Schizophrenia Research: Cognition 4 (2016) 24–31

Contents lists available at ScienceDirect

Schizophrenia Research: Cognition

journal homepage: http://www.schizrescognition.com/

Effectiveness of fast mapping to promote learning in schizophrenia

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ARTICLE INFO

Article history:
Received 6 October 2015
Received in revised form 18 February 2016
Accepted 26 April 2016
Available online 17 May 2016

Keywords:
Schizophrenia
Fast mapping
Incidental learning
Explicit encoding
Memory
Medial temporal lobe

ABSTRACT

Fast mapping (FM), a process that promotes the expeditious incidental learning of information, is thought to support rapid vocabulary acquisition in young children through extra-medial temporal lobe (MTL) regions. A recent study suggested that patients with MTL damage resulting in profound amnesia were able to learn novel word–image associations using an FM paradigm. The present study investigated whether FM would be an effective strategy to promote learning for individuals with schizophrenia, a severe mental illness associated with compromised MTL functionality. Twenty-five patients with schizophrenia and 27 healthy control subjects completed trials of incidental FM encoding (experimental condition) and explicit encoding (EE, control condition) over the course of three visits spaced one week (±2 days) apart. All participants were evaluated for recognition 10 min after each encoding condition was presented, and again one week (±2 days) later. Results indicate that both groups performed better on the EE recognition trials when compared to FM (p's < 0.05). For the FM recognition trials, both groups performed similarly. However, participants with schizophrenia performed significantly worse on the EE recognition trials than healthy control participants (p's < 0.05). While participants with schizophrenia did not perform significantly worse when assessed for FM recognition, these results do not provide enough evidence to suggest that FM facilitates learning to a greater extent in schizophrenia when compared to EE. Whether FM may benefit a subgroup of patients with schizophrenia remains a focus of further investigation.

1. Introduction

Hippocampal abnormalities are involved in the pathophysiology of schizophrenia, as evident from postmortem and in vivo neuroimaging research studies (Baaré et al. 2001; Csernansky et al., 2002; Goldman et al., 2008; Harrison 2004; Heckers and Konradi 2014; Karnik-Henry et al., 2012; Ongur et al. 2006; Rowland et al. 2010). Compromised hippocampal function contributes to learning and memory deficits commonly observed with this illness, as well as compromised performance on hippocampal-dependent behavioral tasks translated from rodent paradigms (Hanlon et al., 2006; Spieker et al., 2012; Spieker et al., 2013; Titone et al., 2004). Strategies to improve memory function in schizophrenia are of clinical significance, as poor memory function is associated with poorer functional outcomes (Sheffield et al., 2014). One strategy that has shown promise in patients with hippocampal amnesia is fast mapping.

Fast mapping (FM) paradigms were first utilized in the late 1970's by researchers seeking to determine whether young children could formulate lexical representations after limited exposure to novel words (Carey 2010). In research conducted by Carey and Bartlett (1978), an FM paradigm was used to see if the word "chromium" could be added to the vocabulary of children incidentally. Children who participated were asked to hand the researcher a "chromium" tray (the tray was olive green in hue) in a conversational context. The hope was that children would learn that the term "chromium" described the color of the tray. Over half of the children in this study displayed evidence that this term had been added to their lexicon when assessed one week later (Carey 2010). In the context of the current study, FM refers to a method of incidental, exclusion-based learning of a novel word–image pair. A word and two images were shown and based on prior knowledge, participants had to deduce that novel words referred to images they were also unfamiliar with.

FM paradigms have been used to examine whether acquisition of novel word–image pairs can be facilitated for amnesiac patients with hippocampal damage, as FM is thought to be dependent on extra-hippocampal neural structures. Thus far, conflicting results have been reported (Sharon et al., 2011; Smith et al., 2014). In a study by Sharon et al. (2011), four amnesiac patients performed better than chance

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http://dx.doi.org/10.1016/j.scog.2016.04.003

level on the FM task and retained novel word–image associations when assessed for recognition one week later. In contrast, performance level was less than chance when using an explicit encoding (EE) strategy. "New learning" demonstrated by these patients with hippocampal amnesia constituted the first report in amnesia literature of patients rapidly acquiring novel word–image associations using an FM paradigm (Smith et al., 2014).

