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The disruptive effects of processing fluency on familiarity-based recognition in amnesia ☆

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ABSTRACT

Amnesia leads to a deficit in recollection that leaves familiarity-based recognition relatively spared. Familiarity is thought to be based on the fluent processing of studied items compared to novel items. However, whether amnesic patients respond normally to direct manipulations of processing fluency is not yet known. In the current study, we manipulated processing fluency by preceding each test item with a semantically related or unrelated prime item, and measured both recollection and familiarity using a remember-know recognition procedure. In healthy controls, enhancing processing fluency increased familiarity-based recognition responses for both old and new words, leaving familiarity-based accuracy constant. However, in patients with MTL damage, enhancing fluency only increased familiarity-based recognition responses for new items, resulting in decreased familiarity-based recognition accuracy. Importantly, this fluency-related decrease in recognition accuracy was not due to overall lower levels of performance or impaired recollection of studied items because it was not observed in healthy subjects that studied words under conditions that lowered performance by reducing recollection. The results indicate that direct manipulations of processing fluency can disrupt familiarity-based discrimination in amnesia. Potential accounts of these findings are discussed.

1. Introduction

Patients with medial temporal lobe (MTL) damage often exhibit pronounced deficits in recollection with less severe or no impairments in familiarity (e.g., Bastin et al., 2004; Yonelinas, Kroll, Dobbins, Lazzara, & Knight, 1998; Yonelinas et al., 2002). Recollection is linked to episodic experience and enables individuals to mentally relive past events in vivid detail, whereas familiarity is characterized as a less-specific feeling of knowing or recency (Gardiner, 1988; Jacoby, 1991; Mandler, 1980; Tulving, 1985; see Yonelinas, 2002 for a review). Familiarity is thought to rely on the assessment of processing fluency, in the sense that studied items are typically processed or identified more rapidly than novel items, and subjects are thought to attribute that processing fluency to the fact that the item was likely studied earlier (Goldinger, Kleider, & Shelley, 1999; Jacoby & Dallas, 1981; Whittlesea, Jacoby, & Girard, 1990; Whittlesea, 1993).

Support for the processing fluency account comes from studies that have directly manipulated the extent to which items are identifiable during a recognition memory test (e.g., Jacoby & Dallas, 1981; Jacoby & Whitehouse, 1989; Lindsay & Kelley, 1996). Although there are conditions in which recollection can be influenced by fluency manipulations (Kurilla & Westerman, 2008; Taylor & Henson, 2012), these manipulations typically affect familiarity and not recollection. For instance, Rajaram and Geraci (2000) conducted a recognition memory experiment in which each test probe was preceded by a briefly presented prime that was either semantically related or unrelated to the probe word. In addition to typical recognition measures, the researchers used the remember-know procedure to obtain measures of recollection and familiarity at test. They found that although recognition discriminability (i.e., overall accuracy) was unaffected by the prime manipulation, the related prime led to a response bias, in which positive recognition responses to both old and new items were higher for items that followed a related rather than unrelated prime. In addition, they found that this increase in positive responses was observed for familiarity-based, but not recollection-based responses. The results were interpreted as indicating familiarity is based, in part, on processing fluency. Similar fluency effects have been observed when the primed item is identical to the test item (e.g., Jacoby & Whitehouse, 1989), when the primed

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item is clearly visible (e.g., Thapar & Westerman, 2009), and when the primed item is gradually revealed to participants (LeCompte, 1995; Watkins & Peynircioglu, 1990).

If processing fluency is generally used as a basis for familiarity-based recognition, then amnesic patients with relatively preserved familiarity may also exhibit these types of fluency effects. However, the extent to which amnesics respond normally to processing fluency is not yet clear because processing fluency has not been examined in amnesics using procedures like those used by Rajaram and Geraci (2000). Indirect evidence, however, comes from two previous studies which used a paradigm in which test words were gradually revealed from behind a visual mask (Conroy, Hopkins, & Squire, 2005; Verfaellie & Cermak, 1999). These studies found that positive recognition response rates in both amnesics and controls were higher for words that were most quickly identified at test. This finding is consistent with the idea that both groups are influenced, at least to some extent, by natural variations in processing fluency. However, only overall recognition responses were examined in these studies, so it is not known how the manipulation of fluency influenced familiarity compared to recollection, nor whether it impacted those processes in similar ways in amnesics and controls.

The current study directly examined the effects of processing fluency on recollection and familiarity-based recognition in both amnesics and controls. Our design was closely matched to that of Rajaram and Geraci (2000) except that context words were presented, clearly visible, before each test probe for 1.5 s. Pilot results using this paradigm indicated that it provided a more robust and reliable increase in semantic fluency compared to methods such as masked priming (which often also require the removal of subjects who report conscious strategies, a practice we hoped to avoid with our patients). Thus, we adopted this more obvious manipulation in lieu of more subtle methods of presenting context words.

In Experiment 1, subjects studied a list of words and then engaged in a recognition memory test wherein each test trial was preceded by a context word that was either a semantic associate of the upcoming test probe, or an unrelated word. To obtain measures of recollection and familiarity, subjects recognized items at test using a modified (see Methods of Experiment 1) remember-know scale (Tulving, 1985). The remember-know procedure is a method for estimating the influence of recollection and familiarity in recognition paradigms by having subjects respond "remember" if they can recollect qualitative information about the study event, respond "know" if the item is familiar without the retrieval of any qualitative information and "new" if the item was not studied. Subjects also indicated if their "know" and "new" responses were associated with high or low levels of confidence, but because the pattern of results did not differ across confidence, we collapsed across confidence.

Although it should be acknowledge that the remember-know procedure is not without its critics (e.g., Donaldson, 1996; Hirshman & Master, 1997; Inoue & Bellezza, 1998; Rotello & Zeng, 2008; Wixted, 2007; Wixted & Stretch, 2004), behavioural and neuroimaging data suggest that these two measures reflect qualitatively distinct forms of memory (e.g., Eichenbaum, Yonelinas, & Ranganath, 2007; Perfect & Dasgupta, 1997; Rajaram, 1993; Skinner & Fernandes, 2007; Yonelinas, 2002), and to the degree that recollection and familiarity are believed to be measurable at all, the remember-know procedure converges with independent measures of recollection and familiarity when instructions on how to make remember-know responses are strict (see Rotello, Macmillan, Reeder, & Wong, 2005; Yonelinas, Dobbins, Szymanski, Dhaliwal, & King, 1996; Yonelinas, 2001). In all experiments then, strict remember-know instructions are used to ensure the validity of subjects' remember-know responses.

