

# Hits and False Alarms in Recognition Memory Show Differential Impairment in Positive and Negative Schizotypy

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The present study examined the extent to which positive and negative schizotypy are associated with impairment in recognition memory in 3 large samples of nonclinically ascertained adults (total  $n = 826$ ). Schizophrenia is associated with a wide array of cognitive deficits, but the study of cognitive impairment in schizophrenia is confounded by generalized performance deficits related to symptoms and consequences of the disorder, and by failure to separately examine positive and negative symptom dimensions. Schizotypy provides a promising framework for examining these deficits relatively unconfounded by symptoms and sequelae of the disorder. The present study obtained recognition memory deficits in positive and negative schizotypy across verbal and figural stimuli in three different samples. Importantly, although discrimination accuracy is impaired across higher scores on both schizotypy dimensions, the mechanism of impairment differs across positive and negative schizotypy. Negative, but not positive, schizotypy was associated with impaired hit rates, whereas the false alarm rates remained unaffected. In contrast, positive, but not negative, schizotypy was associated with increased false alarm rates despite stable hit rates. The results are discussed from the perspective of a signal-detection theoretic model that accounts for negative schizotypy results through reduced signal mechanism, and accounts for positive schizotypy results through increased noise mechanism. These findings further support the utility of multidimensional schizotypy for assessing and understanding episodic memory impairment in the schizophrenia spectrum.

## General Scientific Summary

Schizophrenia is expressed across a wide range of clinical and subclinical presentations known as schizotypy. People with mild schizophrenic-like characteristics demonstrate subtle patterns of memory impairments that are consistent with, albeit less pronounced than, those seen in patients. Furthermore, different schizotypy dimensions are associated with unique patterns of memory impairment.

*Keywords:* schizophrenia, schizotypy, memory, recognition, signal detection

Schizophrenia is a catastrophic mental illness affecting 1% of the population that involves a broad array of cognitive impairment (American Psychiatric Association, 2013; Tandon, Nasrallah, & Keshavan, 2009). Although traditionally classified as a categorical disorder, current models suggest that schizophrenia represents the most extreme manifestation of a continuum of clinical and sub-

clinical symptoms referred to as schizotypy (e.g., Kwapil & Barrantes-Vidal, 2015; Lenzenweger, 2010). Schizotypy offers a useful and unifying framework for understanding schizophrenia-spectrum psychopathology. Schizotypy and schizophrenia are multidimensional, with positive and negative symptoms the most commonly identified dimensions. Positive schizotypy involves odd perceptual experiences (including hallucinations and illusions), magical and delusional beliefs, and suspiciousness and paranoia. Negative schizotypy involves diminished functioning such as flattened affect, social disinterest and withdrawal, anhedonia, avolition, and alogia. These dimensions can be identified in nonclinical samples and are associated with differential patterns of symptoms and impairment (e.g., Gooding, Tallent, & Matts, 2005; Kwapil, Barrantes-Vidal, & Silvia, 2008).

Questionnaire measures offer a reliable and valid method for assessing positive and negative schizotypy (e.g., Chapman, Chapman, & Kwapil, 1995; Kwapil & Chun, 2015). Cross-sectional and longitudinal studies indicate that high scores on measures of positive and negative schizotypy are associated with schizophrenia-spectrum symptoms and impairment (e.g., Barrantes-Vidal et al., 2013; Kwapil et al., 2008). Positive schizotypy is associated with interview-based reports of psychotic-like, schizotypal, and para-

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noid symptoms, whereas negative schizotypy is associated with interview ratings of schizoid, schizotypal, and negative symptoms. Furthermore, in a 10-year longitudinal assessment, positive schizotypy predicted the development of psychotic disorders, whereas both dimensions predicted schizophrenia-spectrum disorders (Kwapil, Gross, Silvia, & Barrantes-Vidal, 2013).

### Cognitive Impairment in the Schizophrenia Spectrum

Cognitive impairment is a hallmark of schizophrenia and related disorders (e.g., Green & Nuechterlein, 1999; Harvey, 2013; Heinrichs & Zakzanis, 1998). Schizophrenia is associated with impairments in multiple domains of cognition, usually on the order of medium to large effect sizes (e.g., Schaefer, Giangrande, Weinberger, & Dickinson, 2013), and these deficits are associated with impaired functioning (e.g., Bowie & Harvey, 2006). Nevertheless, the study of cognitive impairment in schizophrenia is complicated by the consequences that accompany the disorder (e.g., medication) and symptoms that may result in generalized performance deficits. For example, patients' performance on cognitive tasks may be impaired by medications, presence of hallucinations, motivational deficits, or disorganization. Thus, it can be difficult to determine the extent to which specific cognitive deficits are etiologically relevant to the disorder compared to those that represent sequelae of the disorder. Schizotypy offers a promising platform for examining such cognitive impairments given the continuity between deficits observed in schizophrenia patients and those in subclinical schizotypy, and because it allows for the assessment of cognitive performance relatively unaffected by the consequences of disorder (for reviews, see Chun, Minor, & Cohen, 2013; Ettinger et al., 2015; Nelson, Seal, Pantelis, & Phillips, 2013). However, effect sizes for cognitive impairment are expected to be considerably smaller in subclinical schizotypy than in patients. Our studies revealed that psychometrically assessed schizotypy is associated with schizophrenic-like cognitive impairment, and that it is essential to consider the multidimensional structure of schizotypy in order to enhance precision in detecting smaller effects and to understand these deficits (Sahakyan & Kwapil, 2016, 2018a, 2018b).

