more conservative response bias after picture encoding than after word encoding. They suggested that this more conservative response bias observed after picture encoding may depend on a general shift in responding based on participants' metamemorial assessments of the kinds of information they feel they should remember (Strack & Bless, 1994). Because they had encountered pictures with each of the presented words, participants in the picture encoding condition used a general rule of thumb whereby they demanded access to detailed pictorial information in order to support a positive recognition decision; failure to gain access to such distinctive information when tested with related lures would tend to result in a negative recognition decision. Importantly, Schacter et al. (1999) argued that suppression based on metamemorial assessments can function without access to specific information regarding the particular items studied. They hypothesized that the suppression of false recognition observed in the picture encoding group thus relied on a general expectation that a test item should elicit a vivid perceptual recollection if, indeed, it had been presented previously. Participants in the word encoding group, by contrast, would not expect to retrieve distinctive representations of previously studied items and are thus much less likely to demand access to detailed recollections. Schacter et al. (1999) referred to the hypothesized rule of thumb used by the picture encoding group as a distinctiveness heuristic (cf. Chaiken, Lieberman, & Eagly, 1989; Johnson, Hashtroudi, & Lindsay, 1993; Kahneman, Slovic, & Tversky, 1982).

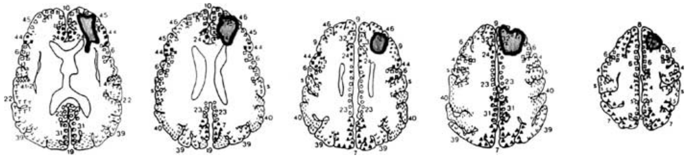
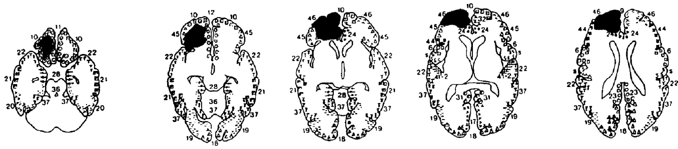
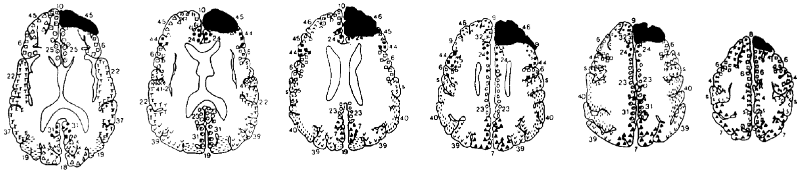
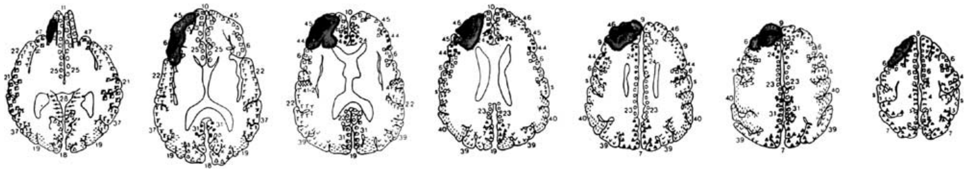
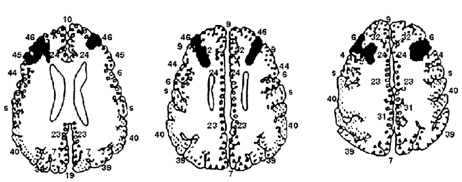
We agree with Dodson and Schacter (2002a,b) who argue that the idea of the distinctiveness heuristic is consistent with Johnson and colleagues' source monitoring framework in which participants can recruit a variety of different decision strategies when making memory judgments (Johnson et al., 1993). Previous studies have found that strategies similar to the distinctiveness heuristic are used when test items are attributed to a particular source (e.g. Anderson, 1984; Foley, Johnson, & Raye, 1983; Hashtroudi, Johnson, & Chrosniak, 1989; Hicks & Marsh, 1999; Johnson, Raye, Foley, & Foley, 1981; Kelley, Jacoby, & Hollinghead, 1989). One example is the "it had to be you" effect which refers to a test bias in which individuals who heard some words and generated others are more likely to claim that falsely recognized words were heard rather than generated (Johnson et al., 1981). Presumably, this bias reflects the metamemorial belief that self-generated information is more memorable than heard information (Johnson & Raye, 1981), leading participants to judge a familiar item to be heard rather than generated because of the absence of recollection of having generated the item. This view of the distinctiveness heuristic is also consistent with the monitoring processes discussed by Schacter, Norman, and Koutstaal (1998) in their constructive memory framework, and with the activation/monitoring account of Roediger, McDermott, and colleagues (e.g. McDermott & Watson, 2001; Roediger, Watson, McDermott, & Gallo, 2001). For example, Hicks and Marsh (1999) demonstrated that a decision strategy based upon the absence of memory for expected source information allows participants to reduce their false recall of semantic associates. (See Dodson & Schacter, 2002a,b,c, for further discussion of the distinctiveness heuristic in relation to retrieval strategies.) In summary, we believe the distinctiveness heuristic is a particular instance of the general class of metacognitive strategies in which the absence of memory for expected information is diagnostic that the item was not studied.