The goal of this study was to investigate whether FM could be a beneficial learning strategy for individuals with schizophrenia. To our knowledge, this is the first study to investigate the effectiveness of FM in this population as a means of facilitating acquisition of novel word–image pairs. We hypothesized that FM would facilitate learning more effectively than an EE paradigm for the schizophrenia group, but not for the healthy control group.

2. Methods

2.1. Participants

A total of fifty-two participants completed this study. 25 were participants with schizophrenia (16 male, 9 female; mean age = 37.64, age range = 18–58), and twenty-seven were healthy control participants (15 male, 12 female; mean age = 33.59, age range = 18–59). See Table 1 for participant characteristics. All study procedures were approved by the Institutional Review Board (IRB) at the University of Maryland, Baltimore. Participants in the schizophrenia group were evaluated for comprehension of consent documents, and all participants gave written informed consent before study procedures were implemented. Participants were monetarily compensated for their time.

Inclusion/exclusion criteria for the schizophrenia group were as follows: (1) age range between 18 and 60 years, (2) a DSM-IV diagnosis of schizophrenia or schizoaffective disorder, (3) competency to sign an informed consent document, (4) no current substance abuse or dependence, (5) not currently pregnant or nursing, (6) No major medical illness or medication that affects brain structure other than that for schizophrenia. Inclusion/exclusion criteria for the psychiatric control group were as follows: (1) age range between 18 and 60 years, (2) no DSM-IV Axis I disorder as determined by the Structural Clinical Interview for DSM-IV Patient Version (First et al., 2002), (3) no current substance abuse or dependence, (4) not pregnant or nursing, (5) no major medical illness or medication that affects brain structure.

Table 1
Subject demographic characteristics.

	Schizophrenia (n = 25)	Controls (n = 27)
Age (years)	38.76 ± 13.01	33.59 ± 14.91
Gender:		
Male	16	15
Female	9	12
Education (years)	12.68 ± 2.06	14.15 ± 1.75
Race:		
Caucasian	14	13
African American	11	12
Asian	0	1
Biracial	0	0
Hispanic/Latino	0	0
MCCB Overall T-Score	32.24 ± 11.68	43.22 ± 10.66
BVMT Raw	18.04 ± 7.79	22.78 ± 6.25
HVLT Raw	20.84 ± 6.33	25.63 ± 5.62
UPSA-2 (Total)	89.36 ± 15.63	102.85 ± 7.66
Psychiatric Ratings:		
BPRS (total)	38.36 ± 9.66	–
BPRS (positive)	8.24 ± 4.64	–
BPRS (negative)	6.8 ± 2.47	–
BNSS	16.68 ± 10.20	–

MCCB: MATRICS Consensus Cognitive Battery; BVMT used to assess short-term visuospatial memory and HVLT used to assess immediate verbal memory.

2.2. Fast mapping and explicit encoding

Over the course of three visits, each spaced one week (± 2 days) apart, all participants completed computerized tasks of FM and EE. During visit 1, all participants completed a practice FM exercise to become familiar with testing procedures. During the self-paced 10-item practice, two images were displayed on the screen at a time. At the bottom of each screen, a question was presented that pertained to the pair of visual stimuli. Participants were required to select their answer choice using the computer keyboard, and feedback was provided after each response.

After the practice session, self-paced FM encoding began. Forty-eight pairs of images were presented. Just as they had during the practice, participants answered questions pertaining to each pair of visual stimuli. Each novel target stimulus was presented two times during the trial, with different accompanying known stimulus. After a 10 min break, FM target categorization accuracy and recognition accuracy were assessed. Participants were first asked to categorize names of target stimuli from the encoding trials by selecting from mammal, fish, flower, or fruit category answer choices. To assess novel target recognition, participants were then shown three images at a time, surrounding the name of a target novel stimulus in the center of the screen. They were asked to point to or tell the tester which image they felt was the best match. Participants then rated their level of confidence in each recognition response from 1 to 5, where 5 indicated the highest level of confidence.

FM target categorization accuracy and recognition accuracy were assessed for a second time one week (± 2 days) later, at the beginning of visit 2. The delayed recognition assessment was formatted identically to the short-term, 10 min delay one. Upon completion of the memory assessment, participants began the control EE task. For EE, participants were instructed to remember the name of each item they were shown. Forty-eight images in total were shown to participants, and each novel target image–word association was shown twice in a randomized order. Mirroring the FM paradigm, there were 10 min and 1 week (± 2 days) delayed recognition assessments for this condition. Visit 3 comprised of the 1 week delay recognition assessment for target stimuli in the EE task, and completion of all remaining study procedures. See Fig. 1 for task illustrations.