### Differential Patterns of Episodic Memory Impairment in Schizotypy

This study focuses on episodic memory deficits, which are reliably documented in schizophrenia (e.g., Aleman, Hijman, de Haan, & Kahn, 1999; Dickinson, Ragland, Gold, & Gur, 2008; Gold, Randolph, Carpenter, Goldberg, & Weinberger, 1992; Meshulam-Gately, Giuliano, Goff, Faraone, & Seidman, 2009; Paulsen et al., 1995; Ranganath, Minzenberg, & Ragland, 2008). Our previous research indicated that dimensions of subclinical schizotypy showed differential patterns of impairment in episodic memory, which could be traced to specific underlying mechanisms. We found impairments in free recall and recognition in negative schizotypy, but not in positive schizotypy (Sahakyan & Kwapil, 2016). Examination of the retrieval dynamics revealed that the impairments stemmed from the context-processing deficits in negative schizotypy (Sahakyan & Kwapil, 2018b). This is consistent with deficits reported in schizophrenia patients with negative symptoms (Barch, Carter, MacDonald, Braver, & Cohen, 2003; Gold et al., 2012; Javitt, Rabinowicz, Silipo, & Dias, 2007; Niendam et al., 2014; Owoso et al., 2013; Richard, Carter, Cohen, & Cho, 2013), but not in patients with positive symptoms

(Barch et al., 2003; Cohen, Barch, Carter, & Servan-Schreiber, 1999; Gold et al., 2012; Javitt et al., 2007; MacDonald & Carter, 2003; Niendam et al., 2014; Owoso et al., 2013). In other tasks, which are explained through the spread of activation of semantic associates, we found deficits in positive, but not in negative schizotypy (e.g., Sahakyan & Kwapil, 2016), thereby demonstrating the differential pattern of episodic memory impairments across the schizotypy dimensions.

Although some of our previous findings were based on an extreme-groups approach with relatively small sample sizes, we replicated many of those results using larger samples with continuous distributions of positive and negative schizotypy across a broad range of scores (Sahakyan & Kwapil, 2018a). However, we have not assessed recognition findings using continuous schizotypy scores. The results with clinical patients indicate that memory deficits in schizophrenic patients are more robust in recall than in recognition (e.g., Aleman et al., 1999; Paulsen et al., 1995). Thus, it is possible that nondisordered schizotypy has deficits in recall, but not necessarily in recognition. The present investigation aimed to examine recognition memory in large samples with continuous distributions of positive and negative schizotypy scores.

### Recognition Memory in Schizophrenia and Schizotypy

Recognition tasks can advance our understanding of the nature of memory deficits in schizotypy because the theories of recognition are among the best established in memory research, and they offer specific explanations about the origins of deficits. Recognition memory refers to the ability to identify previously experienced events encoded into episodic memory. It involves discrimination of events that one experienced in a certain context from events that one did not experience. In the laboratory, recognition is typically investigated by presenting participants with a list of items to study, followed by a test list comprised of items that were studied (targets) intermixed with items that were unstudied (distractors). The participant's task is to discriminate between the targets and the distractors. Correct endorsement of a target is referred to as a "hit," and incorrect endorsement of a distractor is referred to as "false alarm."

Our previous research reported impaired recognition ( $d'$ ) in negative schizotypy, but not in positive schizotypy, although we did not separately evaluate hits and false alarms. Given that  $d'$  is estimated from the joint contribution of hits and false alarms, impaired discriminability could stem from reduced ability to identify old items as having been presented in the experiment (i.e., reduced hits), and/or from increased likelihood of mistakenly endorsing new items as being familiar (i.e., increased false alarms). The specific pattern of hits and false alarms can be informative for the nature of recognition impairment, if such impairment persists when schizotypy is assessed continuously.

Several meta-analyses of recognition performance in schizophrenia consistently confirmed substantial impairment among patients, along with documenting considerable heterogeneity of findings across studies (Achim & Lepage, 2003; Aleman et al., 1999; Heinrichs & Zakzanis, 1998; Pelletier, Achim, Montoya, Lal, & Lepage, 2005). Some studies reported that recognition performance of schizophrenia patients is more affected by hits than false alarms (e.g., Elvevag, Fisher, Weickert, Weinberger, & Goldberg, 2004; Huron & Danion, 2002; Moritz, Woodward, & Rodriguez-Raecke, 2006), whereas others found the opposite (e.g., Weiss, Dodson, Goff, Schacter, & Heck-

ers, 2002). One limitation of these studies is that they did not consider symptom dimensions of the disorder. If hits and false alarms are differentially affected by positive and negative symptoms, it could be one source of the divergent findings in the literature. Among the studies that did consider symptom dimensions, some found that negative symptoms of schizophrenia were associated with poorer overall recognition accuracy (e.g., Aleman et al., 1999; Palmer et al., 1997; Paulsen et al., 1995), whereas others reported significant impairments associated with positive symptoms (e.g., Mahurin, Velligan, & Miller, 1998; Norman et al., 1997). Meta-analysis among schizophrenia patients revealed that both negative symptoms and positive symptoms moderated the effect size for overall recognition accuracy (Pelletier et al., 2005). However, studies often did not assess symptom dimensions or they assessed them as a secondary aspect of studies and may not have had appropriate designs to measure or adequately capture them. Therefore, the purpose of this investigation was to conduct an in-depth examination of hits and false alarms across the continua of positive and negative schizotypy to shed light on the nature of deficits observed in the schizophrenia spectrum. In addition to assessing schizotypy continuously, we included participants tested in the lab and online samples, and we used both verbal and figural stimuli as memoranda for recognition experiments.

## Method

### Participants

The study included three samples. Sample 1 initially recruited 376 participants from Amazon Mechanical Turk (MTurk) online database. To be eligible, participants had to be located in the U.S., and to have a minimum of 95% Human Intelligence Task (HIT) Approval Ratio on MTurk. Research indicates that MTurkers with  $\geq 95\%$  HIT approval ratio score higher on measures of attentiveness compared to participants with lower HIT approval rates (Peer, Vosgerau, & Acquisti, 2014). Note that 40 participants (11%) were dropped from the analyses due to invalid protocols based upon Chapman and Chapman's (1983) infrequency scale (see details below) leaving 336 participants with usable data. Participants were paid \$1.00 for participation. Sample 1 participants included 186 females, 140 males, and 10 who did not report their sex. The average age of participants was  $M = 37.8$  years,  $SD = 11.1$ , with a mean number of years of education  $M = 15.97$ ,  $SD = 2.9$ .

