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False memory in schizophrenia patients with and without delusions

Reena Bhatt [a,*], Keith R. Laws [b], Peter J. McKenna [c]

[a] School of Psychology, Cardiff University, Cardiff, UK
[b] School of Psychology, University of Hertfordshire, Hertfordshire, UK
[c] Benito Menni Complex Asistencial Salut Mental, Spain

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ABSTRACT

Delusions are fixed 'false beliefs' and, although a hallmark feature of schizophrenia, no previous study has examined if delusions might be related to 'false memories'. We used the classic Deese–Roediger–McDermott (DRM) paradigm to compare false memory production in schizophrenia patients who were currently experiencing delusions (ED), patients not experiencing delusions (ND) and healthy control participants. The ED group recalled twice as many false-positive memories (i.e., memory for words not previously seen) as both the controls and crucially, the ND group. Both patient groups also recognised fewer correct words than the healthy controls and both showed greater confidence in their false memories; however, on the recognition task, the ED group made more false-negative (i.e. rejecting previously seen words) high confidence responses than the ND group.

1. Introduction

Fixed false beliefs (i.e., delusions) are a hallmark feature of schizophrenia presenting in virtually all persons with schizophrenia at some time in the course of their illness, (Moritz and Woodward, 2002). Understanding the cognitive basis of schizophrenia symptoms is a major goal of psychological schizophrenia research that could have implications for treatment. One important class of schizophrenia symptom is delusions — false, often bizarre beliefs about persecution, ideas of grandeur and so on.

Although delusions are perhaps the most common and central feature of schizophrenia, to date, little consensus exists about their psychological or neuropsychological basis (see Gilleen and David, 2005). Nevertheless, parallels may be drawn with the fact that healthy participants can be induced to make false recollections. The notion of false memories relates to either remembering events that never happened or remembering them quite differently from the way they happened (Roediger and McDermott, 1995). Researchers investigating false memories have used numerous techniques to demonstrate the phenomenon, although one method that has been widely used is the Deese–Roediger–McDermott (DRM) paradigm (Deese, 1959; Roediger and McDermott, 1995). This method involves presenting participants with lists of words and later testing their memories for the words. Each list of words has strong associates to a critical, target word (often the strongest associate with the list), e.g., needle was the critical unpresented target word for the following presented list: <thread, pin, eye, sewing, sharp, point, prick, thimble, haystack, pain, hurt, and injection>. Following presentation, participants are given a free recall test and after all presentations, they receive a recognition test. Roediger and McDermott found that participants recalled the unseen target word in 40% of the lists, and other unseen words in 14% of the lists.

Laws and Bhatt (2005) used the same DRM technique in healthy participants dichotomised into high and low 'delusion-proneness' groups (based on the Peters Delusional Inventory: PDI: Peters et al., 1999). They found that, as the score on this scale increased so did the number of false memories in the DRM paradigm and that participants with high delusional ideation also attached greater confidence to false- positive errors. Memory dysfunctions have been repeatedly shown within schizophrenia (Aleman et al., 1999). Specifically, studies using the DRM paradigm have established that simple memory intrusions are quite common in patients with schizophrenia (Huron and Danion, 2002; Moritz and Woodward, 2002; Elvevåg et al., 2004; Moritz et al., 2005) and that they may exhibit increased memory confidence for false memories (Moritz and Woodward, 2002; Moritz et al., 2005, 2006). In Moritz and Woodward's (2002) study, the findings suggested that the 'memory responses rated with high confidence by patients with schizophrenia contain a large number of intrusions'. More recent studies report that patients produce a greater percentage of high confidence responses that are errors (this is referred to as knowledge corruption[1] by Moritz and colleagues) and significantly so for false-negative errors (Moritz et al., 2004, 2006). Moritz et al. (2005) proposed that paranoid schizophrenia patients display a stronger tendency to trust information that is actually

* Corresponding author. South Wales Doctoral Programme in Clinical Psychology Archway House 77 Ty Glas Avenue Cardiff CF14 5DX, UK.
E-mail address: reena_bhatt@talk21.com (R. Bhatt).

[1] In this context, Moritz et al. (2005) define knowledge as "statements or hypotheses that are held as accurate with high confidence"p.10.