2.3. Neuropsychological and cognitive testing

Neuropsychological assessments of memory and functional capacity were conducted for all subjects. The MATRICS Consensus Cognitive Battery (MCCB) was used to provide a measure of general cognitive function for participant characterization (Green et al., 2004; Kern et al., 2008; Nuechterlein et al., 2008). MCCB sub-tests targeting verbal learning (Hopkins Verbal Learning Test) and visual learning (Brief Visuospatial Memory Test) were of particular interest for comparison to the FM and EE memory tasks. The UCSD Performance-Based Skills Assessment (UPSA-2) was used to measure functional capacity of all participants across five domains: organization/planning, financial skills, communication skills, transportation, and household skills (Green et al., 2011). UPSA-2 is a validated tool created to assess community functional capacity in schizophrenia patients (Green et al., 2011).

2.4. Symptom ratings

Participants in the schizophrenia group were evaluated for positive and negative symptom severity with the Brief Psychiatric Rating Scale (Kopelowicz et al., 2008) and the Brief Negative Symptom Scale (Strauss et al., 2012).

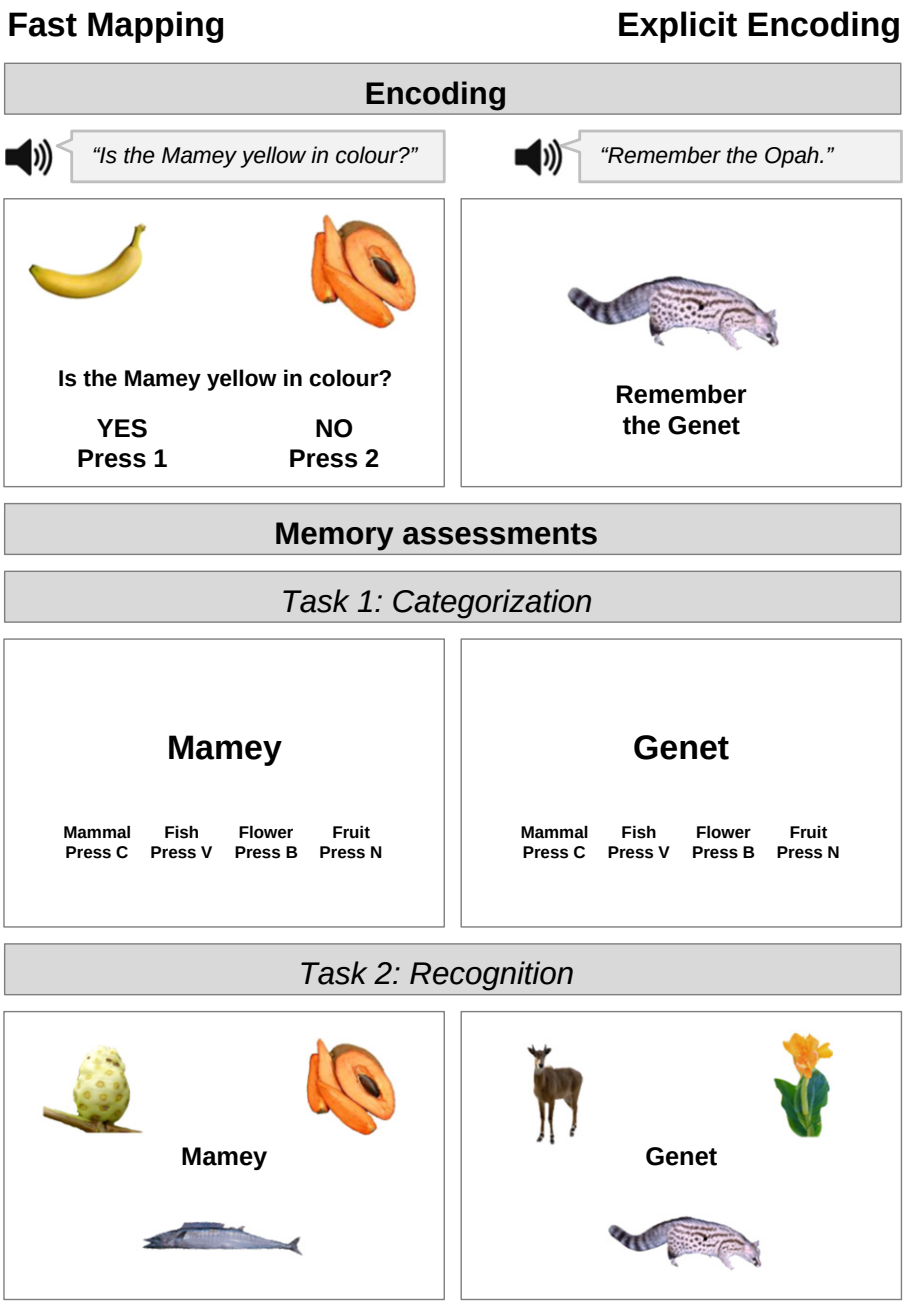

Fig. 1. Illustration of FM and EE tasks. During encoding for both conditions, audio files automatically played in conjunction with on-screen directions.

2.5. Statistical analyses

Demographic variables were analyzed with Chi-square or Fisher's exact tests for categorical data. FM and EE measures were analyzed with a 2 (diagnosis: schizophrenia, control) × 2 (condition: FM, EE) × 2 (delay: 10 min, 1 week) ANOVA. Mean results were carefully described following the omnibus test results irrespective of the significant outcome in order to comprehensively describe patient versus control performance. The relationships between FM and EE task performance, psychiatric symptom severity, and performance on MCCB memory tasks were examined with Pearson's correlations. The significance level was set to $p < 0.05$.

3. Results

3.1. Recognition accuracy

Results of the omnibus test for recognition accuracy revealed main effects of diagnosis ($F = 7.7$, $p = 0.008$), condition ($F = 32.0$, $p < 0.001$), and delay ($F = 5.4$, $p = 0.024$). These results indicated that controls performed better than participants with schizophrenia overall. Both groups performed better overall in the EE versus FM condition and in the 10 min delay versus the 1 week delay. There were no statistically significant interactions (all p's > 0.05).