Sample 2 initially recruited 379 MTurk participants, who were recruited 11 months later than Sample 1 participants (note that we imposed an MTurk restriction that prevented Sample 1 participants from participating in the Sample 2 assessment). The eligibility criteria were the same as for Sample 1 participants. In addition, we verified that the worker IDs were different for participants in the two MTurk samples. Note that 66 participants (17%) were dropped from the analyses due to invalid protocols leaving 313 participants with usable data. The higher rate of invalid responders in this MTurk sample than in Sample 1 likely reflects the elevated rate of nonhuman "bot" participants in MTurk that arose around the time Sample 2 was assessed in 2018 (e.g., Stokel-Walker, 2018). Sample 2 participants were 168 females, 131 males, and 14 who did not report their sex. The average age of participants was  $M = 37.5$  years,  $SD = 11.1$ , with a mean number of years of education  $M = 14.8$ ,  $SD = 3.2$ .

Sample 3 initially assessed 194 college students who participated for course credit and were recruited from a psychology department

participant pool. The lab sample was "enriched" in that in addition to any student from participant pool who could sign up, we also invited students who scored at least 1.5  $SD$  above the mean on the positive or negative dimension of schizotypy in a departmental screening that took place approximately one month prior to the assessment. Note that 17 participants (9%) were dropped from the analyses due to invalid protocols leaving 177 participants with usable data. Sample 3 participants were 111 females and 66 males, with an average age  $M = 19.8$  years,  $SD = 1.6$ . The studies were approved by the Institutional Review Board of University of Illinois at Urbana-Champaign.

### Materials

The three samples received different stimuli for the recognition task. Sample 1 studied words, and Samples 2 and 3 studied faces. The words consisted of 80 English nouns that ranged from four to six letters long, and had a median frequency of 59.50, and an interquartile range of 23.25 (according to Kucera-Frances', 1967 widely used word frequency norms). They were randomly divided into two sets of 40 items. Each item in the two sets served equally often as a target item and a distractor item. The faces included 64 colored images of faces, which were cropped from the neck down and shown over a white background. All images were  $400 \times 400$  pixels. They were selected from a larger pool of faces that were previously used in a stimulus evaluation experiment conducted on MTurk (Lewis-Peacock & Norman, 2014). The selected faces had a moderate rating of typicality (range of 2.55–4.35, mean: 3.35), familiarity (range of 3.06–4.10, mean: 3.52), and memorability (range of 3.15–4.17, mean: 3.74). Half of the faces were male and half were female. The faces were comprised of different age groups, and ethnic and racial backgrounds.

### Procedures

All stimuli were presented on the computer screen, one at a time, at a fixed rate. Participants were instructed to learn them for a later test by relying solely on their memory, without writing or copying the stimuli. Sample 1 participants studied 40 words, presented at a rate of 2 s per word. After the last item, participants received a test list, which contained 40 studied words intermixed with 40 new words. They were instructed to press OLD to indicate that the word was presented during the study session, and to press NEW to indicate that the word had not been presented during the study session. Sample 2 and Sample 3 participants studied 32 faces, presented at rate of 4 s per face. After the last item, they received a test list, containing 32 studied faces intermixed with 32 new faces, and were instructed to press OLD or NEW using similar instructions as described above.<sup>1</sup>

Following the recognition test, all three samples completed the Wisconsin Schizotypy Scales-Brief (Winterstein et al., 2011), which are comprised of shortened forms of the Perceptual Aberration (Chapman, Chapman, & Raulin, 1978), Magical Ideation (Eckblad & Chapman, 1983), Physical Anhedonia (Chapman, Chapman, & Raulin, 1976), and Revised Social Anhedonia (Eckblad, Chapman, Chapman, & Mishlove, 1982) Scales. The brief

<sup>1</sup> The minor variations in the list length and presentation rate between words and faces were determined by pilot testing to offset potential ceiling/floor effects and to approximately equate the levels of performance across different stimuli.

Table 1

*Descriptive Statistics for Negative and Positive Schizotypy Factor Scores, Hits, and False Alarms in the Three Samples, and the Combined Sample*

Samples	Negative schizotypy <i>M (SD)</i>	Positive schizotypy <i>M (SD)</i>	Correlation between negative and positive schizotypy	Hits <i>M (SD)</i>	False alarms <i>M (SD)</i>
MTurk-words ( <i>N</i> = 336)	.49 (1.29)	-.05 (1.13)	.27	.63 (.18)	.18 (.16)
MTurk-faces ( <i>N</i> = 313)	.61 (1.33)	-.08 (1.06)	.38	.69 (.18)	.19 (.16)
Lab-faces ( <i>N</i> = 177)	.28 (1.00)	.03 (1.01)	.29	.79 (.11)	.23 (.16)
Combined ( <i>N</i> = 826)	.49 (1.25)	-.05 (1.08)	.31	.69 (.18)	.19 (.16)

versions of the scales have comparable psychometric properties and validity to the original scales (Gross, Silvia, Barrantes-Vidal, & Kwapil, 2012). Two established factors, positive and negative schizotypy, underlie the original (Kwapil et al., 2008) and brief versions of the scales (Gross, Silvia, Barrantes-Vidal, & Kwapil, 2015; Kwapil et al., 2013). Each participant was assigned positive and negative schizotypy factor scores, which were based upon norms from 6,137 college students and were computed following formulae in Gross, Silvia, Barrantes-Vidal, and Kwapil (2015). Note that the scales are widely used, have solid psychometric properties, and the positive and negative schizotypy factors are associated with differential patterns of symptoms and impairment (e.g., Christensen, Kenett, Aste, Silvia, & Kwapil, 2018; Fonseca-Pedrero, Paino, Ortuño-Sierra, Lemos-Giráldez, & Muñiz, 2014; Gross et al., 2012, 2015). Positive and negative schizotypy scores were continuous predictor variables in the present study, consistent with our view of positive and negative schizotypy as continuous constructs. Although some studies employ extreme group designs, there are no conceptually or empirically meaningful cutoffs for the Wisconsin Schizotypy Scales, and the use of arbitrary cut-points tend to reduce power (see MacCallum, Zhang, Preacher, & Rucker, 2002). The 13 items of the Chapman and Chapman infrequency scale were intermixed with the Wisconsin Schizotypy Scale-Brief items to identify invalid responding. Following Chapman and Chapman's (1983) guidelines, participants who endorsed more than two infrequency items were omitted from further study.

