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Neurocognition and symptoms identify links between facial recognition and emotion processing in schizophrenia: Meta-analytic findings

Joseph Ventura[a,*], **Rachel C. Wood**[a], **Amy M. Jimenez**[b], and **Gerhard S. Hellemann**[a]

[a]UCLA Department of Psychiatry and Biobehavioral Sciences, Semel Institute for Neuroscience and Human Behavior, CA, USA

[b]UCLA Department of Psychology, CA, USA

Abstract

Background—In schizophrenia patients, one of the most commonly studied deficits of social cognition is emotion processing (EP), which has documented links to facial recognition (FR). But, how are deficits in facial recognition linked to emotion processing deficits? Can neurocognitive and symptom correlates of FR and EP help differentiate the unique contribution of FR to the domain of social cognition?

Methods—A meta-analysis of 102 studies (combined $n = 4826$) in schizophrenia patients was conducted to determine the magnitude and pattern of relationships between facial recognition, emotion processing, neurocognition, and type of symptom.

Results—Meta-analytic results indicated that facial recognition and emotion processing are strongly interrelated ($r = .51$). In addition, the relationship between FR and EP through voice prosody ($r = .58$) is as strong as the relationship between FR and EP based on facial stimuli ($r = .53$). Further, the relationship between emotion recognition, neurocognition, and symptoms is independent of the emotion processing modality – facial stimuli and voice prosody.

Discussion—The association between FR and EP that occurs through voice prosody suggests that FR is a fundamental cognitive process. The observed links between FR and EP might be due to bottom-up associations between neurocognition and EP, and not simply because most emotion recognition tasks use visual facial stimuli. In addition, links with symptoms, especially negative symptoms and disorganization, suggest possible symptom mechanisms that contribute to FR and EP deficits.

Keywords

Facial recognition; Emotion processing; Negative symptoms; Neurocognition; Social cognition; Meta-analysis; Disorganization

*Corresponding author at: UCLA Department of Psychiatry, 300 Medical Plaza, Room 2243, Los Angeles, CA 90095-6968, USA. Tel.: +1 310 206 5225; fax: +1 310 206 3651. jventura@ucla.edu (J. Ventura).

Contributors

Joseph Ventura conceived of the study design, data analysis plan, conducted literature searches, supervised the conduct of the study, and wrote the manuscript. Dr. Hellemann conducted the data analysis and commented on drafts of the manuscript. Ms. Wood and Ms. Jimenez preformed literature searches, created tables, and commented on drafts of the manuscript. All authors have contributed to and approved the final manuscript.

Conflict of interest

The authors report no financial conflict of interest regarding this study.

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1. Introduction

Domains of social cognition with relevance to schizophrenia have been identified as primarily including emotion processing, attribution, social cue recognition and social knowledge, and theory of mind (Green and Leitman, 2008; Mancuso et al., 2011). Comprehensive meta-analyses of one well-studied domain, emotion processing, showed a significant and large effect size deficit in schizophrenia patients compared to controls, $d = -.91$, $d = -.85$, and $g = .89$, respectively (Chan et al., 2010; Kohler et al., 2010; Savla et al., 2013). In fact, emotion processing is an important domain of social cognition with implications for community functioning (Kee et al., 2003; Meyer and Kurtz, 2009). However, several investigators have suggested that poor facial recognition, largely considered a control task, might explain schizophrenia patients' impaired performance on emotion perception tasks, both historically (Kerr and Neale, 1993; Mueser et al., 1996; Salem et al., 1996; Penn et al., 1997) and more recently (Sachs et al., 2004; Martin et al., 2005; Combs et al., 2007). In fact, a recent meta-analysis found that facial recognition showed a significant and large effect size deficit in schizophrenia patients as compared to controls ($d = -.71$) (Chan et al., 2010). Although emotion processing has been correlated with cognitive functions such as attention, reasoning, and problem solving, the question still remains regarding whether these deficits are secondary to basic, bottom-up social cognitive processes, i.e., facial recognition. Facial recognition is associated with emotion perception in schizophrenia, but how closely does facial recognition overlap with emotion processing? Some prior research actually suggests that facial recognition and emotion perception are largely distinct domains. Because schizophrenia patients are known to have deficits in each of these domains, they are considered to be important targets of social cognition intervention programs (Kurtz and Richardson, 2012).