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incorrect, whereas healthy controls are more cautious in their evaluation of information that turns out to be incorrect. Overconfidence in errors was thought to arise from the impaired ability to cast doubt on fallible information, whereas healthy controls were able to attach a so-called 'not trustworthy' tag to such representations. Finally, at the neurological level, patients with frontal lobe lesions show a well-documented susceptibility to false recognition/recall and problems with memory monitoring processes (e.g., Janowsky et al., 1989; Schacter and Slotnick 2004). Given that patients with schizophrenia display poor performance on tests of frontal lobe function (e.g., the Wisconsin Card Sort Test: see Laws 1999) and moreover, functional neuroimaging studies have revealed hypofrontality in patients with schizophrenia (for a review, see Hill et al., 2004), such factors may also underpin such memory distortions in patients with schizophrenia.

In the current study, we used the Roediger and McDermott (1995) paradigm to investigate recall, recognition and memory confidence in schizophrenia patients with and without delusions and healthy controls. Laws and Bhatt (2005) speculated whether their findings would relate to those of studies of patients with schizophrenia. A review of studies (using the same DRM paradigm) appears inconsistent with Laws and Bhatt (2005) insofar as schizophrenia patients display no greater incidence of false-positive errors than healthy controls (Huron and Danion, 2002; Elvevåg et al., 2004; Moritz et al., 2004; Lee et al., 2006). All of these studies examined schizophrenia patients *per se* rather than focussing specifically on comparing schizophrenia patients who are experiencing delusions (ED) or not experiencing delusions (ND). Our main aim was to determine whether schizophrenia patients with delusions show a greater tendency to create false memories compared both to schizophrenia patients without delusions and to healthy controls. Furthermore, we aimed to determine if schizophrenia patients with delusions display greater knowledge corruption than schizophrenia patients without delusions and healthy controls.

2. Method

2.1. Participants

Twenty-five patients who met Research Diagnostic Criteria (RDC) for schizophrenia participated. All had a stable chronic illness and were drawn from a sample of day-patients under the care of one of the authors (PJM). The patient sample comprised a group of patients with schizophrenia currently experiencing delusions (ED: $n=13$) and a group who were not experiencing delusions (ND: $n=12$). The presence or absence of delusions was established by a structured psychiatric interview using the Present State Examination (PSE), 9th Edition (Wing et al., 1974). The PSE rates delusions as 0, 1, or 2. A score of 0 means that no delusions are present; 1 is for 'partially held' delusions, that is delusions which the patient has questioned; and 2 refers to delusions that are held with 'full conviction'. All of the patients with delusions in the study scored 2, while all of the patients without delusions were rated as 0 and had been in stable clinical condition, free of delusions for at least 2 years (and much longer in all but one case). The ED patients were exhibiting delusions at the time of testing while the ND group showed no delusions at the time of testing (Table 1 outlines the specific delusions experienced). All patients had a current WAIS-R IQ of greater than 85 and the two patient groups did not differ on WAIS-R IQ, ($M=94.4$ vs. 97.3: $F<1$). In terms of overall severity of symptoms as measured by the Global Assessment Scale (GAS: Endicott et al., 1976), again the ED and ND groups did not differ significantly ($M=35.54$[SD$=3.8$] vs. $M=35.75$ [SD$=4.5$]: $F<1$).

Table 1
Delusions experienced by the patients experiencing delusions ($n=13$).

1.	There is a conspiracy against her involving a group of lesbians; people can read her mind
2.	Two witches are at the centre of a conspiracy against him
3.	He is being poisoned by his wife and perhaps other people
4.	He is a famous writer and playwright; a nurse who he met in hospital many years ago is in love with him and sends him messages through the media
5.	There is a conspiracy against him; people can read his mind
6.	Various persecutory delusions involving the Devil
7.	His memories have been removed; a famous rock singer is in love with him
8.	She is being persecuted by the Devil; she is responsible for evil acts in the world; she is pregnant with an alien baby
9.	He is being tortured by various agencies who affect his bodily functions and cause him pain from a distance
10.	People breaking into his house; he is involved with intelligence services; he has invented various things
11.	He is being watched; he has telepathic powers; he is an important religious figure
12.	He is a rock star and chess master whose memories have been removed
13.	He is in league with the Devil and is going to be killed because of this

Table 2
Demographic characteristics for patients experiencing delusions (ED), not experiencing delusions (ND) and in healthy controls.