## Results

For ease of exposition, Sample 1 will be referred to as MTurk-words, Sample 2 will be referred to as MTurk-faces, and Sample 3 will be referred to as Lab-faces. Descriptive statistics for the negative and positive schizotypy factor scores, their correlation, and the hits and false alarms within each of the three samples is reported in Table 1.

A series of linear regression analyses were computed for each sample assessing hits and false alarms separately. In each of these analyses, the positive and negative schizotypy factor scores were entered simultaneously at the first step, and the Positive  $\times$  Negative Schizotypy interaction term was entered at the second step, in order to examine the interaction over-and-above the main effects. Simple slopes analyses were computed to decompose significant interactions by examining the effect of one predictor at low ( $-1 SD$ ), medium (mean), and high ( $+1 SD$ ) levels of the other predictor. For all regression analyses, beta coefficients, change in  $R^2$ , and effect sizes ( $f^2$ ) are reported. Following Cohen (1992),  $f^2$  values of .15 indicate medium effect sizes and .35 indicate large effect sizes.

The results of all regression analyses are summarized in Table 2. Figure 1 shows regression lines for hits and false alarms as a function of negative schizotypy scores (top panel) and positive schizotypy scores (bottom panel) across the three samples. Within each sample, we observed significantly reduced hit rates as a

Table 2

*Prediction of Memory Performance by Negative Schizotypy, Positive Schizotypy, and Their Interaction*

Samples	Measures	Step 1						Step 2			Total $R^2$
		Negative schizotypy			Positive schizotypy			Negative $\times$ Positive interaction			
		$\beta$	$\Delta R^2$	$f^2$	$\beta$	$\Delta R^2$	$f^2$	$\beta$	$\Delta R^2$	$f^2$	
MTurk-words ( <i>N</i> = 336)	Hits	-.16*	.016	.021	.08	.005	.006	-.10	.009	.009	.027
	False Alarms	-.04	.001	.001	.21***	.042	.044	.09	.008	.008	.050
MTurk-faces ( <i>N</i> = 313)	Hits	-.16**	.022	.023	-.06	.004	.004	-.03	.001	.000	.039
	False Alarms	-.07	.004	.005	.23***	.046	.048	.12	.011	.012	.057
Lab-faces ( <i>N</i> = 177)	Hits	-.27***	.066	.071	.04	.001	.001	.01	.001	.001	.068
	False Alarms	-.02	.000	.000	.16*	.024	.024	.06	.003	.004	.028
Combined ( <i>N</i> = 826)	Hits	-.18***	.029	.030	.03	.001	.001	-.08*	.006	.005	.035
	False Alarms	-.06	.003	.003	.21***	.041	.043	.09*	.007	.007	.048

*Note.* Each row represents a separate regression analysis predicting measures derived from recognition memory performance. Hierarchical regression was used to examine the unique prediction of memory performance by positive and negative schizotypy, and Positive  $\times$  Negative Schizotypy interaction. For each predictor, the standardized regression coefficient ( $\beta$ ), change in R-square, and effect size ( $f^2$ ) are reported.

\*  $p < .05$ . \*\*  $p < .01$ . \*\*\*  $p < .001$ .