Most of the evidence suggests that neurocognition and the identified domains of social cognition are overlapping, yet distinct (Marwick and Hall, 2008; Fett et al., 2011; Ventura et al., 2013). Is facial recognition a fundamental social cognitive skill or ability, as has been suggested by affective neuroscientists? The facial recognition domain is comprised of perceptual and cognitive capabilities needed to identify, encode, recognize, and remember faces (Norton et al., 2009; Lee et al., 2011). If facial recognition is a "lower order" perceptual and social cognitive skill we might expect an association with lower order (bottom-up) neurocognitive skills such as attention (Meyer and Kurtz, 2009; Chung et al., 2011). By way of contrast, some higher order (top-down) cognitive skills such as reasoning and problem solving ability or abstraction skills have been associated with specific higher level social cognitive functions, including second order Theory of Mind (Abdel-Hamid et al., 2009; Bell et al., 2010). Conclusions drawn from studies that examined the relationship between neurocognition and facial recognition indicate a mixed picture of overlapping correlations or that they are two independent systems. Knowing more about the link to neurocognition can help identify where in the conceptualization of social cognitive skills facial recognition is located and how this ability should be classified (Green and Leitman, 2008). Assuming that facial recognition is an independent construct, knowing how the separable neurocognitive domains (Nuechterlein et al., 2004) are differentially or uniformly correlated with facial recognition will help clarify questions about differentiation from emotion processing. This is important because deficits in facial recognition, despite being considered a control task, have been linked to poor neurocognitive functioning in schizophrenia (Mueser et al., 1996).

The results of recent meta-analyses have indicated the importance of examining separately the three major symptom categories (reality distortion, negative symptoms, and disorganization), which are related in specific ways to the key domains of neurocognition, social cognition, and functioning in schizophrenia (Ventura et al., 2013). Our prior work showed that social cognition was related with all three of these major symptom domains and that each association is best understood separately. For example, deficits in patients exhibiting reality distortion might be associated with misattribution bias, whereas patients with negative symptoms might have poorer emotion perception because of reduced emotional experience (i.e., anhedonia) or expression (i.e., affective flattening) (Gur et al., 2006; Sergi et al., 2007). In addition, there is some suggestion that patients with paranoid schizophrenia have better cognitive performance (Nelson et al., 2007). However, very little is known about the relationships between these major symptom dimensions and facial recognition (Green et al., 2008; Marwick and Hall, 2008; Couture et al., 2010). The evidence seems to indicate that specific symptom types might be related in differential ways to separate social cognitive processes, but how they "map onto" facial recognition is less clear (Corcoran et al., 1995; Garety and Freeman, 1999; Greig et al., 2004; Couture et al., 2010). Symptom type and social cognitive deficits appear to be linked in fundamental ways. Even a basic understanding of these relationships with regard to facial recognition could yield benefit considering that remediation of these social cognitive deficits is given to patients who are experiencing these symptoms.

The aims of this study were to use meta-analytic methods to examine relationships in schizophrenia patients between: 1) facial recognition and emotion processing, 2) facial recognition, emotion processing, and the six identified neurocognition domains, and 3) facial recognition, emotion processing, and three symptom domains: reality distortion, disorganization, and negative symptoms.

2. Methods

2.1. Procedures

We conducted a literature search of the following databases: *PsychInfo, PsychAbstracts, EBSCOhost, PubMed,* and *Google Scholar* covering the period from January 1, 1977 to July 31, 2013. Searches were restricted to articles published in the English language. The following key search terms were used: *social cognition, emotion perception, affect recognition, affective prosody, facial identification, facial recognition, schizophrenia, schizoaffective, schizophreniform, neurocognition, neurocognitive functioning, positive symptoms, negative symptoms, disorganization symptoms, and formal thought disorder*. The reference lists of published articles identified by this method were then screened to locate additional relevant studies and we also used the search options in PubMed and Google Scholar that allow for a search of papers with related topics.