3.1.1. Fast mapping

There were no statistically significant differences between groups for the FM recognition trials at either time point (Fig. 2*A*). During the 10 min delay recognition trial, performance of control participants (0.54 ± 0.23) was marginally higher than that of the schizophrenia group (0.45 ± 0.25); $t = 1.42$, $p = 0.162$. One week later, recognition accuracy decreased for both groups, and there were no significant between-group differences. The control group recognition accuracy (0.49 ± 0.20) was similar to that of the schizophrenia group (0.43 ± 0.20); $t = 1.003$, $p = 0.321$.

3.1.2. Explicit encoding

The schizophrenia group performed significantly worse than control participants on the EE recognition tasks (p's < 0.05) (Fig. 2*B*). In the 10 min delay trial, the control group accurately recognized significantly more novel stimuli (0.80 ± 0.16) than the schizophrenia group (0.58 ± 0.27); $t = 3.624$, $p = 0.001$. In the 1 week delayed recognition task, the control group accurately recognized significantly more target stimuli (0.69 ± 0.20) than the schizophrenia group (0.58 ± 0.18); $t = 2.048$, $p = 0.046$.

3.2. Categorization accuracy

Results of the omnibus test for categorization accuracy revealed a significant condition × delay interaction ($F = 4.7$, $p = 0.034$) and significant main effect of diagnosis ($F = 7.9$, $p = 0.007$). These results indicated that controls performed better than participants with schizophrenia overall. Both groups combined performed better in the EE versus FM condition, but the decline from 10 min delay to 1 week delay was larger in the EE condition compared to the FM condition.

3.2.1. Fast mapping

For FM, categorization accuracy was not statistically significantly different between groups (Fig. 3*A*). At the 10 min delay, the control group performed better (0.40 ± 0.17) than the schizophrenia group (0.35 ± 0.19); $t = 1.11$, $p = 0.272$. One week later, categorization performance of the control group was still better (0.39 ± 0.17) when compared to the schizophrenia group (0.34 ± 0.21); $t = 0.968$, $p = 0.338$.