Whereas much is known about the cognitive processes that are involved in using the distinctiveness heuristic, Schacter and Wiseman (2003) note that nothing is known about the corresponding brain processes. However, such metacognitive processes that involve the evaluation and control of one's memory are believed to be dependent upon the frontal lobes (Fernandez-Duque, Baird, & Posner, 2000; Shimamura, 2000; Thaiss & Petrides, 2003). In their reviews, Fletcher and Henson (2001) and Simons and Spiers (2003) note that dorsolateral frontal cortex in particular is important for verification, monitoring, and evaluation of representations that have been retrieved from memory and are maintained by ventrolateral frontal cortex. We therefore thought it likely that the dorsolateral frontal cortex would be important for metacognitive processes such as the distinctiveness heuristic. To test this hypothesis, we studied patients with lesions in dorsolateral frontal cortex (roughly Brodmann areas 9 and 46) from strokes or tumor resections that were at least 1-year-old. We predicted that such patients would be unable to use the metacognitive strategy of the distinctiveness heuristic to reduce their false recognition.

We used a repetition-lag paradigm introduced by Underwood and Freund (1970) and modified by Jennings and Jacoby (1997) and Dodson and Schacter (2002b). In the modified version of this paradigm, participants either study a list of unrelated words or pictures and then make old-new recognition judgments about previously studied items and new words. Each new word occurs twice on the test, with a variable lag (i.e. a variable number of intervening words) between the first and second occurrence. Participants are instructed to say "old" to studied words only, and to say "new" to non-studied words, even when they repeat. Although participants are explicitly told that if a word occurs twice on the test they can safely conclude that it is a new word, participants

Table 1
Patients with frontal lobe lesions

Patient	Gender/age	Lesion site	
A	M/35	L 6 32 8 44 9 45 10 46 24	
B	M/40	R 4 45 6 8 9 44	
C	M/48	R 6 45 8 46 9 10 44	
D	F/34	L 4 24 6 32 8 46 9 10	
E	F/54	L 6 24 8 25 9 44 10 45 11 46	
F	F/51	L 4 45 6 46 8 9 44	

G	M/45	L 9 24 32 45 46		
H	F/45	R 9 10 11 24 45	 46	
I	M/58	L 8 9 10 32 45	 46	
J	F/49	L 9 10 24 44 45	 46	
K	M/25	R 6 9 10 11 24	 32 44 45 46	
L	M/67	R 6 45 46	L 6 46	

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 severely damaged as indicated by increased signal on T2 weighted MRI. Grey areas are outlined in black for clarity. Lesion site numbers correspond to Brodmann areas. The first six patients participated in the word condition, the second six in the picture condition.