Using these search methods, 240 articles were reviewed and 162 of those were identified as potentially relevant to this topic. These studies were then evaluated using the following inclusion criteria: (1) study must have used empirical methods and been published in a peer reviewed journal; (2) study must have contained descriptions of study measures and operational definitions of variables; (3) study must have used structured assessments of symptoms with established scales or standardized methods of symptom assessment; (4) study must have assessed neurocognitive functioning using standardized batteries; (5) study must have been cross-sectional (as defined by an assessment interval of 90 days or less); (6) all participants in the study must have been diagnosed with schizophrenia, schizoaffective disorder, or schizophreniform disorder according to DSM criteria; (7) statistics reported must have been correlation coefficients or other equivalent statistics that could be converted into r as an effect size; (8) study data must not have been included or published previously in another paper included in this analysis.

A total of 102 studies met the inclusion criteria with a combined total sample of 4826 patients. Studies contained inpatients (k = 35), outpatients (k = 48), and mixed samples (k =

17). The aggregate sample characteristics were as follows: 68% of patients were male, the mean age was 36.3 years (5.5), and the mean education was 12.2 years (1.4) (Table 1). These are typical characteristics for a sample of chronic schizophrenia patients participating in research projects.

2.2. Defining facial recognition, emotion processing, neurocognition, and symptoms

2.2.1. Neurocognition—For the current study, *neurocognition* was operationally defined as cognitive functions (such as attention and memory) that are objectively measurable with standardized neuropsychological tests (Table 2). One of the primary goals of the NIMH Measurement and Treatment Research to Improve Cognition in Schizophrenia (MATRICS) was to develop a reliable and valid consensus cognitive battery (Nuechterlein et al., 2004). An essential step in the process was to identify the major separable cognitive deficits in schizophrenia. After evaluating the empirical evidence that consisted of the examination of factor analytic studies, seven separable domains were identified that were replicable across studies (Nuechterlein et al., 2004). The current study included 6 of the 7 MATRICS domains of cognitive functioning: Verbal Learning and Memory, Visual Learning and Memory, Working Memory, Reasoning and Problem Solving, Speed of Processing, and Attention/ Vigilance. Because one of the primary aims of this study was to examine separate neurocognitive domains in relationship to the various types of social cognitive processes, the MATRICS domain of Social Cognition was not included as a neurocognitive domain for the current analyses.

2.2.2. Social cognition: facial identification and emotion processing—For the current study, *Social Cognition* was operationally defined as *Facial Recognition* (FR), not one of the areas traditionally included in definitions of social cognition, and *Emotion Processing* (EP), which has been widely accepted as a domain (Pinkham et al., 2003; Green et al., 2005). The Facial Recognition domain is comprised of perceptual capabilities needed to identify, encode, recognize, and recall faces. Reported relationships used in this meta-analysis came from standardized assessments such as the Benton Test of Facial Recognition (Benton et al., 1983) (Table 3). The Emotion Processing domain refers broadly to capabilities needed to accurately identify, name, discriminate, and process various emotions perceived through facial expressions. Data for this domain must have been measured by standardized assessments such as the Bell-Lysaker Emotion Recognition Test (Bell et al., 1997) (Table 3). A separate category was created that examined emotion processing through voice prosody alone, e.g., the Affective Prosody Test (Van Lancker, 1988).

2.2.3. Reality distortion, disorganization and negative symptoms—The dimension of Reality Distortion included positive symptoms consisting of delusions (e.g. persecutory delusions) and hallucinations (e.g., auditory) as measured by items from structured symptom scales (e.g., PANSS, BPRS). The dimension of Disorganization included positive symptom items such as conceptual disorganization, formal thought disorder, mannerisms and posturing, and bizarre behavior, as measured by structured assessment scales (e.g., PANSS, SAPS). The Combined category was comprised of assessments for which symptoms of reality distortion and disorganization were combined (e.g., the PANSS positive symptom scale which includes delusions, hallucinations, and conceptual disorganization, or the SAPS total score which combines delusions, hallucinations, and formal thought disorder). The dimension of Negative Symptoms included symptoms such as blunted affect, emotional withdrawal, and asociality, as measured by items from structured symptom scales (e.g. SANS, BPRS).

