

# Recollection and Familiarity in Schizophrenia: A Quantitative Review

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Recognition memory judgments can be based on recollection of qualitative information about an earlier study event or on assessments of stimulus familiarity. Schizophrenia is associated with pronounced deficits in overall recognition memory, and these deficits are highly predictive of global functioning. However, the extent to which these deficits reflect impairments in recollection or familiarity is less well understood. In the current article, we reviewed studies that used remember-know-new, process dissociation, and receiver operating characteristic procedures to investigate recollection and familiarity in schizophrenia. We also performed a quantitative reanalysis of these study results to obtain recollection and familiarity estimates that account for methodological differences between studies. Contrary to previous conclusions that recollection is selectively impaired in schizophrenia, we found evidence for both familiarity and recollection deficits across studies, suggesting multi-focal medial temporal lobe and/or prefrontal cortex dysfunction. The familiarity deficits were more variable with frequent small-to-medium rather than medium-to-large effect sizes, suggesting that familiarity could be potentially used as a compensatory ability, whereas recollection is conceptualized as a therapeutic target for new treatment development.

**Key Words:** Episodic memory, familiarity, medial temporal lobe, memory retrieval, recollection, schizophrenia

Episodic long-term memory is severely impaired in patients with schizophrenia (1,2). This deficit is a core feature of the illness (3) and highly predictive of functional outcome (4,5). However, not all aspects of episodic memory are equally affected. For instance, memory performance is disproportionately impaired when patients must organize information during encoding (6), when memory for relationships between items rather than for individual item features is required (7,8), and when retrieval is tested with recall versus recognition tasks (1). To the extent that successful recall performance requires recollection of contextual aspects of the encoding event—whereas recognition memory can be based on the assessment of item familiarity (9)—these results suggest that patients might suffer from a selective deficit in recollection, while familiarity might be preserved. Many recent studies directly examining recollection and familiarity in schizophrenia have supported this hypothesis, suggesting a substantial recollection impairment and preservation of or increased reliance on familiarity processes (10–21), but other studies do not support this conclusion (22–28). Moreover, as described in more detail in the following text, a number of methodological issues complicate interpretation of and integration across extant findings. The goal of the current article is to review and reanalyze published studies of recollection and familiarity to establish more definitively the relative impact of schizophrenia on these two retrieval processes.

Episodic memories can be retrieved on the basis of recollection or familiarity (for a review, see Yonelinas [29]). Recollection reflects a retrieval process whereby qualitative details of an event or episode are accessed, such as meeting someone and remembering who they are and that you saw them at the gym last

week. Familiarity, in contrast, reflects a signal detection retrieval process or an assessment of stimulus recency in the absence of recollection, such as recognizing another shopper at the grocery store but being unable to retrieve their name or remember where you saw them last. Recollection and familiarity are functionally separable (for reviews, see [29,30]) and rely on dissociable brain networks (31,32). For example, within the medial temporal lobe (MTL), recollection is supported by the hippocampus and parahippocampal cortex, whereas the perirhinal cortex (PRC) might be sufficient to support familiarity-based recognition (for reviews, see [32–34]). Establishing the differential impact of schizophrenia on these two retrieval processes might, therefore, inform pathophysiological models of memory dysfunction and prove useful in developing future pharmacological or behavioral treatments.

Multiple experimental and computational procedures have been used to dissociate the relative contributions of recollection and familiarity from recognition memory performance in schizophrenia (Table 1). Most studies have employed the remember-know-new (RKN) procedure (35), in which subjects respond “remember” when they can recollect qualitative information about the study event, and respond “know” when an item is recognized on the basis of familiarity in the absence of recollection. More recently, studies have used the receiver-operating characteristic (ROC) method in which participants rate their subjective confidence (high, medium, low) that an item is either old or new. These confidence ratings are used to plot ROC curves that can be analyzed to estimate the contributions of recollection and familiarity (36,37). One study also examined recognition memory with the process dissociation (PD) procedure (38), which measures recollection as the ability to accurately retrieve source information and familiarity as the ability to recognize items that are not recollected.