3.2.2. Explicit encoding

For EE, categorization accuracy was significantly higher for the control group than the schizophrenia group at both time points (Fig. 3*B*). During the 10 min delay recognition task, the control group accurately categorized significantly more stimuli (0.62 ± 0.20) than the schizophrenia group (0.45 ± 0.16); $t = 3.531$, $p = 0.001$. One week later, the control group categorized more target stimuli correctly (0.50 ± 0.17) than the schizophrenia group (0.39 ± 0.17); $t = 2.36$, $p = 0.022$.

3.3. Confidence ratings for recognition responses

Results of the omnibus test [diagnosis × condition × delay × response (correct/incorrect)] for confidence ratings revealed a significant diagnosis × condition interaction ($F = 5.6$, $p = 0.023$), a significant condition × delay interaction ($F = 6.2$, $p = 0.017$) and a significant condition × response interaction ($F = 7.5$, $p = 0.009$). These results indicated that controls' confidence ratings were significantly higher for EE recognition responses versus FM, whereas participants with schizophrenia reported similar levels of confidence in their responses to EE and FM recognition assessment items. Both groups combined had higher confidence ratings in their EE recognition responses versus FM, but EE confidence ratings declined more from the 10 min to the 1 week delay when compared to FM recognition confidence ratings. Lastly, both groups combined had higher confidence ratings for correct versus incorrect responses, but correct response EE confidence ratings declined more from correct to incorrect responses when compared to FM ratings.

3.3.1. Fast mapping

There were no statistically significant between-group differences in confidence ratings for correct or incorrect responses to recognition accuracy items assessing target FM stimuli during the 10 min or 1 week delay recognition assessments (all p's > 0.3).

3.3.2. Explicit encoding

During the 10 min delay recognition assessment, the control group reported a higher level of confidence in correct responses (4.14 ± 0.57) than the schizophrenia group (3.5 ± 1.2); $t = 2.41$, $p = 0.02$.

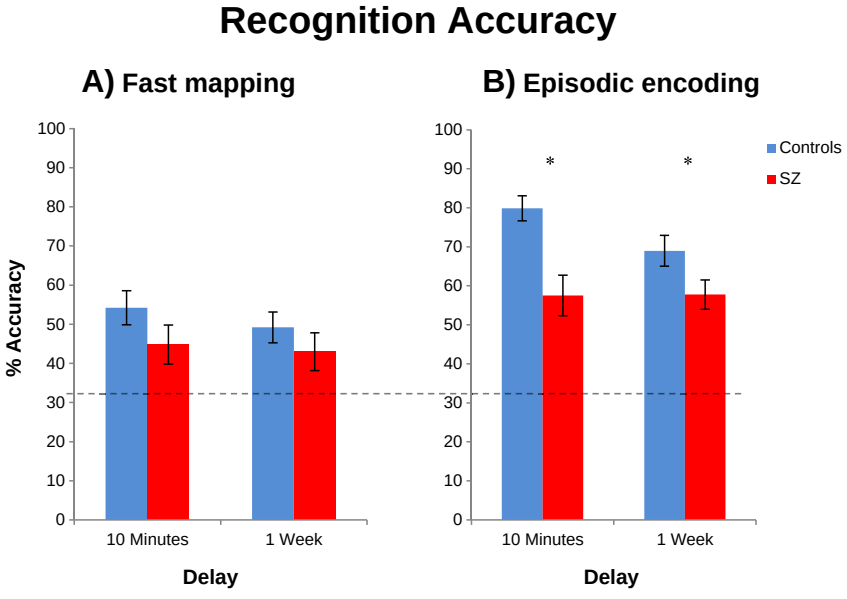

Fig. 2. Group differences in recognition accuracy for SZ and control groups at 10 min and 1 week delay time points for fast mapping (*A*) and episodic encoding (*B*). The horizontal line is representative of chance performance (33%) and the error bars represent standard error. Significant group differences in performance were present for EE at both time points. (*p's < 0.05).