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.)	d.f.	*F*	*p*
	A	B	C	D	E	F	G	H	I	J	K	L					
Global cognitive score																	
MMSE (Folstein et al., 1975)	26	28	30	29	29	29	29	30	29	30	27	29	28.83 (1.27)	29.55 (.60)	(1, 30)	4.69	0.04
Intelligence																	
ANART (Blair & Spreen, 1989)	108	103	120	115	120	129	108	111	114	124	118	127	116.42 (8.06)	120.75 (5.89)	(1, 30)	3.07	0.09
Attention/executive function																	
Trail making B (Adjuant General's Office, 1944)	161	144	61	105	144	114	97	66	89	60	75	59	97.92 (36.28)	66.80 (20.42)	(1, 30)	9.73	<.01
Maze planning (Wechsler, 1991)	5	0	3	0	0	0	0	0	4	0	0	4	1.33 (2.02)	2.50 (1.90)	(1, 30)	2.69	ns
Rey figure (Organization; Hamby et al., 1993)	1	1	1	3	1	2	1	3	1	1	2	2	1.58 (.79)	2.10 (1.25)	(1, 30)	1.64	ns
Short category (Wetzel & Boll, 1987)	15	29	21	48	42	53	24	34	36	25	28	14	30.75 (12.32)	29.55 (16.30)	(1, 30)	<1	ns
Verbal fluency (Monsch et al., 1992)																	
Letters (FAS)	31	23	41	32	50	31	24	43	23	45	44	43	35.42 (16.00)	53.15 (13.54)	(1, 30)	11.23	<.01
Categories (animals, vegetables)	41	34	43	45	28	40	32	58	21	56	52	54	29.42 (9.21)	38.45 (6.56)	(1, 30)	10.49	<.01
Naming																	
Boston naming test (Kaplan et al., 1983)	49	58	57	58	57	57	52	60	59	60	55	60	56.56 (3.37)	58.75 (1.14)	(1, 30)	7.18	0.01
Memory (CERAD; Morris et al., 1989)																	
Word list memory	22	16	19	28	–	–	15	18	14	–	23	21	19.55 (4.45)	23.00 (3.39)	(1, 16)	3.41	0.08
Word list recall	6	5	9	6	–	–	0	4	5	–	9	3	5.22 (2.82)	8.67 (1.66)	(1, 16)	9.98	0.01
Word list recognition	10	8	9	10	–	–	9	9	8	–	10	8	9.00 (0.87)	10.00 (0.00)	(1, 16)	12.00	<.01
Visuospatial ability (Spreen & Strauss, 1998)																	
Rey figure (accuracy)	32	36	36	35	36	35	36	33	36	36	36	36	35.21 (1.47)	35.20 (2.07)	(1, 30)	<1	ns

Note: Missing values in the frontal data are indicated by (–). The results for the CERAD were not available for 11 control participants. d.f., *F*, and *p* values are from of one-way ANOVAs between frontal patients and controls. ns: non-significant, $p > .10$.

in a word only encoding condition nonetheless incorrectly respond “old” to many of the repeated new words, especially when they repeat at a long lag. Jennings and Jacoby (1997), in a similar condition involving only words, observed that younger and older adults falsely recognized repeated new words. Presumably, individuals mistake the familiarity of the repeated new words—derived from their earlier exposure on the test—for prior presentation in the study phase. By contrast, both older and younger adults reduced their false recognition rate to the repeated new words when they studied pictures of the items. Dodson and Schacter (2002b) argued that participants in the picture-encoding condition, like those in Schacter et al. (1999), used a distinctiveness heuristic during the test, inferring that test items are new when they fail to retrieve memory for pictorial information about the item.

2. Methods

2.1. Participants

Twelve right-handed patients with anatomical lesions in frontal cortex participated in the experiment. The patients from the neurology and neurosurgery services at Brigham and Women’s Hospital (BWH), Boston, MA, USA, were specifically recruited because they had lesions in dorsolateral prefrontal cortex (Brodmann areas 9 and 46; see Table 1 for specific lesion localizations). Eleven patients had had brain tumors resected, 1 patient had a stroke. All participants had stable lesions for at least 1 year prior to testing. Twenty control participants were matched to the patients on the basis of age (patient mean = 45.7 years, range = 25–67 years; control mean = 45.8 years, range = 30–66 years), education (patient mean = 16.1 years, range = 13–23 years; control mean = 16.5 years, range = 12–20 years), and gender (seven male patients and five male controls). These variables were also matched between word and picture groups. For the patients, lesion size and laterality was also matched between word and picture groups (Table 1). Control participants were recruited from spouses and friends of the patients, by the use of flyers and posters 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/h for their participation. Participants were excluded if they were characterized by clinically significant depression, alcohol or drug use, neurodegenerative disease, or if English was not their primary language. Controls were also excluded if they had suffered cerebrovascular disease or traumatic brain damage. To obtain measures of the characteristics of participants, standard neuropsychological tests were performed (Table 2).

2.2. Study design and procedure

The repetition-lag paradigm used is similar to that of Dodson and Schacter (2002a, Experiment 1). The stimuli were 210 Snodgrass and Vanderwart (1980) pictures and their corresponding verbal labels, divided into four groups of 50. The lists were balanced so that they had similar mean ratings of picture familiarity (range = 3.5–3.6), picture complexity (range = 2.6–2.8), and word frequency (33). Fifty (plus 10 filler: five at the beginning and five at the end) items were studied, and another group of 50 were the new items on the test. Twenty-five of the new items repeated at lag 2, and the other 25 repeated at lag 48. Four different counterbalancing formats were used to rotate the list of items across participants so that each list could appear as study and new items.