Across methods, results from these studies have consistently suggested that schizophrenia patients exhibit deficits in recollection, but the fate of familiarity has been less clear (Table 1). For example, 16 of 19 studies reported that recollection was reduced in schizophrenia patients relative to demographically matched control subjects (10–19,21–23,25–27), whereas only 3 (1 PD and 2 RKN) found no significant group differences (20,24,28). In contrast, when familiarity was examined, seven studies (1 PD, 3 ROC, 3 RKN) indicated that familiarity was reduced (22–28), seven (all RKN) indicated that familiarity was unaffected (11,14–17,20,21),

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**Table 1.** Summary of RKN, PD, and ROC Studies Included in Review

Study	Study Type	n = HV/PT	Experimental Materials and Procedures	Remember Deficit	Know Deficit	Know Benefit	Recollection Deficit	Familiarity Deficit	Included in Reanalysis
Bonner-Jackson <i>et al.</i> (14)	RKN	n = 15/18	fMRI scanning during incidental or intentional encoding of words	*					X
Danion <i>et al.</i> (10)	RKN	n = 25/25	Physical objects paired by self or experimenter at encoding	*		*			X
Danion <i>et al.</i> (23)	RKN	n = 24/24	Emotional and neutral words	*		*	*	*	X
Drakeford <i>et al.</i> (13)	RKN	n = 16/14	Auditory sentences	*		*			X
Edelstyn <i>et al.</i> (12)	RKN	n = 16/10	Faces and words; 2 schizophrenia patients with delusional misidentification not included in this reanalysis	*		*			X
Grillon <i>et al.</i> (24)	RKN	n = 24/24	Words that are read, repeated, or refreshed at encoding		*				X
Grillon <i>et al.</i> (16)	RKN	n = 25/25	Words that are read, repeated, or refreshed at encoding	*					X
Guillaume <i>et al.</i> (28)	PD	n = 20/20	Emotional faces paired with background scenes at encoding; inclusion phase: "Old" to any face seen previously; exclusion phase: "Old" only to faces with identical expression and background to encoding					*	X
Huron <i>et al.</i> (17)	RKN	n = 30/30	High- and low-frequency words	*					
Huron <i>et al.</i> (21)	RKN	n = 24/24	Words and pictures	*					X
Huron and Danion (11)	RKN	n = 30/30	Semantically related words (e.g., [65,66])	*					X
Martin <i>et al.</i> (22)	RKN	n = 24/25	Faces and words; same, similar, or new stimuli at retrieval	*	*				X
Neumann <i>et al.</i> (18)	RKN	n = 20/20	Positive and negative emotional pictures	*		*			
Ragland <i>et al.</i> (25)	ROC	n = 19/20	fMRI scanning during words presented 3 at a time with, item-specific (rehearse) or relational (reorder) encoding				*	*	X
Ragland <i>et al.</i> (26), Experiment 1	ROC	n = 74/104	Pictures encoded either alone (living/nonliving judgment) or in pairs (size judgment)				*	*	X
Ragland <i>et al.</i> (26), Experiment 2	ROC	n = 64/49	Words encoded either alone (living/nonliving judgment) or in pairs (size judgment)				*	*	X
Sonntag <i>et al.</i> (20)	RKN	n = 21/21	Words, instructed to either remember or forget at encoding						X
Tendolkar <i>et al.</i> (19)	RKN	n = 14/14	ERP recording during retrieval of words	*		*			
Thoma <i>et al.</i> (27)	ROC	n = (11/11)/11	Words; patient group divided into high and low negative symptoms groups				*	*	X
van Erp <i>et al.</i> (15)	RKN	n = 35/35	Word-picture pairs	*		*	*		X

For remember-know-new (RKN) studies that calculated recollection and familiarity estimates, recollection and familiarity results are reported in addition to response proportion results. Inclusion criteria for RKN studies in the reanalysis were reported mean response proportions for each group for "remember," "know," and "new" responses.

ERP, event-related potential; fMRI, functional magnetic resonance imaging; HV, healthy volunteers; PD, process dissociation procedure; PT, patients; ROC, receiver operating characteristic.

\*Effect of schizophrenia originally reported as statistically significant ( $p < .05$ ). X denotes studies that were included in the quantitative reanalysis.

and five (all RKN) indicated that familiarity was increased rather than decreased (10,12,13,18,19) in patients with schizophrenia. These mixed conclusions with regard to familiarity might reflect the fact that there is more heterogeneity in the effects of schizophrenia on familiarity versus recollection. Alternatively, these mixed results might arise due to differences in the manner in which the familiarity estimates have been derived across these different studies.