	ED ($n=13$)	ND ($n=12$)	Controls ($n=20$)	ANOVA
Sex (M, F)	12, 1	11, 1	15, 5	$\chi^2=2.4$, $P=0.3$
	M (SD)	M (SD)	M (SD)	
Age	46.92 (9.15)	47.08 (8.07)	44.50 (8.81)	$F<1$
NART IQ	104.77 (12.82)	109.08 (10.81)	106.50 (10.11)	$F<1$
WAIS-R IQ	94.4 (13.10)	97.3 (6.90)		$F<1$

M = mean, SD = Standard Deviation.

Twenty healthy controls did not differ significantly from the patients for estimated premorbid National Adult Reading Test Intelligence Quotient (NART IQ) (Nelson, 1982) or age (see Table 2). Hence, 25 patients (two females, 23 males) and 20 controls (five females, 15 males) participated in the study. All participants provided written informed consent and the study was approved by the local Health Service Ethics Committee. The healthy controls also completed the Peters Delusional Inventory (PDI: Peters et al 1999), which measures the level of 'delusional ideation' in healthy participants. The PDI is based on the Present State Examination (Wing et al., 1974) and consists of 40 yes–no questions examining proneness to unusual thoughts (ranging from religious beliefs to classical delusional thinking: e.g. Do you ever feel as if you are a robot or zombie without a will of your own? Do you ever feel as if you are being persecuted in some way? Do you ever feel as if there is a special purpose or mission to your life? Do you ever feel as if your insides may be rotting? Do you ever feel as if other people can read your mind?). Peters et al. (1999) have shown that the PDI has good internal consistency (Cronbach $a=0.88$) and test-retest reliability (over 6–12 months was 0.82). In the current study, the controls had a mean PDI score of 5.3 [SD$=5.3$] with a range from 0 to 20.

2.2. Materials/apparatus

2.2.1. False memory task (Roediger and McDermott, 1995)

The participants were shown eight consecutive lists of 15 words (from Roediger and McDermott, 1995). After each list, participants were given 1 min to recall as many items as possible. Following the presentation of all eight lists, participants were given a recognition test in which 23 words were shown one at a time and participants had to report their confidence rating in each word (whether it was old or new and whether they were sure or unsure).

Participants viewed 120 words (eight lists of 15 words) on a computer screen. Each of the eight lists consisted of associates to a critical target word (see Appendix A). The words were presented individually on the centre of the screen for 1.5 s, with a 1.5 s interval between each word. The unseen target words for each of the eight lists were <anger, black, bread, chair, cold, doctor, mountain, and needle>. For example, for the target word <Anger>, the 15 associate words presented were <mad, fear, hate, rage, temper, fury, ire, wrath, happy, fight, hatred, mean, calm, emotion and enrage>. Following presentation of the 120 words, the participants were instructed to immediately recall and write as many of the words as they could remember. The recall task was scored for: Number of Correct Recalls — the number of words that are recalled only from the lists that have been presented to the participants (out of 120 words in total). Number of Target Intrusions — the number of critical target words that have been recalled (out of eight possible words relating to the eight lists presented). Number of Other Intrusions — words that may not be obviously related to the critical target words (or the words given in the lists) or may be just idiosyncratic erroneous recalls.

The recognition test then followed and comprised 23 words: (i) eight studied words, (ii) eight target words (semantically related to the studied words) and (iii) seven unrelated words not previously studied. Participants also rated each word as to their confidence that they had seen it in the previously shown lists. A 4-point Likert Scale was used: 1 (sure old — sure that had studied the word previously), 2 (probably old — maybe previously studied), 3 (probably new) or 4 (sure new — not previously studied in the lists). Comparisons were made for the 'sure' ratings for studied items (including the words that were sure were 'old' i.e., correctly accepted and sure they were 'new' i.e., false negatives); target (containing words they were sure were new 'correctly rejected' and sure were old i.e. false positives); and unrelated words (containing words considered as new i.e., 'correctly rejected' and considered as old i.e., false positives). Finally, following the procedure outlined by Moritz et al (2004), we calculated the Knowledge Corruption Index, KCI that is, which reflects the proportion of high-confidence errors as a proportion of all high-confidence responses.

Table 3
Recall performance for both patient groups and healthy controls.