2.3. Data analysis procedures

We examined the relationships between our social cognition variables (FR and EP), with the three major symptom types, and the six MATRICS domains of neurocognition. We were interested in the differences in effect size magnitude between reality distortion, disorganization, and negative symptoms with FR and EP. We examined separately the relationship between verbal learning, visual learning, working memory, reasoning and problem solving, speed of processing, and attention/vigilance with the six domains of social cognition. The first step for these analyses was to transform the observed (published) correlations in each study using Fisher's *r*-to-*z* transformation. Where indicated, multiple results were averaged from the same domain, e.g., several tests of working memory were combined into a single observation for a given study. The correlation coefficients were then combined into a single estimate of the population correlation by averaging the coefficients weighted by sample size (Hedges and Olkin, 1984). The estimated overall effect sizes were then tested for homogeneity across studies by calculating Q-statistics.

2.4. Sample diagnostics

We found that most of the effects were homogeneous, i.e., all studies have approximately the same effect size (Table 4). The studies that were not homogeneous are identified. If the differences in effect sizes between studies were associated with specific study characteristics, the study characteristic and direction of the relationship are provided (Table 4). In the studies with a heterogeneous effect size, we tested for effect size associations with the key study variables as follows: mean age, mean education, gender ratio, inpatient or outpatient status, sample size, and year of publication. None of these variables were significantly associated with either effect size or homogeneity. The alternative estimates for the overall effect sizes based on the homogeneous subset studies are provided (Table 4). Although a few studies were identified as outliers in some of the neurocognitive domains, we found it difficult to justify excluding one study for not being a valid source of information for a given domain, and yet valid for another. Using this rational, the study results are based on parameter estimates from all studies. For comparison purposes, parameter estimates based on the homogeneous subset studies are provided. Although the significance of the reported *p*-values is potentially inflated, the data presented in the current study can be considered as being a reasonably robust representation of the relationships between the variables of interest.

3. Results

3.1. Relationship of facial recognition and emotion processing

Firstly, using meta-analytic techniques, we found relatively strong evidence indicating that facial identification recognition and emotion processing of facial stimuli are strongly interrelated, $r = .53$ ($k = 8$, $n = 227$), that the studies are homogeneous ($\chi^2 = 9.01$, $p = .53$), and that the sample size of additional studies needed with null results that would make this result non-significant is large (Failsafe $n = 4104$). Facial identification and emotion processing using voice prosody are also strongly correlated, $r = .58$ ($k = 3$, $n = 84$), and the studies are homogeneous (χ^2=1.6, p=.66) with a Failsafe n=734. The few studies that report emotion processing using both modalities, facial stimuli and voice prosody, show that the they are strongly related, $r = .48$ ($k = 2$, n = 75) and that the studies are homogeneous (χ^2 = 0.73, $p = .69$) with a Failsafe $n = 159$.

3.2. Relationship of neurocognition with facial recognition and emotion processing

The relationship between the six MATRICS neurocognitive domains and facial recognition was mostly moderate in effect size and consistent across domains (Table 5). The relationships ranged from .21 to .45. Relatively speaking, reasoning and problem solving (r=.45) and visual memory (r = .41) were more strongly related to facial recognition as compared to the other four domains of neurocognition (r's ranged from .21 to .28). For the relationships between facial recognition and speed of processing, there were too few studies for the correlations to be stable so those values were considered with caution when interpreting the findings (Table 5).

The relationship between the six MATRICS neurocognitive domains and emotion processing – facial stimuli was mostly moderate in effect size and highly consistent across domains (r's ranged from .27 to .30) (Table 5). We found that no one or two neurocognitive domains were, relatively speaking, more strongly related than the other domains of neurocognition. The findings among tests of emotion processing through voice prosody were remarkably similar (r's ranged from .29 to .43) (Table 5). We note that the relative strength of the relationships of the six MATRICS neurocognitive domains and social cognition (FR and EP) was on average similar to that of disorganization and negative symptoms with social cognition (FR and EP).