Experiment 1 indicated that amnesics did not exhibit normal processing fluency effects, and we wondered if healthy participants might also show this pattern of results when their performance was as low as that of the patients. In Experiment 2, we examined performance in young healthy controls under encoding conditions that led to lower levels of performance, and found that lowering performance in healthy subjects did not disrupt the processing fluency effects observed in healthy subjects.

2. Experiment 1

2.1. Methods

2.1.1. Subjects

Patient characteristics and neuropsychological scores are shown in Table 1. Four patients were expected to have relatively selective hippocampal damage (i.e., H group). Patient 1 suffered from a traumatic brain injury due to a car accident, and Patient 4 suffered from limbic encephalitis. Clinical scans suggested that damage in both patients was limited to the hippocampus. Estimates of MTL gray matter volumes for patients 1 and 4 were contrasted with age-matched controls, and indicated that in both patients (listed as patients 1 and 2 in Aly, Ranganath, & Yonelinas, 2013) exhibited reduced bilateral hippocampal volumes, whereas their surrounding perirhinal, entorhinal and parahippocampal cortex showed no evidence of volume reduction. Patients 2 and 3 suffered from a mild hypoxic episode of less than seven minutes as a result of a cardiac arrest and have presumed selective hippocampal damage (Gadian et al., 2000; Hopkins, Kesner, & Goldstein, 1995; Kono, Kono, & Shida, 1983; Rempel-Clower, Zola, Squire, & Amaral, 1996; Smith, Auer, & Siesjo, 1984). These patients have defibrillators and are thus unable to undergo structural MRI scanning to confirm the extent and selectivity of the damage.

Four patients had confirmed damage to the hippocampus and the surrounding cortex (i.e., H+ group). Patients 6, 7, and 8 underwent a standard en bloc anterior temporal lobe resection for epilepsy to remove the anterior 4.5 cm of the left temporal lobe, including the anterior half of the hippocampus, the amygdala, and the anterior third of the parahippocampal gyrus. Patient 5 had a standard anterior temporal lobe resection to remove an astrocytoma and an arachnoid cyst in which approximately 4 cm of the anterior temporal lobe was removed.

In our primary analysis we examined all the amnesic patients as a group, however, because previous work has indicated that the patients with confirmed lesions to the hippocampus and MTL regions outside the hippocampus (H+) had lower familiarity estimates than the patients with suspected selective hippocampal damage (H) (Yonelinas et al., 2002; Quamme, Yonelinas, & Norman, 2007) we also report on these subgroups separately, as a supplementary analysis. We note however, brain damage was determined based on MRIs rather than histology and MRIs were not available for two of the patients, so lesion location can only be inferred. In any case, the fluency effects that we examined in the current experiments were found to be similar for both of the patient subgroups.

Neuropsychological scores for the age and education matched controls ($n=8$) are presented in Table 2. None of the controls had any history of neurological or psychological disorders and all performed well on neuropsychological tests. Patients and controls were not included in the study if they had a history of drug use or evidence of gross visual problems despite corrective glasses. Note that the standardized test z-scores on the patients and the controls appear somewhat higher than what might be expected (e.g., the average delayed memory z-scores for the patients and controls were -1.35 and $+1.80$, respectively). However, this was due largely to the high education levels of our patients and controls (average number of years of formal education was 14.7) and the fact that the WMS-R scores are highly correlated with education. Normal controls with only a high school education who have been tested in our lab (e.g., <13 years) produce delayed memory z-scores of.20, whereas college educated (e.g., average of 14.8 years of education) score at 1.03, and controls with graduate education scores at 1.31. Independent sample t-tests showed that patients and controls did not differ in terms of mean age, $t(14)=0.26$, $p=.80$, $d=0.14$, or years of education, $t(14)=1.63$, $p=.12$, $d=0.87$.

2.1.2. Stimuli

A word pool of 318 cue-target pairs was created from the free association norms of Nelson, McEvoy, and Schreiber (2004). For present purposes, the backward association norms compiled by Nelson et al. were of principal interest: These norms are arranged by target words instead of cue words. For each target word, the norms provide a list of the cue words that gave rise to that target word together with the probability that each cue word gave rise to that particular target word. For example, if RIGHT was the target word of interest, Nelson et al. list *left* as the cue word mostly likely to give rise to RIGHT during free association, with a probability of.93. No words were repeated in this word pool. On average, the normed probability that the cues would give rise to their respective target words was.57 ($SD=.14$).

For each subject, a study list was created by randomly selecting 90 targets from the word pair pool. A test list was created by randomly inter-mixing the 90 studied

Table 1
Summary of neuropsychological characteristics of amnesic patients in Experiment 1.

Patient	Sex	Age	Years since injury	Education	Etiology	WMS-R					Shipley
						Verbal memory	Visual memory	General memory	Attention/conc.	Delayed memory	Est.WAIS-R IQ
1	M	30	9	16	Hypoxic/trauma	−1.33	0.33	−0.87	0.20	−2.13	111
2	M	51	16	16	Hypoxic	−2.53	2.00	−1.40	−0.20	−1.13	96
3	F	52	17	13	Hypoxic	−0.40	−1.53	−0.87	−0.27	−1.33	94
4	F	58	5	12	Encephalitis	−1.80	−0.27	−1.53	0.07	−2.20	112
5	M	58	19	16	L. Temp Lobectomy	−1.40	0.93	−0.80	1.67	−0.40	114
6	M	35	11	16	L. Temp Lobectomy	−1.60	0.40	−1.13	−0.67	−0.60	97
7	M	41	8	10	L. Temp Lobectomy	−2.20	−0.73	−1.87	−0.27	−1.60	87
8	M	65	31	12	L. Temp Lobectomy	*	*	*	*	*	*
Mean	–	48.75	14.50	13.88	–	−1.61	0.16	−1.21	0.08	−1.34	101.57
Std Err		(4.33)	(2.92)	(0.85)		(0.26)	(0.43)	(0.15)	(0.29)	(0.26)	(4.01)
H only (1–4)	–	47.75 (6.12)	11.75 (2.87)	14.25 (1.03)	–	−1.52 (0.45)	0.13 (0.73)	−1.17 (0.17)	−0.05 (0.11)	−1.70 (0.27)	103.25 (4.78)
H+ only (5–8)	–	49.75 (7.04)	17.25 (5.14)	13.50 (1.50)	–	−1.73 (0.24)	0.20 (0.49)	−1.27 (0.32)	0.24 (0.72)	−0.87 (0.37)	99.33 (7.88)