Methodological variability in familiarity estimation has been particularly marked in studies with the RKN procedure. Many studies of schizophrenia that used the RKN procedure have estimated effects on familiarity by simply comparing the proportion of “know” responses between patient and control groups. One problem with this approach is that the proportion of “know” responses does not take into account that “remember” responses can also be associated with some degree of familiarity (39). Another issue is that a “know” response can only be given to an item that has not received a “remember” response, so a reduction in “remember” responses could spuriously inflate the proportion of “know” responses. Thus, it is possible that previous studies of schizophrenia using the RKN procedure either under- or over-estimated familiarity-based recognition in schizophrenia. In addition, some but not all studies have accounted for response bias with signal detection-based models. Response bias incorporation is critical, because response bias often differs between healthy individuals and patients with schizophrenia (40) and could therefore spuriously impact group differences in memory parameter estimates.

In the current review, we attempted to obtain a more definitive understanding of the relative impact of schizophrenia on recollection and familiarity by taking a consistent and systematic approach to characterizing recollection and familiarity across studies of recognition memory in schizophrenia. We performed, as in a prior study of amnesic patients (41), a summary reanalysis of group means reported in the RKN, ROC, and PD literature to obtain comparable recollection and familiarity estimates across studies. We predicted that reanalysis of RKN findings would reveal both recollection and familiarity deficits in schizophrenia patients, consistent with the pattern seen in studies using ROC and PD methods.

## Methods and Materials

### Literature Search

We reviewed 19 published journal articles examining recollection and familiarity in schizophrenia with any of three different recognition memory paradigms: RKN ( $n = 15$ ), PD ( $n = 1$ ), and ROC ( $n = 3$ ) (Table 1). A PubMed search was conducted to identify studies using any of these paradigms to compare recognition memory between patients diagnosed with schizophrenia or schizoaffective disorder and matched healthy control subjects. Search terms were “schizophrenia” with any of the following: “recollection,” “familiarity,” “remember,” “know,” “process dissociation,” or “receiver operating characteristic.” Studies employing these paradigms to test cued recall or autobiographical memory were excluded. Reference lists of included studies were also reviewed for relevant studies not detected in the original database search. This search yielded 12 RKN studies that reported proportions of hits and false alarms for studied (old) and unstudied (new) items receiving “remember” and “know” responses and could therefore be included in the reanalysis, along with the PD and ROC studies (Table 1).

### Quantification of Recollection and Familiarity Effects Across Studies

For each of the RKN studies, summary estimates of recollection and familiarity (Table 1) were calculated for each group (schizophrenia patients and healthy control subjects). When multiple experimental conditions were tested within a study, behavioral measures were averaged across condition, resulting in one recollection and one familiarity estimate for each group/study. Reanalysis of RKN studies yielded recollection and familiarity estimates scaled as probabilities, which are comparable to estimates derived from PD calculations. However, for ROC studies, only recollection is scaled as a probability, whereas familiarity is estimated with signal detection measure  $d'$ . To eliminate scaling differences between studies and allow for direct comparison between recollection and familiarity,  $d'$  estimates obtained from ROC studies were converted into probabilities as follows: the average false alarm rate (across groups) for a particular study was subtracted from the hit rate corresponding to the  $d'$  score of each group (42,43). It should be noted that the use of average false alarm rate was arbitrary and did not impact between-groups effects, because it was applied identically to each group. One ROC study (26) presented results from two independent samples, yielding two sets of recollection and familiarity estimates.

Reanalysis provided estimates of recollection and familiarity for each group but no measures of within-group variance for each study, precluding the use of standard meta-analytic procedures to draw statistical inferences across studies. However, six studies (3 ROC, 1 PD, 2 RKN) reported group means and variability measures for recollection and familiarity estimates that were obtained according to the computational procedures in the following text (15,23,25–28). Therefore, to estimate the effects of schizophrenia on each process, effect sizes (Cohen's  $d$ ) were calculated for each of these six studies, averaged across experimental condition, separately for recollection and familiarity.

### Computational Procedures

**RKN Studies.** Recollection is calculated on the basis of accurate “remember” responses, correcting for “remember” false alarm rate, as follows:

$$\text{Recollection} = (R_{\text{old}} - R_{\text{new}})/(1 - R_{\text{new}})$$

where  $R_{\text{old}}$  is the proportion of “remember” responses to previously studied items and  $R_{\text{new}}$  is the proportion of “remember” responses to nonstudied items.