	ED	ND	Control (C)	ANOVA
	M (SD)	M (SD)	M (SD)	
Recalled correctly ($n=120$)	41.23 (15.18)	37.67 (17.88)	83.45 (13.51)	ED = ND < C
Target words ($n=8$)	5.31 (1.25)	2.67 (1.50)	2.55 (2.01)	ED > ND = C
Other words	8.08 (7.87)	12.00 (15.83)	2.45 (3.71)	ED = ND > C

M = mean, SD = Standard Deviation.

Table 4
Recognition performance for both patient groups and healthy controls.

	ED	ND	Control (C)	ANOVA
	M (SD)	M (SD)	M (SD)	
Recognised correctly ($n=23$)	15.2 (2.1)	16.2 (4.1)	19.0 (1.8)	ED = ND < C
False Positives to targets ($n=8$)	4.6 (1.5)	4.1 (2.7)	3.4 (1.5)	ED = ND = C
False Negatives ($n=8$)	1.8 (1.7)	1.3 (1.7)	0.4 (0.5)	ED = ND > C
Knowledge Corruption Indices				
KCI (%)	46.2 (12.0)	45.5 (20.9)	28.9 (13.6)	ED = ND > C
False Positive KCI (%)	57.2 (18.3)	47.9 (24.9)	43.6 (20.3)	ED = ND = C
False Negative KCI (%)	18.0 (14.7)	12.0 (14.4)	5.2 (7.4)	ED > ND > C

M = mean, SD = Standard Deviation.

3. Results

3.1. Recall

Descriptive statistics of the total, correct, incorrect, target and other words recalled were computed for each of the three groups (See Table 3).

One way ANOVAs were conducted to investigate differences among the three groups in the mean number of correct words, other words and target words recalled.[2] The results revealed significant group effect for correct words, $F(2, 42)=45.39$, $P<0.001$. The pairwise comparisons revealed two contrasts that were significant for the number of correct words recalled (both $P<0.001$: between the healthy controls and both the ED and ND groups. A significant group effect also emerged for target words (false memories) recalled $F(2,42)=11.89$, $P<0.001$. A follow-up contrast analysis revealed no difference between controls and ND patients, while the ED patients were worse than both controls and the ND (see Table 3). Finally, for other words, the result also revealed a significant group difference, $F(2, 42)=4.05$, $P<0.03$, but with ND group making more other errors than healthy controls ($d=1.5$, $P=0.008$).

These analyses confirmed that any false memories were not solely a product of poor memory since both patient groups showed no significant difference in mean correct or other words recalled, although the ED group made more target errors.

3.2. Recognition

A significant group difference emerged in correct recognition for the two patient groups and healthy control group ($M=66$, 70, 82% correct respectively:[3] $F(2, 42)=8.96$, $P<0.001$), with the controls correctly recognising more words than both patient groups.

Group differences emerged for the number of false positive responses: $F(2, 42)=4.69$, $P=0.015$), with the both patient groups making more false positive errors than controls ($P=0.008$ and $P=0.03$ respectively). A significant group effect also emerged for false negative responses: $F(2, 42) = 5.21$, $P=0.01$), with the ED group making more false positive errors than controls ($P=0.003$) and ND group approached significance ($P=0.06$) when compared with controls (see Table 4).

We used signal detection to determine d-prime (d') and criterion (C) for each group. The mean values for d' were: controls $M=2.35$, ED group $M=0.99$ and ND group $M=1.28$. For C, the values were: controls $M=-0.48$, ED group $M=-0.25$ and ND group $M=-0.31$. The d' values indicate a lowered sensitivity in both of the patient groups when compared with controls. The criterion values for each group indicate that all groups showed a tendency to say 'yes' to the stimuli.

Finally, we calculated the KCI that is, the percentage of high confidence recognition responses that were errors: see Table 4. A one-way ANOVA revealed a significant difference in total KCI for the ED group, the ND group and control groups ($F(2,42)=6.63$, $P=0.003$: $M=46\%$, 45% and 29%, respectively). Although no difference emerged between the two patient groups, both showed greater knowledge corruption than the controls (ED, $P=0.005$ and ND, $P=0.003$). In addition, we calculated the KCI separately for false-positive and false-negative errors. Although no group difference was found for false positive KCI ($F(2,42)=1.62$, $P=0.20$), a significant difference emerged for false negative KCI ($F(2,42)=4.74$, $P=0.014$), with ED group making more false negative errors than controls ($P=0.004$). Percentage accuracy comparing recall and recognition is displayed in Fig. 1, while a comparison of false positive recall and recognition error rates is displayed in Fig. 2.