Note. All WMS-R scores are *z*-scores. Scores reported for Shipley are percentiles. Missing scores were not available. The H group consisted of patients with believed to have selective hippocampal damage (patients 1–4) whereas the H+ consisted of patients believed to have more extensive MTL damage (patients 5–8). *Patient 8 was not assessed using the WMS-R but was assessed using the WMS-III. Relevant *z*-scores for this patient were: logical memory I—Recall: −2.75, logical memory II—Recall: −2.75, logical memory I—ihematic total: −2.33, logical memory II—thematic total: −2.41, mental control: −2.41, Visual Reproduction I: −1.34, Visual Reproduction II Recall: −2.05, Visual Reproduction III Recognition: 0.33, Visual Reproduction II Percent Retention: −2.33.

Table 2
Summary of neuropsychological characteristics of healthy control subjects in Experiment 1.

Control	Sex	Age	Education	WMS-R					Shipley
				Verbal memory	Visual memory	General memory	Attention/conc.	Delayed memory	Est.WAIS-R IQ
1	M	30	16	0.60	1.07	1.00	1.33	1.87	114
2	M	57	16	1.60	2.40	2.07	1.67	2.53	117/120
3	F	57	13	1.00	0.20	0.93	0.33	1.27	106
4	F	54	16	1.67	2.40	2.07	1.00	2.53	114
5	F	52	16	0.60	1.47	1.07	–	1.27	116
6	F	54	12.5	1.73	2.00	2.07	–	2.00	100
7	F	27	17	2.33	2.20	2.40	0.60	2.53	97
8	M	51	20	0.80	2.00	1.40	0.53	0.40	110
Mean	–	47.75	15.81	1.29	1.72	1.63	0.91	1.80	109.44
Std Err		(4.28)	(0.82)	(0.22)	(0.27)	(0.21)	(0.21)	(0.27)	(2.75)

Note. All WMS-R scores are *z*-scores. Scores reported for Shipley are percentiles. Missing scores were not available.

targets with 90 new targets, selected from the word pair pool. For half of the studied and half of the new words, the corresponding semantic associate cue was used as the context word at test. For the remaining studied and new words, a cue word from a non-selected target was used. Verifying that unrelated primes were indeed unrelated to their corresponding targets, latent semantic analysis indicated that the mean similarity rating between unrelated primes and targets was.09 (SD=.09) whereas between semantic associate primes and targets was.45 (*SD*=.22) (see Landauer, Foltz, & Laham, 1998 for an in depth explanation of this measure).

2.1.3. Procedure

Experiment 1 began with a study phase wherein subjects were simply told to try to remember each word as best they could, as later their memory would be tested. Subjects studied 90 words at study, which were presented individually in the center of the screen for 1.5 s, with a 0.5 s inter-stimulus interval. After the study phase, subjects were given detailed instructions regarding the difference between recollection and familiarity. To ensure comprehension, subjects were asked to provide the experimenter with examples of recollection vs. familiarity, in their own words. If needed, the experimenter corrected subjects.

During the test phase, individual words appeared in the center of the screen and subjects had to decide whether each word was studied or new. Subjects responded using a hybrid remember-know/confidence scale. If a word was studied, subjects could respond with the “R” key if they “remembered” (i.e., recollected) the word. Alternatively, if the word was only “known” (i.e., familiar) subjects were to press 4 if they were sure that the word was studied, or 3 if they were less sure but still believed the word was studied. If subjects believed a word was new, they were to press 1 if they were sure that the word was new, and 2 if they were less sure but still believed the word to be new. These responses were later collapsed into “know” and “new” (see Section 2.2). A total of 180 words (90 old and 90 new) were presented during this test, and before each word a context word was presented, clearly visible in the center of the screen for 1.5 s. For half of the test trials the context word was a semantic associate of the upcoming test probe, and for the remaining trials the context word was unrelated (i.e., a semantic associate of some non-appearing target) to the upcoming test probe. Subjects were told to read each context word, as it was important, but given no other instruction beyond that. To differentiate context words from test probes, context words appeared in uppercase font, whereas test targets appeared in lowercase font. At study all words appeared in lowercase font.

2.2. Results & discussion

Although subjects made know judgements on a 4-point scale, these responses were collapsed into “know” (“4—sure old” and “3—think old”), and “new” (“1—sure new” and “2—think new”). Hence, the data from Experiment 1 were analyzed as typical remember/know/new data. Furthermore, instead of analyzing raw “know” responses, we converted these responses to familiarity indexes based on the *independent remember-know method* (IRK; Jacoby, Yonelinas, & Jennings, 1997; Mangels, Picton, & Craik, 2001; Ochsner, 2000; Yonelinas & Jacoby, 1995). In this method, whereas recollection is indexed by the proportion of “remember” responses, familiarity is measured as the proportion of “know”

Table 3
Mean proportion of remember [p(R)] and know [p(K)] responses, and mean confidence ratings for non-remembered (i.e., "known" or "new") items for subjects in Experiments 1 and 2. Results are separated by old/new status of test probe and by priming condition. Patient results are further separated by whether patients were expected to have hippocampal damage (H) or more severe MTL damage (H+). Standard errors are shown in parentheses below the means.