To account for response non-independence, the proportion of “know” responses must be divided by the proportion of trials in which a “know” response could have been made (i.e., when a “remember” response was not made). Thus, familiarity is calculated for both old and new items as follows:

$$F_{\text{old}} = K_{\text{old}}/(1 - R_{\text{old}})$$

$$F_{\text{new}} = K_{\text{new}}/(1 - R_{\text{new}})$$

and overall familiarity, correcting for false alarms is estimated as:

$$\text{Familiarity} = F_{\text{old}} - F_{\text{new}}$$

**PD Studies.** In the inclusion condition, an old item can be correctly recognized as old if it is recollected or if it is sufficiently familiar. Therefore, in the inclusion condition, the probability of responding “old” to an item that was previously seen can be represented by:

$$P(\text{“old”}|\text{old})_{\text{inc}} = \text{Recollection} + (1 - \text{Recollection}) \times \text{Familiarity}$$



**Table 2.** Effect Sizes of Schizophrenia on Recollection and Familiarity

Study	Study Type	Recollection	Familiarity
Danion <i>et al.</i> (23)	RKN	−1.86	−.48
van Erp <i>et al.</i> (15)	RKN	−.72	−.20
Guillaume <i>et al.</i> (28)	PD	−.59	−.91
Thoma <i>et al.</i> (27)	ROC	−1.67	−.79
Ragland <i>et al.</i> (25)	ROC	−.63	−.92
Ragland <i>et al.</i> (26), Experiment 1	ROC	−.90	−.55
Ragland <i>et al.</i> (26), Experiment 2	ROC	−.60	−.43

Cohen's *d* was calculated on group means and SDs, averaged across conditions, reported in six studies that obtained recollection and familiarity estimates according to the computational procedures detailed in the Methods section. Negative effect sizes reflect patient deficits. Abbreviations as in Table 1.

### Recollection and Familiarity Across Studies

To investigate the consistency of group differences in recollection and familiarity across studies, we examined difference scores for each test procedure. When group differences (patient – control) in recollection were calculated, the average difference was −.20 across reanalyzed RKN studies, −.18 across ROC studies, and −.08 for the PD study. For familiarity, the average patient-control difference was −.08 for reanalyzed RKN studies, −.14 for ROC studies, and −.12 for the PD study. Additionally, we calculated effect sizes (Cohen's *d*) for each of the studies that estimated recollection and familiarity following recommended computational methods, as detailed in Computational Procedures. As can be seen in Table 2, effect sizes of schizophrenia on recollection were large (−.9 to −1.86) in three studies (23,26,27) and medium (−.59 to −.72) in four studies (15,25,26,28), whereas effect sizes on familiarity were medium to large (−.79 to −.92) in three studies (25,27,28) and small to medium (−.20 to −.55) in four studies (15,23,26).

### Discussion

The dominant hypothesis in the recognition memory literature on schizophrenia has been that recollection is selectively impaired relative to familiarity (10–19,23). In the current article, we reviewed 19 studies of recollection and familiarity in schizophrenia and found that this hypothesis has primarily been driven by RKN studies, whereas studies using PD and ROC procedures suggested deficits in both retrieval processes. To help resolve these discrepancies, we performed a summary reanalysis to obtain computationally comparable estimates of recollection and familiarity across different study procedures, while taking into account potential confounds such as response non-independence and response bias. With application of these methods, a more consistent pattern of results was observed. In agreement with previous ROC and PD studies and contrary to studies using RKN methods, reanalysis of the data revealed that schizophrenia affects both retrieval processes.

### Nature of Recognition Impairments in Schizophrenia

It is widely acknowledged that individuals with schizophrenia have difficulty recollecting contextual details of study events, as reflected by poor performance on source memory tasks (e.g., [45]) and a reduced proportion of “remember” responses during RKN testing (10–19,23). In contrast, these studies have suggested that familiarity is either intact or at least relatively preserved, because patients typically report an equal or greater number of “know” responses compared with healthy control subjects. As

noted earlier, however, the rate of “know” responses does not adequately measure familiarity, because “remember” and “know” responses are non-independent and because familiarity would be expected to contribute to both “know” and “remember” responses. When these factors were accounted for (Figure 1), deficits in both familiarity and recollection were evident. This finding suggests a new interpretation of previous studies of schizophrenia that used the RKN procedure: because “remember” responses are often associated with recollection and a high degree of familiarity, previously documented reductions in “remember” responses in patients with schizophrenia are indicative of deficits in both recollection and familiarity (46).