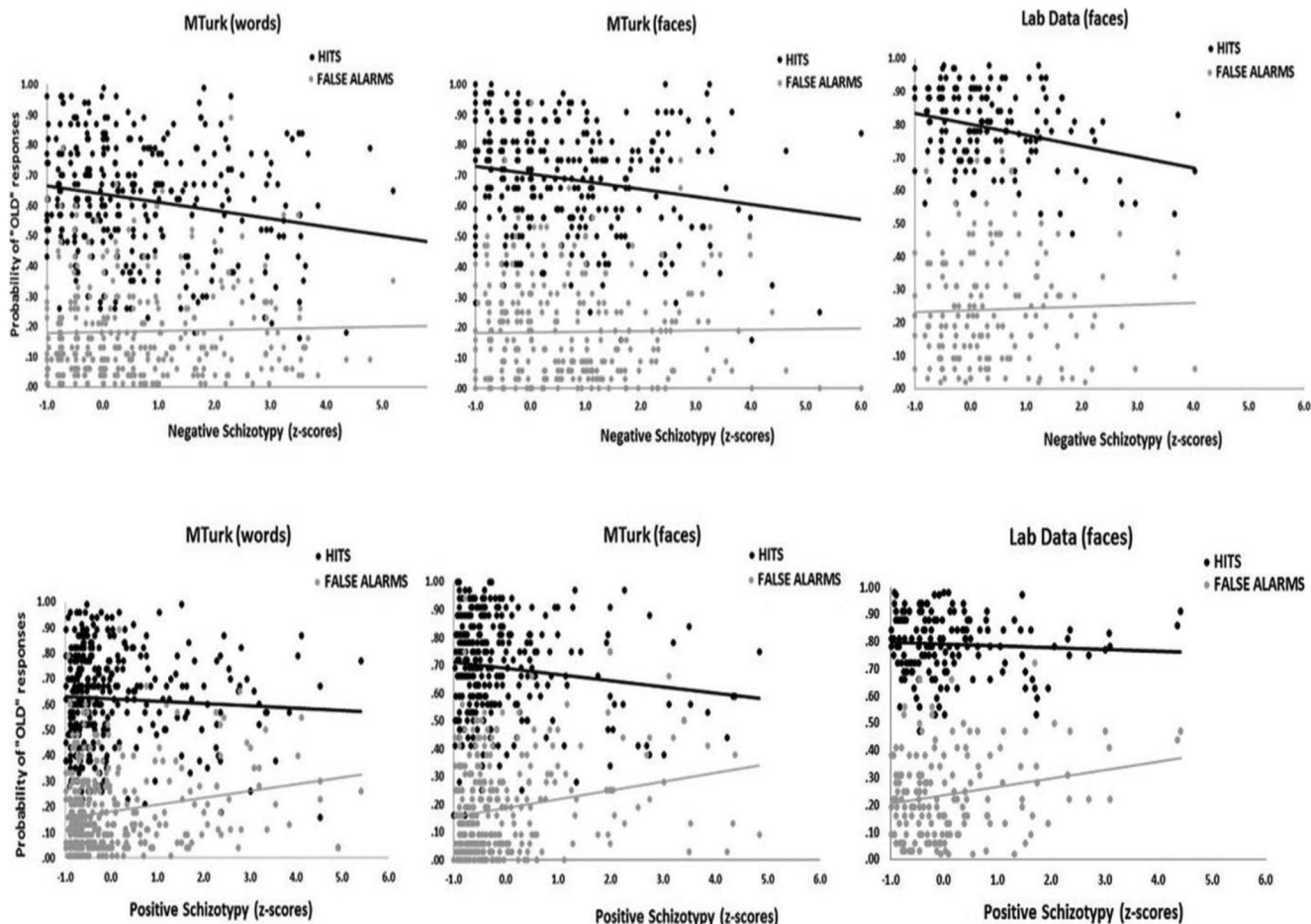


Figure 1. Hits and false alarms across negative schizotypy factor scores (top panel), and positive schizotypy factor scores (bottom panel) in three separate samples.

function of increasing negative schizotypy scores. However, there was no relationship between negative schizotypy scores and false alarm rates. Thus, negative schizotypy was associated with reduced ability to identify old stimuli as old, without an increase in error rates. The ability to correctly reject new items was unrelated to negative schizotypy. In contrast, the reverse pattern of results was observed in positive schizotypy. Within each sample, increasing positive schizotypy scores were associated with significantly increased false alarm rates. However, hit rates were unrelated to positive schizotypy. The interaction of positive and negative schizotypy was not significant in any of the samples.

Given the same pattern of hits and false alarms was obtained in all three samples, we combined the data across the samples to have more power to observe potentially small effects and to gauge an estimate of the overall effect sizes. Figure 2 summarizes the hits and false alarms in the combined dataset. Consistent with the individual samples, the hit rate decreased significantly across increasing negative schizotypy, whereas the false alarm rate increased significantly across increases in positive schizotypy (see Table 2). In the combined dataset, the Positive  $\times$  Negative Schizotypy interaction significantly predicted hit rate. Simple slopes analysis was conducted to decompose the interaction (see Figure

3), indicating that negative schizotypy had a significant inverse association with hit rate at positive schizotypy values of  $-1$  SD ( $p = .037$ ), at the mean of positive schizotypy ( $p < .001$ ), and at positive schizotypy values of  $+1$  SD ( $p < .001$ ). Likewise, the Positive  $\times$  Negative Schizotypy interaction significantly predicted false alarm rates. Positive schizotypy was significantly associated with false alarm rates at the mean values of negative schizotypy ( $p < .001$ ) and  $+1$  SD values of negative schizotypy ( $p < .001$ ), but not at negative schizotypy of  $-1$  SD ( $p = .159$ ). Thus, in individuals who are high in both dimensions of schizotypy, the effects of hits and false alarms are more prominent. However, note that the effect sizes for both of the interaction terms represented small effects.

### Discussion

The purpose of this investigation was to examine recognition memory using a continuous approach to assessing schizotypy. We replicated the same pattern of findings across three different samples that were tested at different times, with both online and lab participants, and using verbal and figural stimuli. Importantly, the pattern of hits and false alarms shown in Figure 2