3.3. Relationship of symptom type with facial recognition and emotion processing

We examined separately the cross-sectional relationships of the three symptom domains, reality distortion, disorganization, and negative symptoms, with facial recognition. Highly consistent and moderate effect size relationships were found between facial recognition with disorganization (r =−.25) and with negative symptoms (r = −.22). In striking contrast, the relationship between facial recognition and reality distortion was near zero (r=−.02). The pattern of effect sizes for the studies that combined reality distortion (hallucinations and delusions) with disorganization in relationship to facial recognition was small to moderate (r = −.25). Combining the effects of these two types of positive symptoms resulted in moderate relationships that were different from the strength of any one of these separate relationships between symptoms and facial recognition. In comparing symptoms and emotion processing – facial stimuli, we found relatively consistent and moderate effect size relationships for disorganization (r =−.32), negative symptoms (r =−.25), and reality distortion (r = −.21). These findings were similar to tests of emotion processing through voice prosody with disorganization (r = −.47), negative symptoms (r = −.25), and reality distortion (r = −.31).

4. Discussion

The relatively strong evidence linking facial recognition and emotion processing through both facial stimuli (r = .53) and voice prosody (r = .58) suggests that the perceptional components of facial recognition are associated with emotion processing beyond modality specific mechanisms. As such, the observed associations are likely due to bottom-up associations between neurocognition and EP, and not simply because most emotion recognition tasks use visual facial stimuli. In addition, the relationship of most of the separate domains of neurocognition to facial recognition was moderate in strength and relatively consistent across domains. However, for reasoning and problem solving and visual memory, the magnitude of the relationship was relatively, but not significantly, higher. Meta-analytic techniques were also used to examine the magnitude of the relationships between facial recognition and the three symptom domains. Consistent with our previous findings and theoretical model, facial recognition was related in similar ways to negative symptoms (r = −.22) and disorganization (r = −.25), as was emotion processing to negative symptoms (r = −.25) and disorganization (r = −.32). Interestingly, although reality distortion was moderately correlated with emotion processing (facial stimuli r = −.21), the relationship to facial recognition was near zero (r = −.02). Based on these findings, we propose that facial recognition is not just a control task, but rather a more central component of emotion processing, and therefore closely linked to social cognition.

Consistent with our previous findings regarding emotion processing (Ventura et al., 2013), most of the six MATRICS domains of neurocognition were moderately correlated with facial recognition. These findings support the hypothesis that facial recognition and neurocognition are related constructs. These analyses also addressed the question of whether the six domains of neurocognition “map on” differentially to facial recognition. Contrary to what prior work might have suggested, there were mostly moderate relationships across neurocognitive domains with facial recognition, with the exception of the relatively higher relationships between facial recognition with visual processing and facial recognition with reasoning and problem solving. The link to visual learning and memory is consistent with facial recognition being a visual task and with the overlap of visual and configural processing skills (Norton et al., 2009; Lee et al., 2011; Soria Bauser et al., 2012; de Jong et al., 2013; Lin et al., 2013). The relationship to reasoning and problem solving suggests the possibility that even bottom-up social cognitive processes might have links to higher order neurocognitive process (Marwick and Hall, 2008). In spite of relatively higher correlations, specific neurocognitive domains do not appear to be selectively associated in specific ways with facial recognition. Thus, facial recognition and emotion processing (face or voice) deficits appear to be part of a generalized social cognitive deficit due to the overlap with all domains of neurocognition. Whether facial recognition or emotion processing explain separate variance in important domains such as functioning requires further study (Chan et al., 2010).

Increasing attention is being given to the examination of emotion processing as measured separately through facial stimuli and voice prosody and their neurocognitive and symptom correlates in schizophrenia patients (Castagna et al., 2013). We found that facial recognition was strongly related to emotion processing whether assessed through facial stimuli or voice prosody. In a similar fashion, the six domains of neurocognition were fairly consistently related to emotion processing whether assessed using facial stimuli or voice prosody. Further, we explored links between the three major symptom types (reality distortion, negative symptoms and disorganization) and emotion processing, as measured using facial stimuli and voice prosody. The relationships between the three major symptom types and emotion processing (face and voice) were fairly consistant, suggesting the role that symptoms play is consistent and independent of modality.

Our results are consistent with a model in which bottom-up perceptual processes are associated with social cognitive abilities such as facial recognition, which are consistently influenced by neurocognitive abilities, all of which contribute to the ability to recognize emotions from any number of cues, including faces and voice tone. Hence, relatively automatic bottom-up processes, i.e., facial recognition and neurocognitive ability not impeded by symptoms appear to be needed for accurate understanding of emotions independent of modality.