An Apple G3 (Cupertino, CA) computer presented all the stimuli in the center of the screen. The pictures were approximately the same size and fit witin a 6 in. × 6 in. area of the screen. The words appeared in lowercase, 48-point letters in the Geneva font. Participants were assigned to either the word or picture encoding condition. Encoding was incidental; no mention was made of a later memory test. Participants performed syllable counting at study, and saw either the picture (for the picture group) or the word (for the word group) visually presented along with the auditory presentation of the word. Participants responded verbally, and the experimenter entered the response into the computer. There was a 1 s delay prior to the presentation of the next study item. Test items were presented in a pseudorandom order, assuring that no more than three study or new items would occur consecutively. Test items from all participants were the visual words only. The test consisted of the 50 studied, 50 new, and 50 lag (lag 2 or 48) items. At test, participants were instructed to respond “old” to items studied during the syllable counting

Table 3
Proportion “old” responses to study, new, and repeated lag items in controls and patients with frontal lobe lesions in the word and picture conditions

Item type	Encoding condition, mean (S.D.)			
	Controls		Patients with frontal lesions	
	Word	Picture	Word	Picture
Study	.59 (.18)	.62 (.11)	.51 (.23)	.58 (.24)
New	.09 (.08)	.09 (.11)	.21 (.17)	.15 (.15)
Lag 2	.14 (.07)	.12 (.15)	.39 (.33)	.23 (.21)
Lag 48	.37 (.13)	.17 (.17)	.37 (.31)	.32 (.31)
Corrected study	.49 (.19)	.52 (.12)	.30 (.17)	.43 (.17)
Corrected lag 2	.05 (.04)	.03 (.07)	.18 (.21)	.08 (.14)
Corrected lag 48	.27 (.17)	.07 (.10)	.17 (.20)	.17 (.18)

task, and were specifically warned to avoid responding “old” to the repeated new words.

3. Results

We note two points prior to presenting the results. First, because the question being answered in these experiments is whether the patients with frontal lobe lesions are able to use the distinctiveness heuristic, the critical analysis is whether or not there is an effect of Condition (picture versus word encoding) within this Group—particularly for lag 48 since recollection may be used to counter false recognition of short lags such as lag 2 (Dodson & Schacter, 2002a; Jennings & Jacoby, 1997; see Discussion below for explication of this issue). Second, because we were interested in determining not only when significant differences between groups and conditions were present, but also when no differences were present, we have included measures of effect size, either η or r, with the results of the statistical tests. The means and standard deviations for the data can be found in Table 3; data for individual patients can be found in Table 4.

3.1. New items (baseline false alarms)

An ANOVA with Group (patients versus controls) and Condition (word versus picture) as between-subject variables for “old” responses to new items showed a trend toward an effect of Group [$F(1, 28) = 3.48$, $p = .073$, $\eta = .332$], no effect of Condition [$F(1, 28) < 1$, $\eta = .126$], and no interaction [$F(1, 28) < 1$, $\eta = .126$]. The trend toward of an effect of group is present because the patients showed a tendency toward making more false alarms to new items than the older adults (Table 3).

3.2. Study items (true recognition)

The analogous ANOVA for “old” responses to study items yielded no effects [Group: $F(1, 28) < 1$, $\eta = .158$; Condition: $F(1, 28) < 1$, $\eta = .145$] and no interaction [$F(1, 28) < 0.1$, $\eta = .005$]. Analysis of the data after correction for baseline false alarms by subtracting “old” responses to new items from “old” responses to study items revealed an effect of Group [$F(1, 28) = 5.69$, $p = .024$, $\eta = .411$], no effect of Condition [$F(1, 28) = 1.93$, $p = .175$, $\eta = .255$] and no interaction [$F(1, 28)<1$, $\eta = .158$]. The effect of group is present because “old” responses to study items were greater in the controls than the patients after correction for baseline false alarms (Table 3).