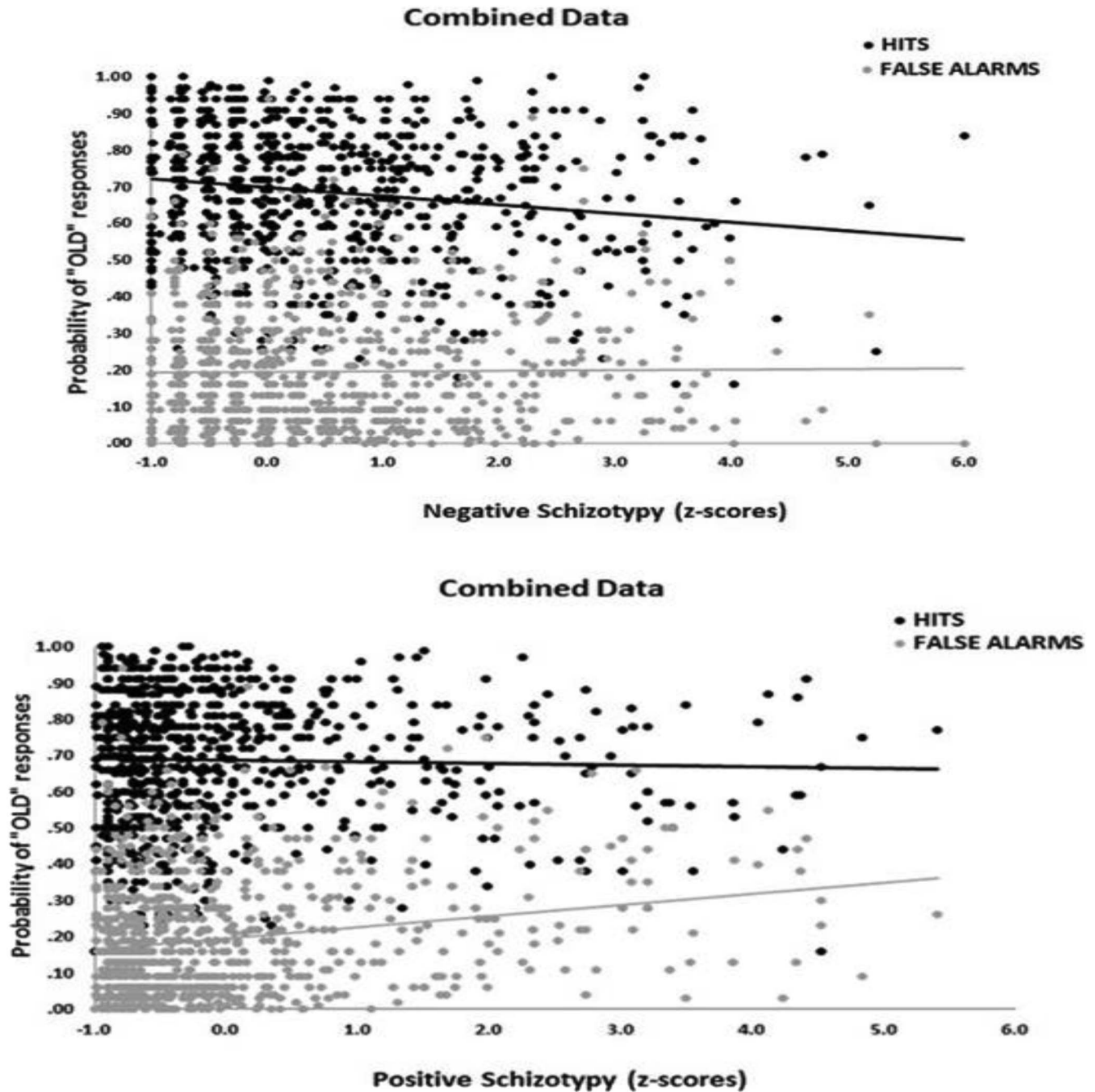


Figure 2. Hits and false alarms across negative schizotypy factor scores (top panel), and positive schizotypy factor scores (bottom panel) combined across all participants.

clearly indicates that positive and negative schizotypy have different effects on recognition. Discrimination accuracy is impaired across higher scores on both schizotypy dimensions. This is seen in the convergence of the regression lines toward the right side of the graphs, indicating that hits and false alarms are getting closer. However, the mechanism for this convergence differs across schizotypy dimensions, and the differences are informative of the ways in which these symptom dimensions

manifest themselves in cognitive impairment. As expected, the effect sizes in the present study were generally small (especially in comparison with the effect sizes for cognitive impairment in patients with schizophrenia). However, we believe that the consistency of findings across samples and the differential results for positive and negative schizotypy indicate that these small effects convey a meaningful story about cognitive impairment across the schizophrenia spectrum.

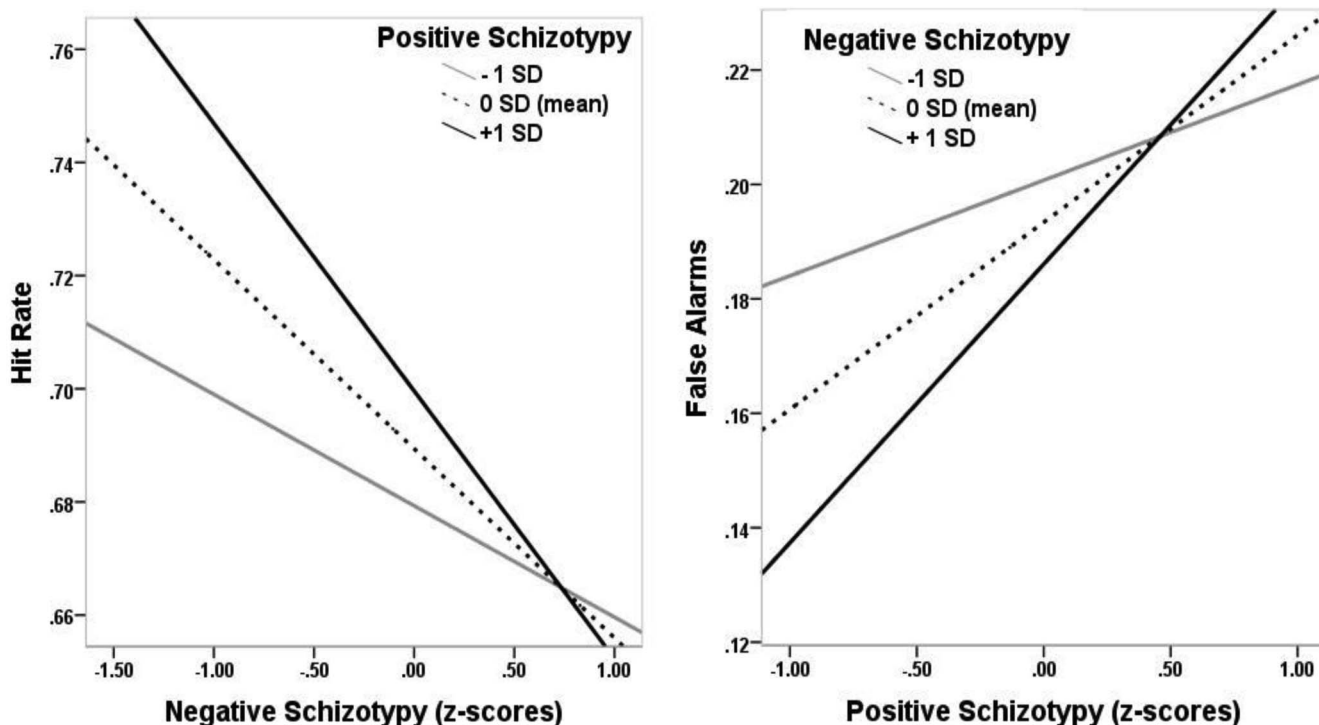


Figure 3. Relationship between hit rate and negative schizotypy at low ( $-1 SD$ ), medium ( $0 SD$ ), and high ( $+1 SD$ ) levels of positive schizotypy (left panel). Relationship between false alarm rate and positive schizotypy at low ( $-1 SD$ ), medium ( $0 SD$ ), and high ( $+1 SD$ ) levels of negative schizotypy (right panel).