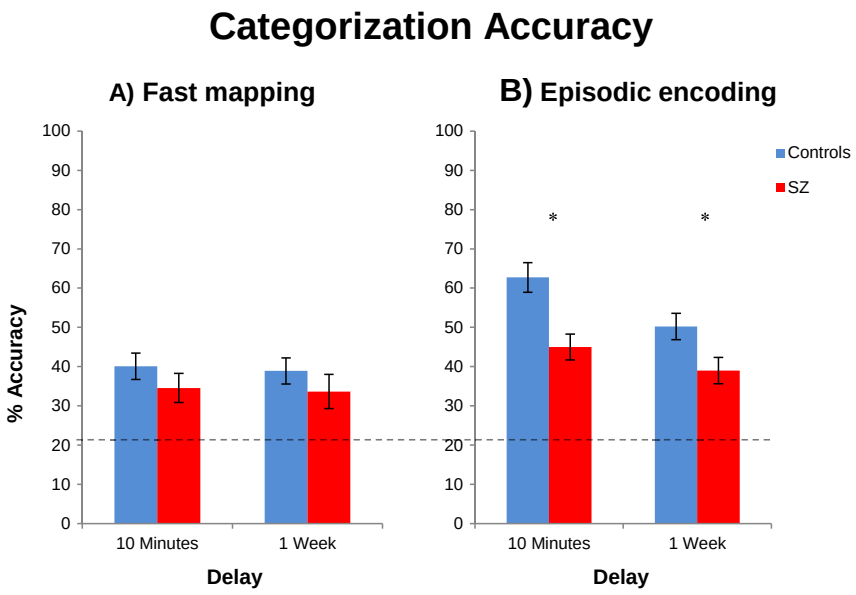

Fig. 3. Group differences in categorization accuracy for SZ and control groups at 10 min and 1 week delay time points for fast mapping (*A*) and episodic encoding (*B*). The horizontal line is representative of chance performance (25%). No significant group differences were present for fast mapping (*A*) at either time point, but statistically significant group differences were present at both time points for EE such that controls accurately categorized a higher percentage of target stimuli. (*p's > 0.05).

There were no significant differences between the groups during the 1 week delay assessment, or when comparing confidence in incorrectly reported responses (all p's > 0.3).

3.4. Neuropsychological and cognitive measures

FM encoding performance did not significantly correlate with composite MCCB scores for the control or schizophrenia groups at either time point (see tables 2-3).

For the control group, total composite scores on the MCCBwere significantly correlated with performance on EE recognition tasks such that higher overall MCCB scores were related to higher EE recognition accuracy at the 10 min ($r = 0.567$, $p = 0.002$) and the 1 week delay time points ($r = 0.447$, $p = 0.019$). For the schizophrenia group, total composite scores on the MCCB were also significantly correlated with performance on EE recognition tasks. Better performance on 10 min ($r = 0.595$, $p = 0.002$) and 1 week delay ($r = 0.566$, $p = 0.002$) EE recognition trials was related to higher overall MCCB scores.

The relationship between visuospatial memory function and performance on FM and EE recognition assessments was also examined. In the schizophrenia group, higher accuracy on the 10 min delay FM recognition trial was significantly correlated with better performance on the BVMT ($r = 0.418$, $p = 0.037$). This effect was not observed in the control group, and there was no significant correlation between BVMT scores and FM performance for either group when assessed 1 week later. Higher scores on the BVMT were significantly correlated with better performance on the 10 min delay EE recognition trial for both the control ($r = 0.501$, $p = 0.008$) and schizophrenia ($r = 0.638$, $p = 0.001$) groups. This effect was no longer present when the groups were evaluated one week later.

Higher overall UPSA-2 scores were significantly correlated with higher recognition accuracy in the 10 min delay EE recognition assessment in both the control ($r = 0.455$, $p = 0.017$) and schizophrenia ($r = 0.634$, $p = 0.001$) groups. For the schizophrenia group only, overall UPSA-2 scores were also significantly correlated with FM categorization accuracy during the 10 min delay recognition trial ($r = 0.476$, $p = 0.016$) and EE categorization accuracy during the 10 min delay recognition trial ($r = 0.407$, $p = 0.043$).

3.5. Psychiatric symptom ratings

Positive or negative symptom severity in the schizophrenia group, as evaluated with the BPRS and BNSS, did not significantly correlate with performance on the FM recognition trials. BPRS negative symptom scores correlated with EE 10 min delay recognition accuracy results such that higher negative symptom scores were correlated with decreased performance ($r = -0.41$, $p = 0.042$).

Table 2
Healthy control group means and standard deviations for FM and EE performance; correlation matrix with overall MCCB scores and select measures.