3.3. Delusion proneness in healthy controls

We examined the correlations between the PDI scores of the healthy controls with performance on the recall (targets) and the recognition tasks (KCI measures). A significant correlation emerged between PDI scores and the number of targets recalled that is false positives ($r=.48$, $P=0.03$); and a nonsignificant inverse correlation was found for PDI and number of items correctly recalled ($r=.20$, $P>.05$).

4. Discussion

Our findings corroborate the well-documented verbal recall and recognition memory impairments that occur in patients with

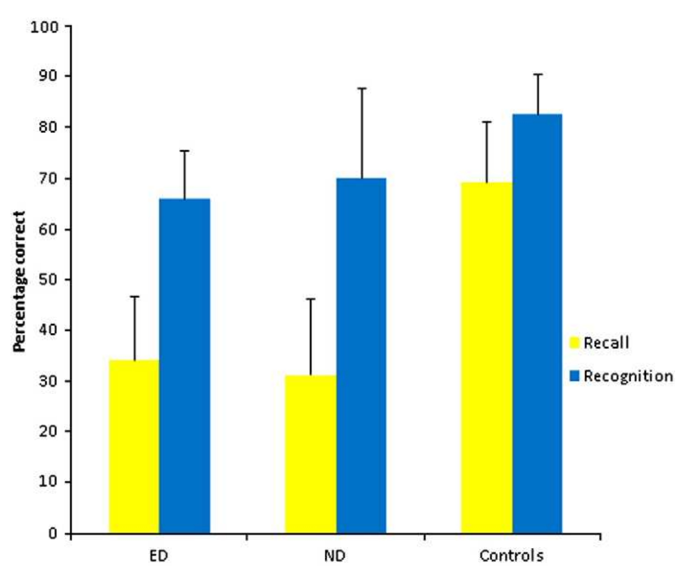

Fig. 1. Recall and recognition memory accuracy (%) in the three groups. *Note*. Error bars = standard deviation.

[2] On the recall task, Levene's tests revealed that the group variances differed significantly for targets and other errors. We therefore also ran nonparametric ANOVAs; however, these made no difference to the outcomes and so we report the ANOVA results here.

[3] False-alarm-rate-corrected hit rates were 33%, 41% and 65%, respectively.

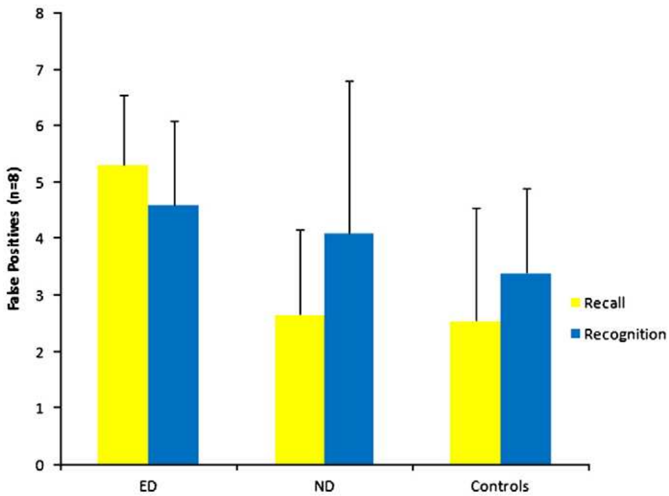

Fig. 2. False positive (target) recall and recognition ($n=8$) in the three groups. *Note.* Error bars = standard deviation.

schizophrenia (see Aleman et al., 1999; McKenna et al., 2002). As expected, the patients were less impaired at recognition than recall, where both patient groups recalled approximately half as many of the studied words as healthy controls. Although the two patient groups did not differ in recall, the ED group made significantly more false-positive recalls (i.e., targets) than the ND group and the controls. On the recognition phase of the experiment, we confirmed greater Knowledge Corruption in both schizophrenia groups, with KCI scores that are comparable to those previously reported (for a review, see Moritz and Woodward, 2006). Furthermore, the ED group did show a significantly greater KCI for false-negative responses than the ND group; however, the three groups failed to differ in false-positive KCI. Finally, in our healthy controls, scores on the Peter's Delusional Inventory (PDI: Peters et al., 1999) correlated significantly with false positive memories on the recall task confirming our previous-finding of greater target recall in those who with high as opposed to low PDI scores. Since the patient groups and the controls did not differ in age or estimated premorbid IQ and the two patient groups did not differ in WAIS-R IQ, NART IQ, age or overall symptom severity (as measured by the Global Assessment Scale: Endicott et al., 1976), the memory problems documented here cannot be explained as artefacts of age, intellectual functioning (cf. Huron and Danion, 2002).