Figure 4 illustrates a signal-detection theoretic model (Green & Swets, 1966; Wickens, 2001) consistent with the patterns obtained throughout the three samples. A signal-detection model describes probability distributions of evidence generated by old and new items, and a response criterion (indicated by the dashed line going through the black dot) that maps continuous evidence onto a binary response. Any evidence value experienced by the participant higher than the black dot elicits endorsement of the test item. For both positive and negative schizotypy, impairments in memory discriminability can be seen by the fact that the distributions are closer to one another in the bottom two panels than in the top two panels of Figure 4. Yet the specific origin of that impairment differs for the two dimensions of schizotypy.

In the top two panels, models are shown that yield performance consistent with what is seen in individuals with low schizotypy scores. The bottom two figures illustrate one interpretation of how the different dimensions of schizotypy affect recognition. Positive schizotypy, shown on the right, leads to an increase in the evidence yielded by noise trials. That is, new items yield greater evidence for oldness in individuals with high positive schizotypy than in individuals low on the positive schizotypy. This interpretation is consistent with the view of positive schizotypy as a failure to effectively gate noise and also with the presence of hallucinations as an extreme manifestation of positive schizotypy. Individuals high in negative schizotypy show a different pattern. Signal values are lower on average for individuals with high negative schizotypy, leading to a reduction in recognition discriminability. However, in this case it reflects not an enhancement of noise but a

reduction of signal—individuals high in negative schizotypy simply remember the old items less well.

This model provides one parsimonious account of the empirical findings, but it does not preclude other interpretations in which response criteria and discriminability vary in more complex ways across positive and negative schizotypy. Note, however, that whereas differences in hits (or in false alarms) across the two dimensions of schizotypy could be affected by adopting a more liberal or conservative response criterion, the response criterion account by itself is insufficient to explain the overall set of findings. This is because regardless of the adopted response criterion (i.e., liberal or conservative responding), hits and false alarms would be expected to either both increase, or both decrease as a result of response criterion. In contrast, the pattern of empirical findings indicates that only one of the components of recognition memory is affected by a particular schizotypy dimension (hits or false alarms, but not both), making it inconsistent with a purely response bias interpretation. If there are any differences in response bias across positive and negative schizotypy, then those are compounded by discrimination sensitivity findings, which indicate that both positive and negative schizotypy showed a reduction in recognition sensitivity as the signal and noise distributions moved closer together.

Both single-process and dual-process accounts of recognition memory could offer potential explanations for the pattern of reduced hits along with constant false alarms observed in negative schizotypy. We entertain some mechanisms from the perspective

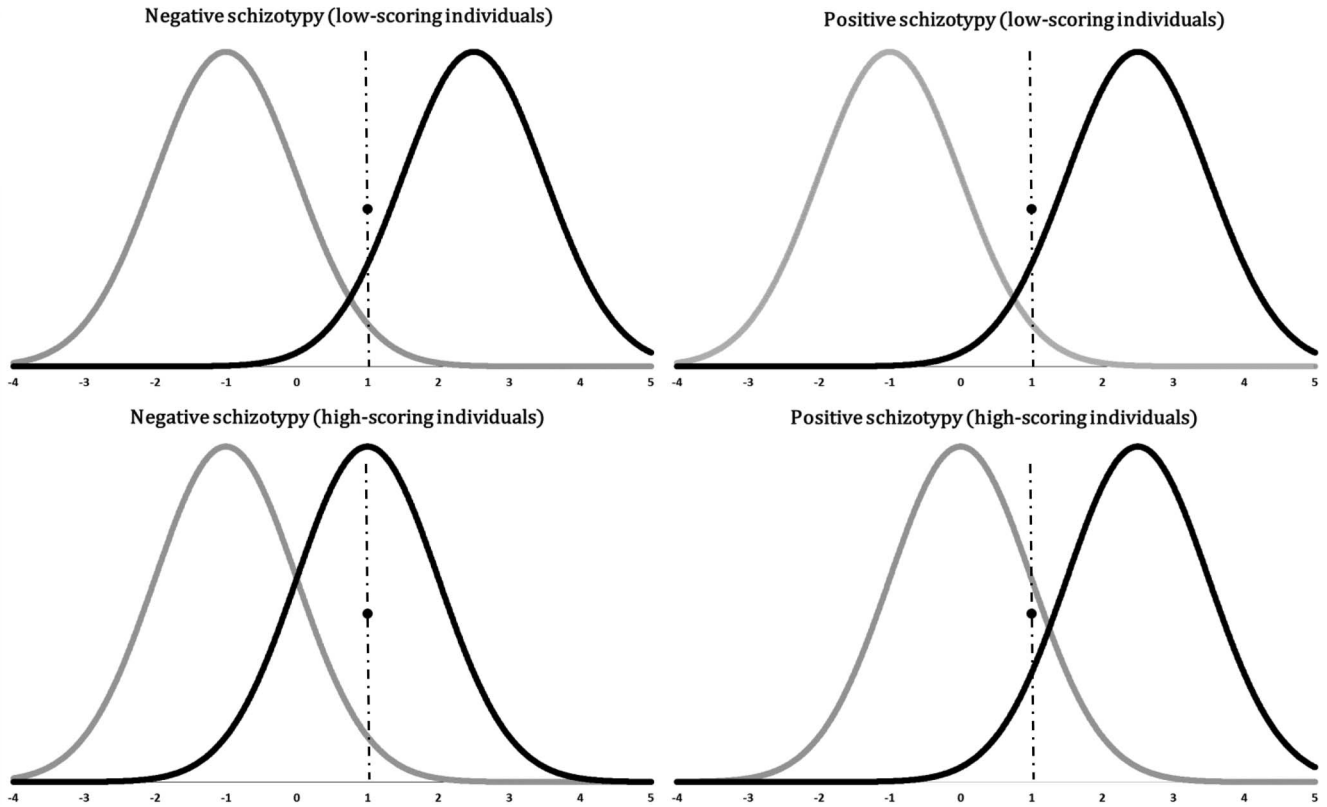


Figure 4. A signal-detection theoretic model illustrating differential patterns of recognition impairment across negative and positive schizotypy dimensions.

of both class of models, and note that differentiating between various interpretations will require additional research.