Far less is known about the implications of the relationship between symptoms and facial recognition compared to what is known about emotion processing in schizophrenia (Fett et al., 2011; Ventura et al., 2013). Facial recognition, considered for a time to be a control task, might indeed be fundamental for social learning to occur in social interactions (Frith and Frith, 2008). Facial recognition, given its bottom-up nature, might be considered fundamental to the processing of social signals or social stimuli, because much of social learning or social perception occurs outside of conscious awareness. The decision to recognize a face as trustworthy, familiar, or as the source of salient information happens rapidly and must be made before progressing to the next step of a social interaction. Our findings suggest that the presence of negative symptoms and disorganization might disrupt this fundamental process. The plausibility of these ideas is supported by the demonstrated links between disorganization and negative symptoms with social cognitive processes (Lin

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et al., 2013; Ventura et al., 2013). In fact, some theorists have hypothesized a link between negative symptoms such as social withdrawal or alogia with the development of facial recognition and emotion perception deficits (Penn et al., 2008). Patients who do not interact socially might lose these abilities or skills. Interestingly, the relative magnitude of the relationship between facial recognition and emotion processing, whether measured through facial stimuli or voice prosody, with disorganization and negative symptoms was similar to the magnitude of the relationships to most domains of neurocognition.

Our findings suggest that the three major symptom types might be associated in differential ways to social cognitive processes such as facial recognition as compared to emotion processing (Frith, 1992; Penn et al., 1997; Hardy-Baylé et al., 2003; Kohler et al., 2003). We found that the symptom group known as reality distortion was not related to facial recognition (correlation near zero). The absence of a significant inverse relationship might suggest that reality distortion, which often involves suspiciousness or paranoia and hyper-vigilance, might in fact be associated for some patients with an enhanced ability to scrutinize faces and recognize their perceptual features. In comparison, for emotion processing, reality distortion might be associated with misattribution of the emotional features portrayed by the facial stimuli. Further, deficits in emotion processing might involve the misattribution of ambiguous negative emotions, i.e., sad emotions can be misinterpreted as angry, or the misreading of another’s intentions that might be related to paranoid thinking. This again supports the need in research studies to separate positive symptoms such as reality distortion (delusions and hallucinations) from other positive symptoms such as disorganization, as these symptom groups have different links to neurocognition, social cognition, and functional outcome (Ventura et al., 2010, 2013). Further, our finding that disorganization and negative symptoms were related at a similar magnitude to facial recognition and emotion processing is an indication of the relevance of symptoms in understanding various aspects of social cognitive processes.

We have previously discussed the limitations of meta-analyses that examine symptoms, neurocognition, and social cognition so we will only briefly review them here (Ventura et al., 2010, 2013). There is an average of about 25% shared variance between facial recognition and emotion processing, which leaves a large amount of variance in social cognitive processes that needs to be explained in other ways. Similarly, patterns of correlations and magnitudes of relationships between symptom and neurocognitive variables and facial recognition and emotion processing in the current analyses, while potentially suggestive, do not indicate that they necessarily reflect shared variance. There is still a fair amount of variance in several of these social cognition constructs that seems to be unique to each construct. Additionally, the causal direction of these associations has not been established, but is hypothesized for these analyses by the authors. Future longitudinal research may be aimed at clarifying the direction of these links. There is also the issue of “popularity.” Fewer studies of neurocognition have addressed facial recognition than emotion processing which suggests that caution is needed in interpreting our findings.

Schizophrenia patients are known to have deficits in facial recognition and emotion processing, which are both considered to be important targets of social cognition intervention programs and fortunately were among the most amenable to intervention (facial recognition d = .67 and emotion perception d = .47) (Kurtz and Richardson, 2012). Our findings suggest that social cognition training, even if aimed ultimately at teaching higher order social cognitive skills, should begin by addressing facial recognition deficits, modeling the bottom-up nature of social cognition. Perhaps mastery at this “lower level” skill should be a requirement for advancement to “higher” levels. The link found between fundamental neurocognitive skills such as attention and working memory and facial recognition and emotion processing supports this view. Further, these findings suggest that patients who are disorganized or have negative symptoms might need a more intensive and targeted approach, or specific elementary level pre-training, to address how these symptoms might interfere with their learning process. This highlights the relative importance of symptoms in understanding the nature of social cognitive deficits with implications for treatment planning and conducting treatment programs to optimize effects.