As far as we are aware, this is the first study to directly compare false memories in patients with and without delusions; and to examine false memories in such patients using a recall paradigm that is, where the patients are not prompted to make specific false memories (as happens for recognition tasks). Our findings show that the ED group not only make significantly more false-positive recall errors than controls, but crucially they make more than the ND group. This link between the presence of delusions and false memories is further underscored by the fact that the level of delusion proneness (PDI scores) in controls correlated significantly with the number of false-positive errors made by them during recall. This association accords with previous work showing that healthy controls with high PDI scores make more false-positive recall errors in this paradigm than those with low PDI scores (Laws and Bhatt, 2005; Dehon et al., 2008), although not perhaps with schizotypal traits in general (see Dagnall and Parker, 2009).

Turning to the recognition task, both patient groups made more recognition errors than controls. Nonetheless, we found no evidence of greater false-positive or false-negative errors in the ED group than the ND group. Previous studies using the DRM paradigm have produced varied reports concerning false recognition in patients with schizophrenia, with reports of no greater false memories (Moritz et al., 2004, 2006) or even fewer false memories than healthy controls (Huron and Danion, 2002; Elvevåg et al., 2004). Although in the current study, only seven words (from 120) were common to both the recognition and the recall tasks, we must consider a potential confounding effect of the recall task preceding the recognition task. While the logic of memory research determines the order of these tasks, we cannot eliminate the possibility that recognition performance may have been different if only a recognition test had been used (as per other recent studies). Nonetheless, any impact of recall on recognition would apply to all three groups (since each did the task in precisely the same manner) and so would not account for the differences that emerged. We also note that our findings accord with previous work reporting no difference in false positive recognition for patients and controls (Moritz et al., 2004, 2006). By contrast, far less attention has been paid to the emergence of false positive memories in recall paradigms and although no significant differences for target recognition, deluded patients made significantly more false-positive responses in the recall task than controls and critically, more than ND group. Recall may therefore be a more sensitive monitor of false memory in patients experiencing delusions. In this context, it is also worth noting that previous studies have examined unspecified groups of patients with schizophrenia and so, did not specify the presence or absence of delusional thinking — although as noted above, almost all will have experienced delusional thinking at some time. Since previous samples would likely comprise a mix of those patients who experience delusions and those who do not, the precise mix could affect the possibility of finding an effect.

Both patient groups did, however, show elevated KCIs when compared with controls that is, they expressed greater confidence in their erroneous responses. This accords with previous work showing that patients with schizophrenia exhibit increased memory confidence for false memories (Moritz and Woodward, 2002; Moritz et al., 2005, 2006). Analysis of KCI for false-positive and false-negative error separately revealed no differences in false-positive KCI; however, the ED group showed a larger false-negative KCI than the healthy controls and crucially, larger than for the ND group. Again, several studies have documented significantly greater false-negative errors in patients with schizophrenia (Moritz et al., 2004, 2005; Moritz and Woodward, 2006). Although greater confidence in false-negative errors differentiated the ED and ND groups, and has been documented in schizophrenia patients generally, this has not been related to aspects of psychopathology including delusions. For example, Moritz et al. (2005) found no correlations between any positive symptom and Knowledge Corruption measures (including false-negative KCI). Nonetheless, one possibility is that false-positive and false-negative responses are related to different aspects of delusions (e.g., formation and maintenance). One possibility is that increased confidence in false negative responding underpins the defensive responses that deluded individuals often employ when confronted with evidence that contradicts their false beliefs. Rather, they would prefer to reject patently true information if it proves problematic for their delusional beliefs.