	p("Remember")				p("Know")				Confidence			
	Old		New		Old		New		Old		New	
	Assoc.	Unrel.	Assoc.	Unrel.	Assoc.	Unrel.	Assoc.	Unrel.	Assoc.	Unrel.	Assoc.	Unrel.
Controls (Exp 1)												
	.40	.44	.03	.01	.42	.30	.35	.24	2.99	2.63	2.25	2.01
	(.06)	(.05)	(.01)	(.01)	(.04)	(.05)	(.05)	(.04)	(0.10)	(0.13)	(0.08)	(0.07)
MTL patients (Exp 1)												
	.23	.20	.08	.05	.41	.42	.44	.32	2.59	2.59	2.38	2.15
	(.05)	(.03)	(.04)	(.03)	(.06)	(.07)	(.04)	(.06)	(0.15)	(0.12)	(0.15)	(0.10)
H												
	.26	.24	.10	.08	.39	.41	.46	.31	2.57	2.77	2.37	2.18
	(.10)	(.03)	(.08)	(.05)	(.11)	(.10)	(.02)	(.06)	(0.28)	(0.09)	(0.23)	(0.06)
H+												
	.19	.16	.06	.03	.42	.43	.42	.32	2.60	2.40	2.39	2.13
	(.05)	(.05)	(.03)	(.02)	(.08)	(.12)	(.08)	(.12)	(0.16)	(0.19)	(0.22)	(0.22)
Shallow encoding (Exp 2)												
	.13	.13	.08	.06	.46	.37	.35	.28	2.56	2.30	2.20	2.01
	(.03)	(.03)	(.03)	(.02)	(.04)	(.04)	(.04)	(.03)	(0.08)	(0.11)	(0.09)	(0.08)

responses divided by the proportion of non-"remember" responses. Thus, the familiarity indexes were calculated as $F=K/(1-R)$. These indexes were calculated separately for old and new items.

Calculating familiarity indexes in this way is preferable to examining raw "know" responses because raw "know" responses are limited by the proportion of "remember" responses in the remember-know paradigm. Researchers have demonstrated that estimates of familiarity, as measured by the IRK method, are consistent with estimates of familiarity as measured by other techniques, whereas raw "know" responses do not (Yonelinas et al., 1998; Yonelinas, 2002; Yonelinas & Jacoby, 1995). Hence, familiarity indexes as calculated in the IRK method provide a more accurate estimate of familiarity than do raw "know" responses. Although we focus our analyses on the IRK results, for completeness, the proportion of raw "know" responses can be seen in Table 3, along with the proportion of "remember" responses and mean confidence ratings of non-remembered (i.e., "known" and "new") responses. It should be noted that the qualitative patterns observed using the IRK method to estimate familiarity do not change if we considered raw "know" response rates. Raw "remember" responses were used as recollection recognition responses. Finally, an alpha level of.05 was used as our criterion for significance in all significance tests. Effect size estimates were computed using partial eta-squared (η_p^2) or Cohen's *d*, where appropriate.

The proportion of recollection and familiarity-based responses to old and new words in Experiment 1 can be seen in Fig. 1. Specifically, Fig. 1A and D plot the recollection and familiarity-based responses for controls, whereas Fig. 1B and E plot the recollection and familiarity-based responses for patients. In all cases, data is separated based on the context word type (semantic associate vs. unrelated). The following analyses focuses first on age-matched controls, then on amnesic patients, then on a comparison across the two groups. We focus on individual group results first for simplicity sake: so that the effects within-group can be understood before attempting to make comparisons across groups. As well, presenting within-group analyses first allows us to relate our findings to the existing literature, before considering the between-group analysis.

2.2.1. Healthy controls

Rajaram and Geraci (2000) observed that the presence of a semantic associate prime at test had no impact on recollection-based responses but did increase the proportion of familiarity-based responses for old and new words alike. Fig. 1A plots the proportion of recollection-based responses to old and new items for controls, separated by whether the corresponding test word was preceded by a semantic associate context word or an unrelated context word. To assess whether the context word had an impact on recollection-based responses, these data were analyzed in a 2 (old vs. new) × 2 (associate vs. unrelated) within-subject ANOVA. The only significant effect was that there were more recollection responses to old words than to new words, $F(1,7)=10.15$, $MSe=0.01$, $p<.05$, $\eta_p^2=.56$. Context word type had no main effect and did not interact with old/new status, both F's <1.60, $p>.25$.

Turning to familiarity-based responses, Fig. 1D plots the proportion of familiarity-based responses to old and new items, separated by whether the corresponding test word was preceded by a semantic associate context word or an unrelated context word. To assess whether the context word had an impact on familiarity-based responses, these data were analyzed in a 2 (old vs. new) × 2 (associate vs. unrelated) within-subject ANOVA. There were more familiarity-based responses to old words than to new words, $F(1,7)=75.32$, $MSe=0.01$, $p<.01$, $\eta_p^2=.92$, and importantly there were more familiarity-based responses in response to semantic associate context words than unrelated context words, $F(1,7)=30.15$, $MSe=0.01$, $p<.01$, $\eta_p^2=.81$. There was no interaction, $F<1$. Replicating Geraci and Rajaram then, we find that for healthy controls, semantic associate context words of test items increase familiarity-based responses to both old and new words, while having no effect on recollection responses.

2.2.2. Amnesic patients

Similar to controls, recollection-based responses for old and new words can be seen for patients in Fig. 1B. To assess whether the context word had an impact on recollection-based responses,