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Table 1

Study sample characteristics.

Number of Studies (*k*)	102
Total N	4826
Inpatients/Outpatients	35 Inpatient Studies
	48 Outpatients Studies
	17 Mixed
	2 Did not report
Gender Ratio	68% Male
Age	Mean = 36.3 (5.5) Years
Education	Mean = 12.2 (1.4) Years
Ethnicity (reported for 29 studies, N = 1504)	773 (51%) Caucasian
	485 (32%) African American
	114 (8%) Asian American
	77 (5%) Hispanic
	55 (4%) Other/Mixed

Table 2

Neurocognitive domains and assessment measures (representative tests).

Neurocognitive domain	Neurocognitive tests
Verbal Learning and Memory	Logical Memory Subtest – WMS-R
	Hopkins Verbal Learning Test (HVLT)
Visual Learning and Memory	Visual Reproduction Subtest – WMS-R
	Rey-Osterreith Complex Figures Test (ROCF)
	Benton Visual Retention Test (BVRT)
Working Memory	Digit Span Forward/Backward –WAIS
	Spatial Span Forward/Backward – WMS-R
	Letter-Number Sequencing - WAIS-III/Letter-Number
	Memory - WMS-III
Reasoning and Problem Solving	Wisconsin Card Sorting Test (WCST)
	Gorham's Proverbs – Interpretation
Speed of Processing	Trail Making Test A & B
	Digit Symbol Substitution Test – WAIS
Attention/Vigilance	Continuous Performance Test (CPT)
	Degraded Stimulus Continuous Performance Test (DS-CPT)
	Visual-Spatial N-Back Task

Table 3

Facial recognition and emotion processing measures (representative tests).

Facial Recognition	Benton Test of Facial Recognition (Benton)
	Facial Identity Discrimination Task (FIDT)
	Kinney's Identity Matching Test
	Test of Facial Recognition
	Warrington Recognition Memory Test for Faces
	Test of Memory and Learning, Facial
Emotion Processing – Facial Stimuli	Bell-Lysaker Emotion Recognition Test (BLERT)
	Facially Expressed Emotion Labeling Test (FEEL)
	Penn Emotion Recognition Test and Emotion Discrimination Task (Penn)
	Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT) Branch 1 (Identifying Emotions)
	Face Emotion Discrimination Test (FEDT)
	Face Emotion Identification Test (FEIT)
	Tool for Recognition of Emotion in Neuropsychological Disorders
	Penn Emotion Acuity
	EMODIFF
	Ekman and Friesen's “Pictures of Facial Affect”
Emotion Processing – Voice Prosody	Prosody Task (Perception of Auditory Affect)
	Emotional Prosody Perception Task
	Explicit Recognition of Emotional Prosody Task
	Vocal Emotion Stroop Task
	Sarcasm Perception (VOICE)
	Voice Emotion Identification Test (VEIT)
	Voice Emotion Discrimination Test (VEDT)
	Affective Prosody Test

Table 4

Meta-analysis diagnostics.