Although our current findings emphasize that both recollection and familiarity are impacted by schizophrenia, results of the reanalysis also align with previous conclusions that recollection is strongly impacted. Across studies, recollection deficit effect sizes were large or medium, compared with mostly medium- or small-sized effects on familiarity, with the magnitude of effect sizes appearing larger for recollection than for familiarity in all but three of the examined studies. The familiarity impairment was also less consistent, with approximately a quarter of studies suggesting either a small familiarity impairment or a slight familiarity advantage in patients. In contrast, all studies revealed a recollection deficit (Figure 1).

### Putative Neural Underpinnings of Recollection and Familiarity Deficits in Schizophrenia

Previous neuroimaging and focal lesion studies have demonstrated that regions within the MTL and prefrontal cortex (PFC) played a critical role in recollection and familiarity components of recognition memory performance. Within the MTL, functional imaging and lesion studies in humans have consistently demonstrated that the hippocampus is critical for the encoding and retrieval of the contextual details necessary for successful recollection (31–33,42,47,48). This conclusion has been supported by animal lesion studies in rats and monkeys employing recollection-like memory paradigms (33,49–52). In contrast, functional imaging and focal lesion studies have demonstrated that familiarity can be supported by the PRC without hippocampal involvement (33,42,48,51,52). Within the PFC, it is unclear whether different subregions might differentially support recollection and familiarity, but available evidence suggests that the PFC is critical for both processes, particularly when control of strategic memory processes is important for task performance (43,53–56). On the basis of the results of our review, we hypothesize that recollection and familiarity impairments in schizophrenia do not solely reflect disruption limited to the hippocampus, because selective hippocampal dysfunction would not yield familiarity deficits across studies. Instead, it is likely that dysfunction in other areas, including the PFC (57) and PRC (58–60), additionally contribute to memory deficits in schizophrenia by affecting familiarity.

### Study Limitations and Future Implications

Although RKN, PD, and ROC paradigms can yield quantitatively comparable recollection and familiarity effects, each of these procedures has different methodological limitations to consider for future studies of recognition memory in schizophrenia. A potential limitation of both PD and RKN methods is that they are procedurally complex and metacognitively demanding, raising concerns about their implementation in schizophrenia patients with known metacognitive deficits (40,61). Although metacognition is also required for making the confidence judgments required by the



ROC procedure, reliable confidence ratings can be obtained in children as young as age 6 (62), and our previous research has shown that patients with schizophrenia can generate appropriate response distributions to permit successful modeling of recollection and familiarity estimates (26).

Although reanalysis of previous study data increased the consistency of group difference results, there was still marked variability in the pattern of effects across studies. Although too few studies of recollection and familiarity in schizophrenia currently exist to draw strong conclusions, it is likely that procedural differences—both at encoding and retrieval—contributed to discrepancies in effects across studies within each method. For instance, within the ROC studies, one study used intentional encoding and a list discrimination procedure at retrieval (27), whereas the other studies used incidental encoding and subjective recollection judgments at retrieval (25,26). It is also possible that sample differences might account for some of the variability in results across studies. For example, several studies have shown that both recollection and familiarity might be affected similarly by cognitive factors such as IQ (27) and clinical factors such as the severity of negative but not positive symptoms (25,27). Examination of individual difference factors should be an important component of any future large-scale study of recollection and familiarity in schizophrenia.

Characterizing recollection and familiarity deficits in schizophrenia might lead to better-targeted treatment for memory impairments in the disorder. For instance, because familiarity deficits seem to have small-to-medium rather than medium-to-large effect sizes, familiarity might be better-treated as a compensatory process during cognitive training, in which patients learn strategies to increasingly rely on familiarity strength to improve overall memory performance. However, increased reliance on familiarity is not likely to fully overcome episodic retrieval deficits of patients. Therefore, it will also be important to develop new pharmacological and cognitive training procedures aimed at improving recollection. These recollection training procedures are already being developed for healthy aging and mild cognitive impairment individuals and hold promise for translation to individuals with schizophrenia (63,64).

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