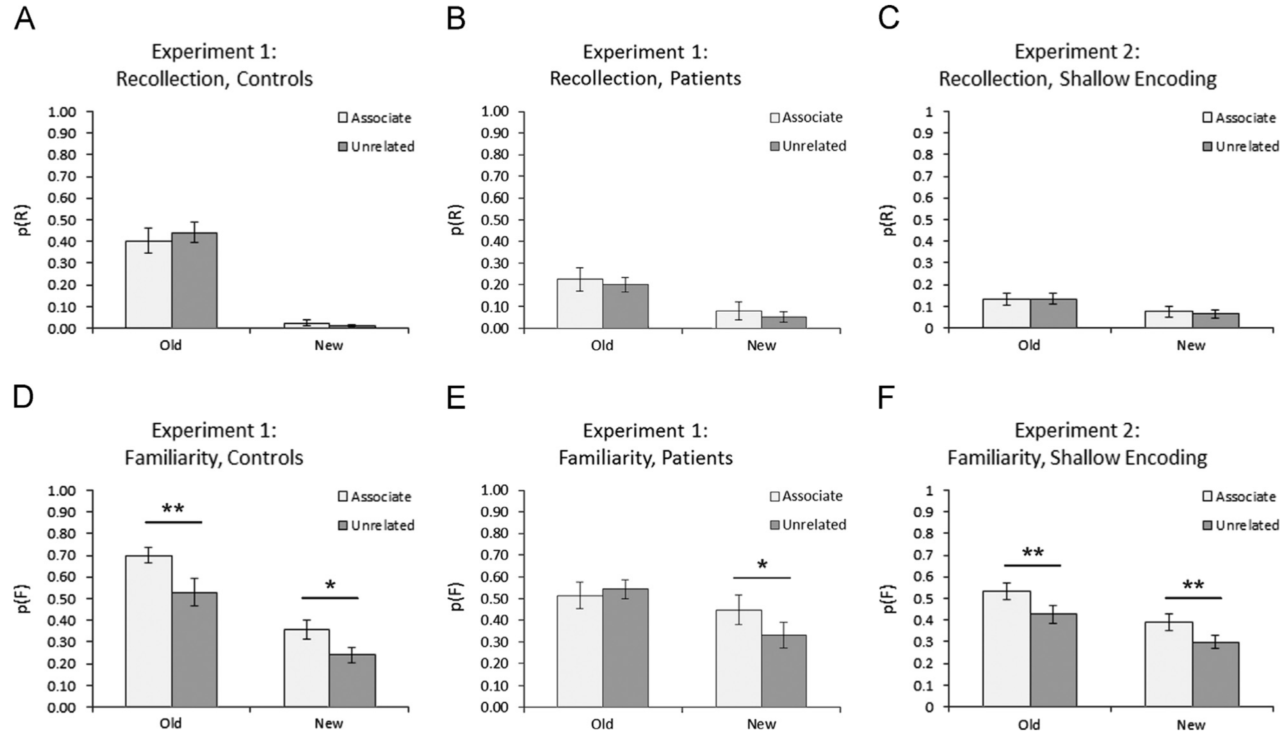

Fig. 1. Mean proportion for recollection [p(R)] or familiarity [p(F)] responses in Experiments 1 and 2. Recollection was measured as p("remember") whereas familiarity was measured as p("know")/1 − p("remember"). Results are separated by whether the test probe was old or new, and by whether the test probe was preceded by a semantic associate context word (associate) or an unrelated context word (unrelated). Panels separate recollection and familiarity responses, and subject groups across Experiments 1 and 2. Errors bars represent standard error of the mean. *$p < .05$, **$p < .01$.

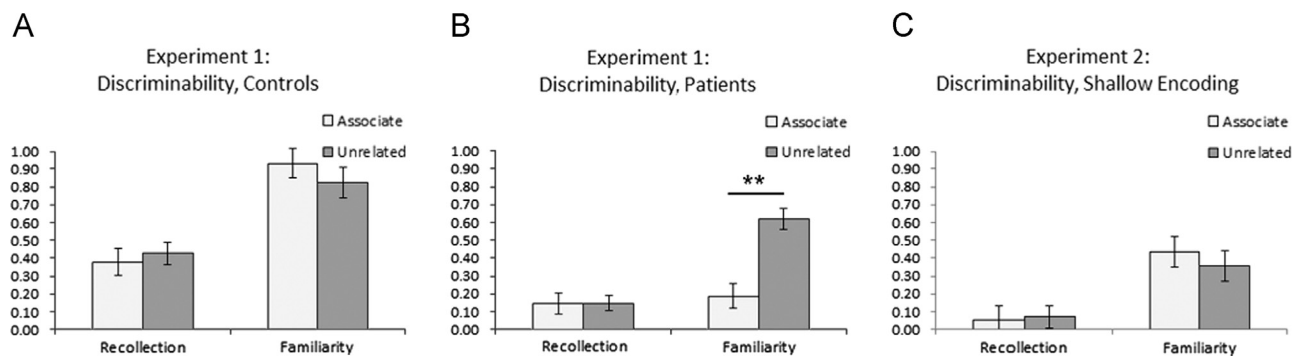

Fig. 2. Mean discriminability between old and new items for recollection and familiarity responses in Experiments 1 and 2. Recollective discriminability was measured as p(R|old) − p(R|new) whereas familiarity was measured as d′ of p(F) between old and new items. Results are separated by whether the test probe was preceded by a semantic associate context word (associate) or an unrelated context word (unrelated). Panels separate recollection and familiarity responses, and subject groups across Experiments 1 and 2. Errors bars represent standard error of the mean. *$p < .05$, **$p < .01$.

these data were analyzed in a 2 (old vs. new) × 2 (associate vs. unrelated) within-subject ANOVA. Like controls, the only significant effect was that there were more recollection responses to old words than to new words, $F(1,7)=50.38$, $MSe=0.003$, $p<.01$, $\eta_p^2=.89$. Context word type had no main effect and did not interact with old/new status, both F's < 1.

Familiarity-based responses for old and new words can be seen for patients in Fig. 1E. To assess whether the context word had an impact on familiarity-based responses, these data were analyzed in a 2 (old vs. new) × 2 (associate vs. unrelated) within-subject ANOVA. Similar to controls, there were more familiarity-based responses to old words than to new words, $F(1,7)=11.43$, $MSe=0.01$, $p<.05$, $\eta_p^2=.62$, however, in contrast to controls, there was no main effect of context word type, $F(1,7)=1.11$, $MSe=0.02$, $p=.33$, $\eta_p^2=.14$. Context word type did interact with old/new status, $F(1,7)=31.31$, $MSe=0.001$, $p<.01$, $\eta_p^2=.82$. Using paired-sample t-tests, this interaction was found to indicate that for new words, there were more familiarity-based responses when a test probe was preceded by a semantic associate context word vs. an unrelated context word, $t(7)=3.27$, $p<.05$, $d=2.47$, but for old words there was no effect of context word type, $t(7)=0.53$, $p=.61$, $d=0.40$. Hence, for patients, there was an effect of the context word however, it differed from the pattern observed for healthy controls in the sense that it only increased familiarity for new items. Further analysis of this interaction and a direct comparison with controls follows next.