Variables of interest	Chi-square	*df*	*P*	Studies needed to drop for homogeneity	*r* for homogeneous subset	*P* for homogeneous subset
Facial Identification and Emotion Processing- Facial Stimuli	9.01	10	.53	–		
Facial Identification and Emotion Processing- Voice Prosody	1.6	2	.58	–		
Facial Identification & Verbal Memory	1.31	4	.86	–		
Facial Identification & Visual Memory	2.69	5	.75	–		
Facial Identification & Working Memory	.00	2	1.00	–		
Facial Identification & Reasoning and Problem Solving	3.81	2	.15	–		
Facial Identification & Speed of Processing	NA[a]			–		
Facial Identification & Attention/Vigilance	1.19	3	.76	–		
Facial Identification & Reality Distortion	1.99	4	.74	–		
Facial Identification & Positive Symptoms	.80	3	.85	–		
Facial Identification & Disorganization	3.49	5	.62	–		
Facial Identification & Negative Symptoms	20.44	12	.06	–		
Emotion Processessing- Facial Stimuli & Verbal Memory	28.44	15	.02	Gur et al., 2006	.23	<.01
Emotion Processessing- Facial Stimuli & Visual Memory	3.01	12	1.00	–		
Emotion Processessing- Facial Stimuli & Working Memory	22.22	9	.01	Bell et al., 2009	.36	<.01
Emotion Processessing- Facial Stimuli & Reasoning and Problem Solving	17.71	15	.28	–		
Emotion Processessing- Facial Stimuli & Speed of Processing	15.97	17	.53	–		
Emotion Processing- Facial Stimuli & Attention/Vigilance	31.06	17	.02	Bell et al., 2009	.25	<.01
Emotion Processessing- Facial Stimuli & Reality Distortion	45.70	18	.00	Martin et al., 2005; Weniger et al., 2004	.20	<.01
Emotion Processessing- Facial Stimuli & Positive Symptoms	34.23	22	.05	Marsh et al., 2010	.16	<.01
Emotion Processessing- Facial Stimuli & Disorganization	39.21	22	.01	Hoeschel et al., 2001	.33	<.01
Emotion Processessing- Facial Stimuli & Negative Symptoms	132.35	59	.00	Yu et al., 2012; Eack et al., 2010; Demirbuga et al., 2013; Suslow et al., 2003; Nelson et al., 2007; Bell et al., 2006; Turetsky et al. 2007; Behere et al., 2009; Nienow et al., 2006; Herbener et al. 2005	.28	<.01
Emotion Processessing- Voice Prosody & Verbal Memory	4.08	4	.40	–		
Emotion Processessing- Voice Prosody & Visual Memory	NA[a]			–		
Emotion Processessing- Voice Prosody & Working Memory	1.40	3	.71	–		

Variables of interest	**Chi-square**	***df***	***P***	**Studies needed to drop for homogeneity**	***r* for homogeneous subset**	***P* for homogeneous subset**
Emotion Processessing- Voice Prosody & Reasoning and Problem Solving	2.10	2	.35	–		
Emotion Processessing- Voice Prosody & Speed of Processing	3.85	4	.43	–		
Emotion Processing- Voice Prosody & Attention/Vigilance	2.43	4	.66	–		
Emotion Processing- Voice Prosody & Reality Distortion	.64	2	.73	–		
Emotion Processing- Voice Prosody & Positive Symptoms	NA[a]			–		
Emotion Processing- Voice Prosody & Disorganization	8.90	3	.03	Pijnenborg et al., 2009	.60	<.01
Emotion Processing- Voice Prosody & Negative Symptoms	8.52	7	.29	–		

[a]Insufficient number of studies ($N < 3$) to assess homogeneity.

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Table 5

Correlations between neurocognition, symptoms, facial recognition, and emotion processing.

	Facial recognition	N (k)	Emotion processing (facial stimuli)	*N* (k)	Emotion processing (voice prosody)	*N* (k)
Neurocognitive domains						
Verbal Memory	.21	194 (4)	.27	1046 (15)	.30	194 (4)
Visual Memory	.41	156 (5)	.30	620 (12)	.43	156 (5)
Working Memory	.28	62 (2)	.28	575 (9)	.31	62 (2)
Reasoning and Problem Solving	.45	68 (2)	.28	972 (15)	.30	68 (2)
Speed of Processing	.24	35 (1)[1]	.29	1037 (17)	.34	35 (1)[1]
Attention/Vigilance	.28	108 (3)	.29	922 (17)	.29	108 (3)
Symptom Domains						
Reality Distortion	−.02	203 (4)	−.21	757 (18)	−.31	81 (2)
Disorganization	−.25	240 (5)	−.32	987 (22)	−.47	124 (3)
Negative Symptoms	−.22	487 (12)	−.25	2825 (53)	−.25	312 (7)
Positive Symptoms[b]	−.25	138 (3)	−.18	1076 (22)	−.13	36 (1)[a]

Note: *N* = total number of subjects, k = number of studies,

[a] only one study for this domain.

[b] Correlations from studies that combined measures of reality distortion and disorganization.