3.3. Lag items (false recognition)

An ANOVA with group (patients versus older adults) and Condition (word versus picture) as between-subject variables and lag (“old” responses to lags 2 and 48) as a within-subject variable yielded an effect of lag [$F(1, 28) = 9.71$, $p = .004$, $\eta = .508$], no effect of Condition [$F(1, 28) = 2.50$, $p = .128$, $\eta = .285$], and a trend toward an effect of Group [$F(1, 28) = 3.30$, $p = .080$, $\eta = .324$]. This trend toward a group effect is present because the frontal patients showed somewhat higher levels of false recognition of the lags than controls. The effect of lag is present because, overall, false recognition of lag 48 items was greater than that of lag 2 items. Although neither the lag × Group [$F(1, 28) = 2.89$, $p = .100$, $\eta = .307$] nor Condition × Group [$F(1, 28) < .01$, $\eta < .001$] interactions were present, the three-way interaction of lag × Group × Condition was significant [$F(1, 28) = 6.26$, $p = .018$, $\eta = .428$]. To understand this three-way interaction, separate one-way ANOVAs were carried out for the frontal patients and controls, with Condition (word versus picture) as the between-subject variable and lag 2 and lag 48 as the within-subject variables. Whereas control subjects showed no effect of Condition for lag 2 [$F(1, 18) < 1$, $r = .105$], an effect of Condition was present for lag 48 [$F(1, 18) = 8.61$, $p < .009$, $r = .692$]—demonstrating that our control subjects could use the distinctiveness heuristic to reduce their false recognition of a repeated lag item, consistent with prior studies (Dodson & Schacter, 2002a,b). In contrast, the patients showed no effect of Condition for either lag 2 [$F(1, 10) = 1.02$, $p = .335$, $r = .320$] or lag 48 items [$F(1, 10) < 0.1$, $r = .095$] (Table 3). This suggests that our patients with frontal lobe lesions were unable to use the distinctiveness heuristic to reduce false recognition of repeated lag items.

Analysis of the lag items after correction for baseline false alarms yielded similar results: the same effect of lag [$F(1, 28) = 9.71$, $p = .004$, $\eta = .508$], a trend toward an effect of Condition [$F(1, 28) = 3.46$, $p = .072$, $\eta = .333$], and no effect of Group [$F(1, 28) = 1.01$, $p = .309$, $\eta = .192$]. The effect of lag is again present because false recognition of lag 48 items was greater than that of lag 2 items. The trend toward an effect of condition is present because overall,

Table 4
Proportion “old” responses to study, new, and repeated lag items in individual patients with frontal lobe lesions in the word and picture conditions

Item type	Encoding condition and patient identifier											
	Word						Picture					
	A	B	C	D	E	F	G	H	I	J	K	L
Study	.22	.64	.46	.52	.33	.88	.72	.80	.76	.30	.64	.26
New	.06	.18	.04	.16	.30	.50	.18	.42	.14	.04	.06	.04
Lag 2	.20	.64	.04	.24	.28	.92	.40	.40	.44	.00	.04	.08
Lag 48	.04	.68	.04	.36	.36	.76	.40	.88	.24	.04	.04	.32

participants in the word condition showed a greater tendency toward making false alarms to lag items than those in the picture condition. The same three-way interaction was present [$F(1, 28) = 6.26$, $p = .018$, $\eta = .428$]; again there were no lag × Group [$F(1, 28) = 2.89$, $p = .100$, $\eta = .307$] or Condition × Group [$F(1, 28) < 1$, $\eta = .141$] interactions. One-way ANOVAs were performed to understand the three-way interaction. These showed that an effect of Condition was present for lag 48 items in the control subjects [$F(1, 18) = 10.04$, $p = .005$, $r = .747$] but not in the patients [$F(1, 10) < .01$, $r = .018$]. Neither group showed an effect of Condition for lag 2 items [controls: $F(1, 18) < 1$, $r = .235$; patients: $F(1, 10) < 1$, $r = .306$]. Thus, the analysis of the corrected data also demonstrates that our control subjects—but not our patients with frontal lesions—were able to use the distinctiveness heuristic to reduce their false recognition to repeated lag items.

3.4. Additional analyses

Additional analyses performed demonstrated that neither lesion laterality (left versus right), nor frontal lobe function as measured by standard neuropsychological testing (Table 2), correlated with the patients ability to reduce their false recognition of repeated lag 2 or lag 48 items [lesion laterality: Fs(1,9) < 1; neuropsychological correlations: rs < .5, ps > .10]. See Table 4 for the individual patients' data.

4. Discussion

Using a modified repetition lag paradigm, we found that patients with frontal lobe lesions showed lower levels of true recognition of studied items (after correction for baseline false alarms), and higher levels of uncorrected false recognition of lag items. The patients also showed a trend toward making more baseline false alarms than controls. Importantly, whereas control subjects who studied pictures and words together made fewer false alarms to lag 48 items compared with those who studied words only, the patients who studied pictures and words together made nearly identical numbers of false alarms to these items as those who studied words only.