2.2.3. Controls vs. patients

To facilitate our comparison of controls vs. patients, we calculated discriminability indexes for each subject. Recollection discriminability was calculated using p(R|old) − p(R|new), whereas familiarity discriminability was calculated as d' between p(F|old) and p(F|new) (see Jacoby et al., 1997; Mangels et al., 2001; Ochsner, 2000; Yonelinas & Jacoby, 1995). Comparing discriminability allows us to easily examine how well patients vs. controls could discriminate old from new items under different conditions. Discriminability indexes for controls can be seen in Fig. 2A, and for patients can be seen in Fig. 2B.

Recollection results (Fig. 1A and B) were initially examined in a 2 (control vs. patient) × 2 (associate vs. unrelated) × 2 (old vs. new) mixed ANOVA. Old items were discriminable from new items, $F(1,14)=115.86$, $MSe=0.01$, $p<.01$, $\eta_p^2=.89$, and consistent with the past literature, healthy controls were better at this discrimination than were amnesic patients, $F(1,14)=25.41$, $MSe=0.01$, $p<.01$, $\eta_p^2=.65$. Healthy controls also showed a borderline effect, making more recollective responses than amnesics in general, $F(1,14)=3.56$, $MSe=0.03$, $p=.08$, $\eta_p^2=.20$. No other effects were significant, all F's < 1.45, p's > .25. Overall then, amnesics showed impaired recollective responses and recollective discriminability. This finding was further supported by a direct analysis of recollection discriminability.

Recollection discriminability was analyzed in a 2 (control vs. patient) × 2 (associate vs. unrelated) mixed ANOVA. Replicating the standard amnesic effect, controls showed better recollection discriminability than did patients, $F(1,14)=25.41$, $MSe=0.02$, $p<.01$, $\eta_p^2=.65$. No effect of context word type or interaction was observed, both F's < 1.30, p's > .27. Hence, by all metrics amnesic patients showed impaired recollection, independent of context word status.

Familiarity results (Fig. 1D and E) were first examined in a 2 (control vs. patient) × 2 (associate vs. unrelated) × 2 (old vs. new) mixed ANOVA. Old items were discriminable from new items, $F(1,14)=67.76$, $MSe=0.01$, $p<.01$, $\eta_p^2=.83$, however healthy controls were better able to make this discrimination than were amnesic patients, $F(1,14)=10.19$, $MSe=0.01$, $p<.01$, $\eta_p^2=.42$. Importantly however, more familiarity-based responses were made to words preceded by semantic associate context words, $F(1,14)=13.80$, $MSe=0.01$, $p<.01$, $\eta_p^2=.50$, and this effect interacted not only with the group factor (marginally), $F(1,14)=3.98$, $MSe=0.01$, $p=.06$, $\eta_p^2=.22$, but also with old/new status (i.e., a three-way interaction), $F(1,14)=7.52$, $MSe=0.005$, $p<.05$, $\eta_p^2=.35$, (no other effects were significant, all F's < 1.73, p's > .21). This three-way interaction indicated that healthy control subjects showed an increase in familiarity-based recognition responses in response to semantic associate context words at test. Because this influence was equivalent for old and new items, there was no difference in overall discriminability due to context words. For amnesic patients however, semantic associate cues impaired the ability to discriminate old from new items, leading to an increase in familiarity-based responses to new items but not to old items. To follow up this interpretation, a direct examination of familiarity-based discriminability was conducted.

Familiarity discriminability was analyzed in a 2 (control vs. patient) × 2 (associated vs. unrelated) mixed ANOVA. Once again, controls showed better overall discriminability than did patients, $F(1,14)=9.14$, $MSe=0.20$, $p<.01$, $\eta_p^2=.40$, however, a significant interaction was observed, $F(1,14)=7.23$, $MSe=0.08$, $p<.05$, $\eta_p^2=.34$. Using paired-sample t-tests, we found that this interaction indicated that patients had better discriminability when the context word was unrelated to the test probe, as opposed to when the context word was a semantic associate of the test probe, $t(7)=6.78$, $p<.01$, $d=5.13$, whereas for controls there was no effect of context word on familiarity discriminability, $t(7)=0.57$, $p=.58$, $d=0.40$. Finally, although patients' familiarity may appear somewhat impaired, even in the unrelated prime condition, in Fig. 2, an independent-sample t-test indicated that patients' familiarity discriminability did not differ from controls in the unrelated prime condition, $t(14)=0.97$, $p=.35$, $d=0.52$. There was no main effect of context word type, $F(1,14)=2.56$, $MSe=0.08$, $p=.13$, $\eta_p^2=.16$. Hence, all analyses of familiarity-based responses converge on the notion that whereas healthy controls' ability to discriminate old from new was unaffected by task irrelevant fluency, amnesic patients' ability to discriminate old from new was impaired by task irrelevant fluency.

To determine whether the current fluency manipulation differentially influenced the patients with damage to the hippocampus and MTL regions outside the hippocampus (H+) compared to the patients expected to have selective hippocampal damage (H), we examined performance in the two groups separately. An examination of Table 3 indicates that the fluency manipulation had similar effects on recognition performance in the H and H+ subgroups, namely the associative prime led to an increase in knowing responses to new items, but not old items. Most importantly, for the H group, mean estimates of familiarity discriminability was .71 (SE=.17) in the unrelated condition and .18 (SE=.13) in the associative condition, and this difference was significant, $t(3)=3.73$, $p<.05$, $d=4.31$. In addition, for the H+ group, mean familiarity discriminability was .53 (SE=.22) in the unrelated condition and .20 (SE=.16) in the associative condition, and this difference was significant, $t(3)=8.36$, $p<.01$, $d=9.65$. Thus, the fluency manipulation reduced familiarity discriminability in both patient subgroups, and therefore does not appear to be limited to only one type of patient.

The between-groups analyses are consistent with the within-groups findings, while also highlighting an important aspect of our results: For controls, semantic associate context words shifted familiarity-based responses for both old and new items, resulting in a bias, but with no effect on discriminability. For amnesic patients however, semantic associate context words increased false alarm rates without impacting hit rates, and so reduced familiarity-based memory accuracy. These results are consistent with past work that looked only at the influence of fluency manipulations on overall recognition rates (Conroy et al., 2005; Verfaellie & Cermak, 1999), but further demonstrate that amnesics' familiarity processes are vulnerable to manipulations of processing fluency in a manner that healthy controls' familiarity processes are not.