We must consider the possible relationships between accurate memory and false memory. On the one hand, we might expect false memory intrusions to be inversely related to memory accuracy, but on the other hand, if memory is poorer, then this might inadvertently protect against false memories (see Elvevåg et al., 2004; Lee et al., 2006). Hence, it is necessary to determine if poorer memory in schizophrenia patients induces or even possibly protects against false memories (i.e., target intrusions). In this study, we can eliminate the possibility that poor memory alone accounts for the presence of false memories since both patient groups exhibited similar levels of recall and recognition memory impairment; however, the ED patients spontaneously recalled twice as many false memories and made significantly more false negative recognitions. The greater incidence of false memories in the ED patients is not, therefore, a simple consequence of the well-documented poorer memory associated with schizophrenia. Moreover, the association between PDI scores and false memories in the control subjects would be inconsistent with such an account since the latter recall twice as many items and also recognise significantly more (see also Laws and Bhatt 2005). Turning to the corollary question, since both patient groups had comparable memory impairment, the lower level of false memories in the ND group also cannot readily be attributed to a protective effect of poorer memory generally. Hence, arguments concerning how false memories reflect individual differences in memory that is, good or poor memory, cannot account for the systematic differences between those patients with and without delusions.

Manifestly, the false target memories are semantically related to the studied words and in this experimental context, evidence concerning semantic priming effects in schizophrenia might be relevant (for a review, see Pomarol-Clotet et al., 2008) especially perhaps to the recall findings. Priming studies measure the level of assistance that a word (the prime) gives to the processing of another word (the target) as a measurement of their proximity with semantic space. This semantic priming effect is attributed to the spread of activation initiated by the display of the prime word that is thought to pre-activate semantically related information. For example, the prime-target pairing <lemon-sour> would be expected to result in faster responding than <lemon-chair>. In addition, because concepts are assumed to be associated within a network, activation may spread, not only to directly related concepts, but also to more distant concepts within the semantic memory network. For example, the word <lemon> may activate the related concept <sour>, which in turn activates <sweet> resulting ultimately in <lemon> priming <sweet> (e.g., Spitzer, 1997). Such an account has found favour in some explanations of symptom of thought disorder (Pomarol-Clotet et al., 2008); however this framework may be relevant to the tendency of the ED group to recall more false memories that is because of a greater spread of activity from the studied word lists to the unseen targets (see also Moritz et al., 2002). Although further work is required to examine potential differences in the spread of activation within the semantic memory systems of patients with and without delusions, the manner in which concepts are activated and inhibited may play a major role in the development or the maintenance of delusional memories.

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Appendix A. Stimulus words presented to participants

List	1	2	3	4	5	6	7	8
	Mad	**White**	Butter	Table	**Hot**	Nurse	Hill	Thread
	Fear	Dark	Food	Sit	Snow	Sick	Valley	**Pin**
	Hate	Cat	Eat	Legs	Warm	Lawyer	Climb	Eye
	Rage	Charred	Sandwich	Seat	Winter	Medicine	Summit	Sewing
	Temper	Night	Rye	Couch	Ice	Health	Top	Sharp
	Fury	Funeral	Jam	Desk	Wet	Hospital	Molehill	Point
	Ire	Colour	Milk	Recliner	Frigid	Dentist	Peak	Prick
	Wrath	Grief	Flour	Sofa	Chilly	**Physician**	Plain	Thimble
	Happy	Blue	Jelly	Wood	Heat	Ill	Glacier	Haystack
	Fight	Death	Dough	Cushion	Weather	Patient	Goat	Thorn
	Hatred	Ink	Crust	Swivel	Freeze	Office	Bike	Hurt
	Mean	Bottom	Slice	Stool	Air	Stethoscope	**Climber**	Injection
	Calm	Coal	Wine	Sitting	Shiver	Surgeon	Range	Syringe
	Emotion	Brown	Loaf	Rocking	Arctic	Clinic	Steep	Cloth
	Enrage	Grey	**Toast**	**Bench**	Frost	Cure	Ski	Knitting
Target	*Anger*	*Black*	*Bread*	*Chair*	*Cold*	*Doctor*	*Mountain*	*Needle*

Bold items appeared in the recognition test phase; targets in italics did not appear in the recall phase, but occurred as erroneous related targets in the recognition phase (see Appendix B).

Appendix B. Items from the recognition task

Targets (unseen)	Seen	Unrelated
Anger	Toast	Friend
Black	Hot	Melody
Bread	Physician	Band
Chair	Pin	Speed
Cold	White	Snail
Doctor	Climber	Flow
Mountain	Hatred	Man
Needle	Bench	

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