As discussed by Dodson and Schacter (2002a,b), the modified repetition lag paradigm used in the present study is particularly helpful because, in addition to allowing the examination of the distinctiveness heuristic, it also enables analysis of the potentially separable processes of familiarity versus recollection of source information. Familiarity of repeated new words contributes to false recognition when participants do not recollect their prior encounter with the word on the test and do not use the distinctiveness heuristic to reject these words. Recollection of the source, or item-specific, information of seeing the repeated new word earlier on the test may serve as a "recall-to-reject" mechanism, reducing false recognition when the new words repeat after short lag intervals (see Clark & Gronlund, 1996; Rotello & Heit, 1999; Rotello, Macmillan, & Van Tassel, 2000). Recollection of the new words that repeat at longer intervals, such as lag 48, is more difficult. False recognition of items at lag 48 were thus elevated relative to items at lag 2 in our study because participants did not recollect seeing the word on the earlier test and mistakenly thought that the familiarity of the item was attributable to having seen it on the study list. Lastly, the distinctiveness heuristic may be invoked by the picture group when participants encounter a familiar test word and they do not recollect source information about where they saw the item. In this situation, an item is presumed to be new when it does not elicit the expected memory information (of a picture corresponding to the word).

Previous research using this modified repetition lag paradigm has shown that healthy younger and older adults are able to use the metacognitive strategy of the distinctiveness heuristic to reduce their false recognition (Dodson & Schacter, 2002a,b). In the present study, we tested patients whose frontal lobe lesions included Brodmann areas 9 and 46 with this paradigm to examine the hypothesis that dorsolateral frontal cortex is necessary for participants to use the distinctiveness heuristic. We found that the patients with frontal lobe lesions were unable to reduce their false recognition to lag items. Because it is prudent to be cautious in interpreting a null finding in an experiment with small numbers of subjects, it is worthwhile to review the effect size for the critical analyses, since effect size is independent of sample size. For the lag 48 items in the patients, the effect of Condition (word versus picture) yielded r's of .095 ($r^2 = .009$) uncorrected and .018 ($r^2 < .001$) corrected. Because r^2 may be interpreted as the proportion of variance explained (Rosenthal & Rosnow, 1991), whether the patients were in the word versus the picture group explained less than 1% of the variance of the data. By contrast, the same comparison yielded r's of .692 ($r^2 = .479$) uncorrected and .747 ($r^2 = .559$) corrected for the control subjects. We therefore feel confident that the conclusion reached—that the frontal patients are unable to use the distinctiveness heuristic—is not related to the relatively small numbers of subjects in this study. We believe this finding indicates that patients with frontal lobe lesions are impaired in their use of the metacognitive expectations that are central to the distinctiveness heuristic.

Advances in functional neuroimaging, along with more traditional studies of patients with brain lesions, has led to an improved understanding of the regional specificity within the frontal lobes in relation to memory processing (see Simons & Spiers, 2003, for a recent review). Medial frontal cortex—particularly medial orbitofrontal cortex—has been linked to the processing of stimulus-reward associations. Lateral frontal cortex, by contrast, is important for goal-directed processing of memory including the encoding of discrete memory traces and the strategic search, retrieval, and evaluation of the contents of the retrieved memory trace. In their review, Fletcher and Henson (2001) suggest that the anterior and lateral frontal cortex may be divided into three areas. Ventrolateral frontal cortex (inferior to the inferior frontal sulcus and roughly Brodmann areas 44, 45, and 47) was found to be active during successful encoding and during the initial stage of retrieval, suggesting it is important in updating and maintaining information in working memory so that it can be processed further by other brain systems. Dorsolateral frontal cortex (superior to the inferior frontal sulcus and roughly Brodmann areas 9 and 46) may be activated in complex encoding tasks, but it is more likely to be active during the second stage of retrieval in episodic memory when the information obtained from the initial search is evaluated. It is believed to be important in the selection, manipulation and monitoring of information which is already active in working memory. Anterior frontal cortex (anterior to the anterior edge of the inferior frontal gyrus and roughly Brodmann areas 8 and 10) is active during intentional (rather than incidental) retrieval, and in particular when a participant needs to adopt or change specific strategies of memory retrieval to assist in goal-directed behavior. Thus, it is believed to be important in selecting goals and coordinating the activities of ventrolateral and dorsolateral frontal cortex to achieve these goals.