3. Experiment 2

In Experiment 2 we tested healthy undergraduates in the same paradigm used in Experiment 1. The difference here was that we modified the procedure in order to reduce recollection for all subjects, in an attempt to render them comparable to amnesics in that regard. To this end, subjects engaged in shallow encoding at study, wherein they were asked to judge as quickly as possible whether each word contained the letter "r". Study trials lasted 1.5 s or until a response was made. Because deep encoding is often associated with increased recollection (e.g., Craik & Lockhart, 1972; Gallo, Meadow, Johnson, & Foster, 2008), shallow processing should limit recollection. Additionally, at test, subjects were asked to make their recognition decisions as quickly as possible, a manipulation which should encourage familiarity-based retrieval over recollection (Hintzman, Caulton, & Levitin, 1998; Hintzman & Caulton, 1997). Using these two methods, we expected that, like amnesic patients, undergraduate subjects would show few recollection responses and little to no recollective discriminability.

The critical question was whether subjects in Experiment 2 would mimic amnesics insomuch as they would show impaired familiarity-based recognition in response to semantic associate context words, or whether their responses would instead resemble that of the healthy controls in Experiment 1 (i.e., semantic fluency might lead to an increase in both hits and false alarms and so would not impact recognition discrimination).

3.1. Methods

3.1.1. Subjects

Twenty undergraduate students from the University of Toronto participated in Experiment 2 in exchange for course credit. One subject was dropped from subsequent analyses for failing to show any ability to discriminate between old and new items (i.e., false alarm rates > hit rates).

3.1.2. Stimuli

The same word pool as Experiment 1 was used.

3.1.3. Procedure

The procedure of Experiment 2 was similar to that of Experiment 1 except that during the study phase, subjects were not told to encode the study items for a later test. Instead, subjects engaged in a letter-recognition task, whereby for each word they were to press the M-key as quickly as possible if the word contained the letter R, and to press the Z-key as quickly as possible if the word did not contain the letter R. At test, subjects were asked to make their recognition decision as quickly as possible, but all other instructions and procedures remained the same as Experiment 1.

3.2. Results and discussion

Like Experiment 1, confidence ratings were collapsed into "know" and "new" responses and familiarity scores were calculated from raw "know" responses using the IRK method. Raw "remember" responses were used as recollection recognition responses. The recollection recognition rates of Experiment 2 can be seen in Fig. 1C, and familiarity recognition rates can be seen in Fig. 1F. To assess whether the context word had an impact on recollection-based responses, recollection recognition responses were analyzed in a 2 (old vs. new) × 2 (associate vs. unrelated) within-subject ANOVA. The only significant effect was that there were more recollection responses to old words than to new words, $F(1,18)=10.71$, $MSe=0.01$, $p<.05$, $\eta_p^2=.37$. Context word type had no main effect and did not interact with old/new status, both F's <1.

To assess whether the context word had an impact on familiarity-based responses, familiarity recognition responses were analyzed in a 2 (old vs. new) × 2 (associate vs. unrelated) within-subject ANOVA. There were more familiarity responses to old words than to new words, $F(1,18)=22.48$, $MSe=0.02$, $p<.01$, $\eta_p^2=.56$, there were more familiarity responses to test words that were preceded by semantic associate context words vs. unrelated context words, $F(1,18)=41.92$, $MSe=0.004$, $p<.01$, $\eta_p^2=.70$, and there was no interaction, $F<1$. Overall then, semantic associate context words lead to a reliable increase in the familiarity-based recognition responses, regardless of old/new status.

As a final check of the influence of semantic fluency, discriminability indexes were calculated for data in Experiment 2, in the same manner as was done in Experiment 1. These discriminability indexes can be seen in Fig. 2C. In Experiment 1, amnesic patients showed poorer familiarity discriminability during semantic associate context word trials vs. unrelated context word trials. In Experiment 2, there was no significant difference in familiarity discriminability between the context word conditions, $t(18)=0.69$, $p=.50$, $d=0.32$. Both by the raw response rates and by the discriminability indexes then we find no evidence that subjects in Experiment 2 showed disrupted semantic fluency processing. Like the controls in Experiment 1, semantic associate context words increased familiarity responses to both old and new words, and unlike the amnesic patients in Experiment 1, there was no difference in familiarity discriminability on semantic associate context word trials vs. unrelated context word trials.

4. General discussion

Past research has shown that, in healthy controls, enhancing the fluency of test items in a recognition paradigm leads to an increase in familiarity-based recognition responses, regardless of old/new status (Rajaram & Geraci, 2000; see also Jacoby & Whitehouse, 1989; LeCompte, 1995; Thapar & Westerman, 2009; Watkins & Peynircioglu, 1990). In support of these findings, in Experiment 1 we found that healthy control subjects showed an increase in familiarity-based recognition responses when the test items were preceded by a clearly visible, associated word. This increase in positive recognition responses acted equally on old and new items, and so there was no difference in overall familiarity discriminability on fluent vs. baseline trials. For MTL amnesic patients however, enhancing fluency disrupted their ability to discriminate old from new items. This manipulation increased the familiarity-based recognition responses to new items, but had no significant effect on responses to old items.

Previous work that examined the influence of process fluency on amnesia focused only on overall recognition (Conroy et al., 2005; Verfaellie & Cermak, 1999). By directly measuring the contributions of recollection and familiarity, the current results extend previous findings by revealing that fluency manipulations specifically disrupt familiarity-based recognition accuracy in amnesic patients. More so, this effect could not be explained by the general inability to recollect studied items, as the fluency manipulation did not disrupt familiarity-based recognition in healthy individuals, even when recollection was reduced (e.g., Experiment 2).

4.1. Fluency and familiarity

If the presence or absence of recollection for studied items cannot explain the disrupted familiarity-processes observed in amnesics, what can? One possibility, that we think can be ruled out, is that the disruptive effects of processing fluency on familiarity-based discrimination in amnesics was simply the result of a ceiling effect. That is, the associative prime word might have had a smaller effect on old items than new items in the patients because the old items were already so highly familiar – due to the study phase – that their familiarity could not be significantly increased (cf. Conroy et al., 2005). This could explain why fluency increased the false alarm rate without increasing the hit rate, and so could result in a decrease in discriminability, as was observed. However, if this were the case, we would have expected to see the same pattern for the healthy controls (e.g., a diminished effect of primes in hit rates). In fact, such a ceiling effect should have been even more of a problem in the controls who had higher hit rates than the patients. However, the sematic prime had larger effects on the hit rates in the controls than in the patients, which leads us to view this account as unlikely.