	M	SD	Correlations					
			1	2	3	4	5	6
1. FM 10-min recognition accuracy	0.54	0.23						
2. FM 1-week recognition accuracy	0.49	0.21	0.41*					
3. EE 10-min recognition accuracy	0.80	0.17	0.14	0.12				
4. EE 1-week recognition accuracy	0.69	0.21	0.15	0.02	0.55**			
5. MCCB total	43.22	10.66	0.08	−0.04	0.57**	0.45*		
6. HVLT	25.63	5.62	0.09	−0.06	0.63**	0.48*	0.73**	
7. BVMT	22.78	6.25	0.26	0.03	0.50**	0.32	0.60**	0.45*

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Table 3
Schizophrenia group means and standard deviations for FM and EE performance; correlation matrix with overall MCCB performance and select measures.

	M	SD	Correlations								
			1	2	3	4	5	6	7	8	9
1. FM 10-min recognition accuracy	0.45	0.25									
2. FM 1-week recognition accuracy	0.43	0.24	0.69**								
3. EE 10-min recognition accuracy	0.58	0.27	0.21	0.32							
4. EE 1-week recognition accuracy	0.58	0.19	0.43*	0.57**	0.76**						
5. MCCB total	32.24	11.68	0.27	0.35	0.60**	0.57**					
6. HVLT	20.84	6.33	0.35	0.34	0.62**	0.50*	0.64**				
7. BVMT	18.04	7.79	0.42*	0.29	0.64**	0.58**	0.70**	0.68**			
8. BPRS Pos	8.24	4.64	−0.02	−0.20	0.02	0.11	−0.13	−0.19	−0.03		
9. BPRS Neg	6.80	2.47	−0.01	0.12	0.41*	0.16	0.47*	0.59**	0.55**	−0.26	
10. BNSS Total	16.68	10.20	0.18	0.37	0.17	0.13	0.45*	0.45*	0.39	−0.15	0.65**

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

4. Discussion

This study investigated whether FM could facilitate learning and memory in individuals with schizophrenia. Based on findings from research studies on amnesic patients with hippocampal damage (Sharon et al., 2011), we hypothesized that the schizophrenia group would benefit from FM. Since previous studies have shown that schizophrenia patients have compromised hippocampal structure and functionality (Baaré, 2001; Csernansky et al., 2002; Goldman et al., 2008; Karnik-Henry et al., 2012; Ongur et al., 2006; Rowland et al., 2010), we predicted that a hippocampal-independent method of learning like FM would be beneficial to this patient population. While the schizophrenia group did not perform significantly worse on the FM recognition condition compared to the control group, they did not perform better than they had on the EE recognition condition. Therefore, these results do not provide evidence that the FM paradigm facilitated learning above EE in this patient group.

FM performance did not correlate with symptom severity, functional capacity, general cognitive function, or memory function in either the control or schizophrenia group. In contrast, EE performance was related to these measures in both groups except for symptom severity, as ratings were only conducted with the patient group. The significant association between EE recognition accuracy and scores on tests of functional capacity, general cognitive function and memory was not surprising, as these tasks rely on explicit memory circuitry involving the medial temporal lobe.

Our results are consistent with Sharon et al. (2011) in that the patient group performed similarly on the FM condition as the control group. In contrast, our patient group performed better on the EE condition than the FM, whereas the amnesia patient group in Sharon et al. (2011) performed better on FM than EE condition suggesting that the amnesia patient group benefited from FM strategy but our patient group did not. The pattern of better learning with EE than FM is consistent with two recent studies (Greve et al., 2010; Smith et al., 2014). Smith et al. (2014) reported that patients with medial temporal lobe amnesia did not learn with FM or EE, contradicting results produced by Sharon et al. (2011). Possible differences between the two studies that may explain the conflicting findings include the severity of medial temporal lobe damage and memory deficits of individual patients. It is possible that FM may benefit patients with amnesia who exhibit damage specific to the hippocampus and with less severe memory deficits. This partially explains why the majority of patients with schizophrenia in our study, and older healthy participants (Greve et al., 2010), did not benefit from FM above EE. Both schizophrenia and healthy aging are characterized by widespread brain alterations including those in neocortical medial temporal lobe structures (Karnik-Henry et al., 2012; Pantel et al., 2003; Rasetti et al., 2014;), not specific just to the hippocampus.