Keeping in mind the Fletcher and Henson (2001) model, it is important to note that while our 12 patients were specifically selected because they showed damage to dorsolateral frontal cortex (Brodmann areas 9 and 46), 11 of these patients also showed damage to ventrolateral frontal cortex (Brodmann areas 44, 45, and 47), and 10 of them also showed damage to anterior frontal cortex (Brodmann areas 8 and 10) (see Table 1). This lack of regional specificity is, of course, common when working with patients, since strokes and tumor cells rarely obey the boundaries of functional or cytoarchitectural regions. Thus, although we hypothesized that dorsolateral frontal cortex would be critical for the use of the distinctiveness heuristic, it may be that ventrolateral or anterior frontal cortex is the critical region. Budson et al. (submitted for publication) suggested that the distinctiveness heuristic is a retrieval orientation that facilitates reliance upon recollection to distinguish studied from non-studied items (see also Herron & Rugg, 2003; Robb & Rugg, 2002). Engaging a particular retrieval orientation may be more likely to activate anterior than dorsolateral frontal cortex according to the Fletcher and Henson model. Additionally, although one cannot draw reliable neuroanatomical inferences regarding the neural generators of event-related potential data, it is interesting to note that differences in brain activity associated with the use of the distinctiveness heuristic in the study of Budson, Droller, et al. were in midline frontal and central electrodes, again possibly related to activity of anterior frontal cortex. In brief, while we believe that our study can definitively conclude that patients with lesions in their anterior and lateral frontal lobes are impaired in their ability to use the metacognitive expectation of the distinctiveness heuristic to reduce false recognition of repeated new items, future studies will be needed to determine whether there is a smaller critical region within the frontal lobes that when damaged will preclude the use of the distinctiveness heuristic.

While we have argued that the results of the present study are attributable to the inability of the patients with frontal lesions to use the distinctiveness heuristic, the question arises as to whether impaired recollection of source information could also explain these results. Previous research has shown that patients with frontal lobe lesions are unable to suppress their false recognition across multiple study-test trials, which Budson et al. (2002) argued was attributable to their impaired item-specific recollection and/or source memory. Other studies have also shown that source memory is impaired in patients with frontal lesions (e.g. Janowsky, Shimamura, Kritchevsky, & Squire, 1989c; Janowsky, Simamura, & Squire, 1989a,b; Schacter, Harbluk, & McLachlan, 1984). Further, Dobbins, Foley, Schacter, and Wagner (2002) have shown that whereas item memory tasks activate only ventrolateral frontal cortex, source memory tasks activate ventrolateral, dorsolateral, and anterior frontal cortex. We would thus expect that source memory tasks would be impaired in our patients who have lesions in all of these areas. In fact, failure of source memory may help explain the higher levels of false recognition of lag 2 items in the patients relative to controls [uncorrected: $F(1, 28) = 6.35$, $p = .018$, $\eta = .430$; corrected: $F(1, 28) = 4.75$, $p = .038$, $\eta = .381$]. These differences are likely present because (as discussed above) controls are able to recollect the source of these recently repeated new words and use a recall-to-reject strategy, whereas the patients are impaired in recollection of such source information. Differences in source memory between patients and controls cannot, however, explain the results of the lag 48 items. Control subjects exhibit great difficulty in using a recall-to-reject strategy to reduce their false recognition to items with such a long lag—as can be seen by the results in Table 3 which show that levels of uncorrected false recognition of lag 48 items for those in the word condition were the same for patients and controls. Because lag items are present on the test as words only for both those in the picture and word condition, any differences observed between word and picture groups for lag 48 items are likely attributable to the use of the distinctiveness heuristic.

The results of the lag 2 items deserve additional comment. Whereas the numerical differences present between word and picture groups for control subjects were small for these items (.02 uncorrected and corrected), such differences were larger for the patients (.16 uncorrected and .10 corrected) (Table 3). Reflecting these differences, the relevant effect sizes were $r = .105$ and $r = .235$ in control subjects, versus $r = .320$ and $r = .306$ in the patients, for the uncorrected and corrected data, respectively. Thus, if we assume that this variance is not due to random effects, it is probable that with larger numbers of patients (roughly $n = 48$) the differences in lag 2 items between those in the word and picture conditions would become statistically significant, although they would only explain a relatively small proportion of the variance of the data ($r^2 = .102$ uncorrected and .094 corrected). This supposition, however, does not weaken our conclusion that patients with frontal lobe lesions are unable to use the distinctiveness heuristic. It is not logical that the patients would use the distinctiveness heuristic to reject items that repeat at short lags but not items that repeat at long lags. If participants are using the metacognitive expectation of the distinctiveness heuristic, then it should not matter whether items repeat after short lags, after long lags, or are simply new: If the false alarm rate is above the level where floor effects are present, and if subjects are invoking the distinctiveness heuristic, then its effect should be present for all non-studied items. Floor effects are present in the results of the controls in the current study for new and lag 2 items, but the results of other studies can illustrate this point. For example, younger and older participants in the picture condition in Dodson and Schacter (2002a, Experiment 1) invoked the distinctiveness heuristic to reduce their false recognition of new, lag 24, and lag 48 items; a similar reduction was seen in Budson et al. (submitted for publication) for both new and lag 48 items, while floor effects were present for lag 2 items. The etiology of the numerical differences in the lag 2 items between the word and picture conditions for the patients with frontal lobe lesions, if real, is unknown. Future studies with larger numbers of patients will be needed to understand this result.