One of the widely studied class of models of recognition memory is the strength account, according to which the process of studying an item increases its preexperimental strength/familiarity, and that people use the information about the familiarity of the test item to make an old/new decision. The retrieving effectively from memory (REM) model (Shiffrin & Steyvers, 1997) belongs to a family of single-process models of recognition memory (e.g., Dennis & Humphreys, 2001; Hintzman, 1988; McClelland & Chappell, 1998; Murdock, 1997), and it offers a potential mechanism that could produce decreasing hit rates, without affecting the false alarm rates—a pattern observed in negative schizotypy. According to REM, item's quality of encoding could be negatively affected either due to encoding inaccurate features of the item, producing noisy representations of those items, or due to encoding fewer features about the items, despite encoding those features accurately (i.e., reduced accuracy vs. reduced quantity of encoded information). In REM, deficits in accuracy of encoded information lower the hits without affecting the false alarms, whereas deficits in quantity of encoded information reduce the hits, while simultaneously increasing the false alarms (e.g., Malmberg, Zeelenberg, & Shiffrin, 2004). The pattern of results observed in negative schizotypy is more consistent with impaired accuracy interpretation, rather than impaired quantity of encoded features. For example, while encoding features of the presented face, high negative schizotypy participants might incorrectly encode the color of the

eyes, or the hair, despite encoding all relevant features. In other words, negative schizotypy participants may encode the same amount of information as anybody else, but negative schizotypy may disrupt the correctness of the encoded information.

Another prominent class of models, known as dual-process accounts, propose a second informational dimension to the strength theory. According to this perspective, recognition judgments are based on the contribution of two processes—familiarity and *recollection*, which is a separate, independent process rather than a stronger version of familiarity (e.g., Jacoby, 1991; Mandler, 1980; Yonelinas, 1994). Old responses occur either when an item's familiarity exceeds a subjective criterion, or through recollection of specific details about the encoding experience of that item. In schizophrenia research, it was proposed that familiarity might be relatively spared compared with conscious recollection, which is impaired (e.g., Danion, Rizzo, & Bruant, 1999; Ragland, Valdez, Loughhead, Gur, & Gur, 2006). Some researchers using the remember/know paradigm have found evidence of impaired conscious recollection in schizophrenia (Huron & Danion, 2002; Huron et al., 1995). A meta-analysis comparing item recognition and associative recognition among schizophrenia patients revealed a larger decrement in associative recognition than item recognition (Achim & Lepage, 2003), consistent with the notion of impaired recollection in schizophrenia. Thus, the pattern of reduced hits along with stable false alarms that we observed in negative schizotypy is also consistent with the dual-process accounts of recognition, according to which recollection is impaired in negative schizotypy, lowering



the hits, without influencing the false alarms rates. Overall, several mechanisms could explain the pattern of obtained results, and additional research is needed to tease apart between various interpretations.

The present study builds upon the findings of Sahakyan and Kwapil (2016, 2018a, 2018b) that demonstrate that positive and negative schizotypy are associated with distinct patterns of impairment in episodic memory. The findings in recognition memory add to our previous findings for free recall memory deficits. Countless studies have demonstrated that schizophrenia is characterized by gross disruptions in cognitive performance that are in turn associated with real-world impairment in functioning. However, these studies often are unable to tease apart the extent to which specific cognitive impairments represent premorbid deficits that may be etiologically relevant to the development of schizophrenia-spectrum disorders as opposed to representing disease markers or sequelae. Identifying cognitive impairments that play a role in the etiology of schizophrenia-spectrum psychopathology and that occur in the premorbid, active, and residual phases is essential for understanding the nature and development of such disorders. Schizotypy provides a promising framework for this line of work given that the same underlie pathognomonic processes are presumed to underlying the subclinical and clinical expressions of the schizotypy continuum. Furthermore, as demonstrated by the present study, considering the multidimensionality of schizotypy and schizophrenia is essential for understanding this complex and heterogeneous psychopathology. Finally, repeatedly assessing these cognitive phenomena in diverse samples using varying stimuli can demonstrate the stability and boundaries of impaired cognitive processes in schizotypy. The finding that the distinct pattern of recognition memory deficits in positive and negative schizotypy were consistent across multiple samples and varying stimuli in the present study supports these findings. Note that future studies should consider other factors besides schizotypy that might impact memory and examine the extent to which the schizotypy dimensions account for memory impairment over-and-above these factors.

We believe that a strength of the present study is that it employed both college student and MTurk participants. Nevertheless, both of these samples have their limitations. College student samples tend to have a high proportion of the highest functioning members of their age cohort and may represent a conservative approach for identifying individuals at risk for schizophrenia-spectrum disorders. MTurk samples often are more diverse (especially in age and location) than college student samples, but concerns have increasingly been raised about nonhuman bots (e.g., Stokel-Walker, 2018). Nevertheless, we believe that MTurk samples provide useful complements to traditional college student samples assuming that appropriate steps are taken to screen for invalid respondents. The infrequency scale that we employed is widely used and screens for participants (or bots) that produce random or purposefully exaggerated responses. Obviously, this does not mean that we screened out every nonhuman or nonattentive MTurk subject. Nevertheless, we were able to detect comparable patterns of findings across the MTurk and college student samples.

In summary, the present findings provide further support for the continuum model of schizotypy and schizophrenia, and the necessity of examining schizotypy as a multidimensional construct. Our

studies have focused on the positive and negative symptom dimensions, but current models and measures also support the inclusion of a cognitive and behavioral disorganization factor (e.g., Kwapil, Gross, Silvia, Raulin, & Barrantes-Vidal, 2018). Consistent with our previous studies of episodic memory, the present findings support the use of psychometric inventories for identifying schizotypy in nondisordered individuals and indicate that schizophrenic-like memory deficits can be assessed in nonclinically ascertained samples. However, as Sahakyan and Kwapil (2018b) noted, clinical neuropsychological batteries that are useful for detecting large effect sizes in patients may not be sufficient for detecting subtle cognitive deficits in nondisordered schizotypes. Furthermore, reliance on summary indicators from clinical instruments (i.e., overall accuracy) may obscure specific deficits that characterize positive and negative schizotypy.

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