Nascent findings from Atir-Sharon et al. (2015) suggest that learning through FM in healthy adults may be mediated by the anterior temporal lobe (Atir-Sharon et al., 2015; Merhav et al., 2015), but these findings have not yet been reproduced. Temporal pole alterations in gray matter volume (Gur et al., 2000; Wright et al., 1999), fMRI activation during tasks (Lee et al., 2010), and functional connectivity during resting state (Xu et al., 2015) have been observed in schizophrenia. Temporal pole impairment could provide one explanation for why FM did not facilitate an enhancement in learning and memory in our patient sample.

Six participants (24%) with schizophrenia did perform better on the FM recognition trials when compared to EE recognition. This is not surprising when considering that previous research has highlighted the heterogeneity in learning performance in schizophrenia (Armstrong et al., 2012; Koch et al., 2010; Spieker et al., 2012). Inspection of the means indicated that these participants do not differ in symptom severity but performed worse on verbal memory [16.3 (8.0) vs. 22.3 (5.2)] and general cognitive function [24.0 (7.4) vs. 35.0 (11.7)] measures. Therefore, it is possible that there is a subgroup of patients with schizophrenia with more severe memory impairments that might benefit from FM. Three controls (11%) also performed better on FM compared to EE recognition. Similarly, these control participants had lower verbal memory [26.5 (5.1) vs. 19.0 (6.6)] and general cognitive function [31.0 (7.4) vs. 45.0 (10.1)] measures compared to the control group average. Hence, it is possible that FM may benefit those with very poor explicit memory function. These result trends are intriguing and additional research with a larger sample size is warranted to determine if this is the case.

Explicit memory has been extensively researched in schizophrenia. In general, patients with schizophrenia perform significantly worse than controls on a broad range of explicit memory tasks. There is evidence to suggest that reduced episodic memory can be attributed to abnormal encoding in this clinical population, and it has been suggested that a binding deficit exists between the processing of information pertaining to objects and spatial context (Talamini et al., 2010). Recognition memory is somewhat preserved in this population (Aleman et al., 1999; Talamini et al., 2010). In a meta-analysis of 70 studies by Aleman et al. (1999), patients with schizophrenia performed significantly better on tasks in which retrieval cues were given when compared to tasks of delayed free recall, but performance on both types of memory testing was significantly worse than in comparison healthy control samples.

The study of implicit memory in schizophrenia is not as well understood. Though implicit memory as a whole seems to be unimpaired in this population (Soler et al., 2011), it is important to note that implicit

memory is multidimensional and that there are dissociations between tasks which target different subtypes. Generally, assessments of implicit memory can be broken down into two subgroups: purely perceptual tasks involving study-specific stimuli, and conceptually driven tasks which require participants to understand broader concepts that may require breadth of knowledge surpassing the context of a given task (Soler et al., 2011). Schizophrenia patients perform worse than controls on tasks of probabilistic classification such as the "weather prediction" task (Horan et al., 2008), while performance is similar to that of controls on tests of artificial grammar (Horan et al., 2008), word-fragment completion (Soler et al., 2011) and word stem completion (Soler et al., 2015). The current study introduces fast mapping as an assessment of implicit memory in this population, and serves to extend the current body of literature by providing further evidence that implicit memory is complex and driven by varying mechanisms.

There are study limitations that deserve mentioning. First, patients with schizophrenia were taking antipsychotic medications that could have impacted our results. It is unknown whether dopaminergic antagonists impact mechanisms underlying FM. Secondly, this study did not examine if hippocampal or other brain regions, such as the temporal pole, were related to FM performance. Future studies will incorporate neuroimaging in order to examine which regions mediate FM in patients with schizophrenia.

In conclusion, results from this study indicate that FM does not facilitate learning and memory better than an explicit encoding strategy in schizophrenia. FM may be of benefit to a subgroup but further research is necessary to draw this conclusion.

Role of Funding Source

Our work was supported by National Institute for Mental Health grants T32MH067533 and R01MH094520.

Contributors

S.A.K. and S.J.N. collected all participant data, S.A.K. and B.W.K. performed statistical analyses, S.A.K. and L.M.R. wrote and revised the manuscript. S.J.N., B.W.K., S.A.W. and L.E.H. reviewed the manuscript prior to submission. We would like to thank Drs. Asaf Gilboa and Eve Attali, who graciously provided us with the FM and EE tasks utilized in this study. We would also like to thank all of our participants, especially the patients, for their willingness to take part in our research.

Conflict of Interest

The authors declare no conflict of interest.

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