The findings of a recently completed study may also be informative in interpreting the present results. Budson, Dodson, Daffner, and Schacter (in press) examined the distinctiveness heuristic in patients with Alzheimer's disease (AD) using a very similar repetition-lag paradigm with lags of 0, 4, and 24 items. They found that although their memory for studied items was even more impaired than our frontal lobe patients (proportion of corrected study items less than .30), they were able to use the distinctiveness heuristic to reduce their false recognition to repeated lag items as well as healthy older adult controls (effect size [η] of Condition was .417 in healthy older adults and .423 in patients with AD).[1] The fact that in this paradigm patients with AD—even with their very impaired memory—were able to use the distinctiveness heuristic strengthens the results of the present study. First, this study demonstrates that patients with other types of brain damage are able to use the distinctiveness heuristic. Second, that patients with AD were able to use the distinctiveness heuristic in the setting of showing worse memory than our patients with frontal lobe lesions shows that ability or inability to use the heuristic is not simply related to overall memory performance.

The idea that metacognitive processes such as the distinctiveness heuristic are impaired in patients with frontal lobe lesions is consistent with the work of Stuss, Gallup, and Alexander (2001) who found that these patients are impaired in 'theory of mind', and with Thaiss and Petrides (2003) who, in reconciling their results with the literature, suggested that patients with frontal lobe lesions show deficits in the metacognitive contributions to source memory retrieval rather than to source memory retrieval per se. In addition, two literature reviews suggest that midfrontal brain regions in particular may be critical for metacognition (Fernandez-Duque et al., 2000; Shimamura, 2000). Previous studies have also shown that the frontal lobes are involved in strategic search for mnemonic information (Gershberg & Shimamura, 1995; Incisa della Rocchetta & Milner, 1993; Petrides, 1996), in judging the relative recency of stimuli (Kopelman, Stanhope, & Kingsley, 1997; Ladavas, Umilta, & Provinciali, 1979; Milner, Corsi, & Leonard, 1991; Shimamura, Janowski, & Squire, 1990; Smith & Milner, 1983), inhibiting responses on the basis of familiarity alone (Shimamura, 1995), and are important in post-retrieval monitoring and verification processes (Goldmann et al., 2003; Rugg, Fletcher, Frith, Frackowiak, & Dolan, 1996; Schacter et al., 1996; Schacter, Buckner, Koutstaal, Dale, & Rosen, 1997; Wilding & Rugg, 1996). Particularly relevant to our present study, the frontal lobes also provide the ability to avoid false recognition (Delbecq-Derouesne, Beauvois, & Shallice, 1990; Melo, Winocur, & Moscovitch, 1999; Parkin, Bindschaedler, Harsent, & Metzler, 1996; Parkin, Ward, Bindschaedler, Squires, & Powell, 1999; Rapcsak, Reminger, Glisky, Kaszniak, & Comer, 1999; Rapcsak et al., 2001; Schacter, Curran, Galluccio, Milberg, & Bates, 1996a; Ward et al., 1999) and to suppress false recognition when it occurs (Budson et al., 2002). These results, that patients with lesions of frontal cortex are impaired in their ability to use the metacognitive expectation of the distinctiveness heuristic to reduce false recognition of repeated new items, fit in well with previous research that has demonstrated the importance of the frontal lobes in strategic and monitoring processes in normal episodic memory. The present study suggests that the distinctiveness heuristic—a metacognitive strategy that may be engaged by healthy individuals to reduce their false recognition—is dependent upon the frontal lobes.

[1] Although the patients with AD were able to use the distinctiveness heuristic in the study of Budson et al. (in press) to reduce their false recognition, their memory impairment prevented them from using the heuristic selectively, and thus for those patients in the picture condition levels of true recognition of were reduced as well.

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