Two other accounts do seem to be consistent with the existing data. The first is that amnesics are reluctant to use familiarity under conditions in which there are multiple sources of processing fluency. That is, it may be that familiarity and fluency-based processes are relatively normal in amnesics, but, given that patients are quite aware of their own memory impairments, they are reluctant to rely on familiarity in situations in which fluency is obviously being biased. Thus, for example, amnesics may be more willing to trust their feelings of familiarity in situations where a prime and target do not semantically match, because they may assume that all feelings of familiarity arising from the target are related to the familiarity of that target, and cannot be attributed to the prime. However, if the prime and target do match, amnesics may become less confident in their feelings of familiarity.

Moreover, amnesics may be especially uneasy with extremely strong feelings of familiarity, as they may not believe that their impaired memory system would ever produce such a strong sense of familiarity. Thus, old items in the prime condition, which may have high levels of familiarity owing to both recent study and priming, may be more likely to be dismissed than new items, resulting in hits rates suffering much more so than false alarms rates in the prime condition. In line with this account, the fluency manipulation caused familiarity-based discrimination to decrease in the patients, and only impacted the false alarm rate in the patients.

This 'reluctance to use fluency' account is consistent with previous studies, which have shown that amnesic patients exhibit less of a recognition memory impairment when they are unaware their memory is being tested, when they are prompted to use fluency, or when fluency is made more salient (Keane, Orlando, & Verfaellie, 2006; Verfaellie, Giovanello, & Keane, 2001; see also Dorfman, Kihlstrom, Cork, & Misiaszek, 1995). For example, Verfaellie et al. (2001) found that when subjects were told that a large proportion of test items were studied, recognition accuracy increased in amnesic patients, but only resulted in a shift in response bias in the control subjects, suggesting that amnesics may be less likely to fully utilize familiarity unless prompted to do so. In another line of work, Keane et al. (2006) demonstrated that amnesics were better able to discriminate old from new items when perceptual fluency did not compete with the fluency due to recent study, suggesting that amnesics are capable of using fluency to judge familiarity, but may not do so when there are competing sources of fluency.

A second plausible explanation for the current results is that the hippocampus may be useful in maintaining information about the general experimental context that is useful in separating different sources of fluency, such as episodic study fluency from prime-driven fluency. For example, under conditions in which there are conflicting sources of familiarity, the hippocampus may play a role in setting up a general retrieval context that helps focus the familiarity signal. For the unrelated prime trials, the global familiarity of the test items may be sufficient to discriminate between old and new items. However, in the context of the related primes, global familiarity would be less diagnostic, as both fluency due to study and fluency due to the prime would contribute to familiarity. In these conditions, controls may use their memory for the study context to help constrain how familiarity is assessed. That is, rather than probing memory with the test item alone and assessing the global match signal to what is stored in memory, controls might probe memory with the test item along with additional information about the study context (i.e., things studied in this particular room, or processed under a certain set of encoding instructions). This would help counteract the interfering effects of the semantically-related prime. Presumably, however, amnesic patients would be less likely to remember the experimental context and so would have a reduced ability to separate episodic fluency from the prime fluency.

The 'reluctance to use fluency' and the 'reduced ability to separate sources of fluency' explanations just described are both post hoc accounts, and thus further studies aimed at testing these accounts will be critical. Moreover, future studies examining the conditions under which familiarity is reduced in patients will be useful in order to determine conditions that optimize the memory performance of amnestic patients.

4.2. Fluency and recollection

Although most past studies that have examined fluency manipulations have found that fluency primarily affects familiarity (e.g., Jacoby & Dallas, 1981; Jacoby & Whitehouse, 1989; Lindsay & Kelley, 1996; Rajaram & Geraci, 2000), a few studies have demonstrated that fluency may sometimes influence recollection as well. For example, Kurilla and Westerman (2008) have shown that fluency can increase both "remember" and "know" ratings, if participants provide a rating of both recollection and familiarity for every item at test (see the independent "remember"/"know" procedure; Higham & Vokey, 2004). In addition, Taylor and Henson (2012) found that conceptually related cues could increase the proportion of "remember" responses at test, if conceptual primes were inter-mixed with repetition primes. Moreover, other studies have shown that recollected responses can be associated with high levels of perceptual fluency (Berry, Shanks, Speekenbrink, & Henson, 2012; Sheldon & Moscovitch, 2010).

In the current study, the fluency manipulation was found to have large effects on familiarity-based responses but it did influence remember reports. However, to explore this issue further we examined the current results using receiver-operating characteristic (ROC) modelling techniques to estimate the influence of recollection and familiarity (see Yonelinas, 1994, 1997). It should be noted that this approach is not ideal in the current study since subjects were not actually treating the 5-point scale as a confidence scale, and so these results should be taken with caution. Nonetheless, re-analyzing the results of Experiment 1 suggested that the fluency manipulation led to a decrease in familiarity in the patients, but a decrease in recollection in the control subjects.

Although the results of the ROC analysis must be taken with caution, they are consistent with the idea that at least in healthy subjects, fluency manipulations may not be limited to impacting familiarity. Further studies aimed at understanding when fluency manipulations impact recollection will be useful.

5. Conclusion

In summary, MTL amnesia is a deficit that results in impaired recollection with relatively spared familiarity. However, the spared familiarity processes of amnesics differ qualitatively from the intact familiarity of healthy individuals. Whereas increasing the fluency of items at test increases old and new recognition responses for healthy controls, but leaves the relative accuracy of their recognition responses intact, this same manipulation impairs the ability of amnesics to discriminate old from new items based on familiarity. This phenomenon is not due to overall lower levels of recognition or impaired recollection for studied items, as healthy undergraduate subjects with reduced recollection of studied items do not show this pattern. Fluency that arises from the context word thus appears to interfere with familiarity or lead amnesics to be less likely to make familiarity-based memory attributions, and results in a further disruption of their recognition memory ability.

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