

Provided for non-commercial research and education use.
Not for reproduction, distribution or commercial use.



This article appeared in a journal published by Elsevier. The attached copy is furnished to the author for internal non-commercial research and education use, including for instruction at the authors institution and sharing with colleagues.

Other uses, including reproduction and distribution, or selling or licensing copies, or posting to personal, institutional or third party websites are prohibited.

In most cases authors are permitted to post their version of the article (e.g. in Word or Tex form) to their personal website or institutional repository. Authors requiring further information regarding Elsevier's archiving and manuscript policies are encouraged to visit:

<http://www.elsevier.com/copyright>

Contents lists available at [ScienceDirect](http://www.sciencedirect.com)

Psychiatry Research

journal homepage: www.elsevier.com/locate/psychres

Correspondences between theory of mind, jumping to conclusions, neuropsychological measures and the symptoms of schizophrenia

Todd S. Woodward^{a,b,*}, Romina Mizrahi^{c,d}, Mahesh Menon^{c,d}, Bruce K. Christensen^e^a Department of Psychiatry, University of British Columbia, Vancouver, Canada^b Department of Research, BC Mental Health & Addictions Research Institute, Vancouver Canada^c Schizophrenia Program and PET Centre, Centre for Addiction & Mental Health, Toronto, Canada^d Department of Psychiatry, University of Toronto, Toronto, Canada^e Department of Psychiatry and Behavioural Neurosciences, McMaster University, Hamilton, Canada

ARTICLE INFO

Article history:

Received 8 February 2008

Received in revised form 26 September 2008

Accepted 23 October 2008

Keywords:

Memory

Executive functions

Positive symptoms

Negative symptoms

Fluency

ABSTRACT

Tasks measuring reasoning biases and social cognition were originally applied to the study of schizophrenia in order to shed light on the cognitive underpinnings of positive symptoms. However, the empirical evidence for overlap between these tasks, and their association with positive symptoms, remains preliminary. In the current study we explore these associations using multivariate methodology, with primary interest in two commonly studied paradigms: jumping to conclusions (JTC) and theory of mind (ToM). We also included measures of memory, executive function and fluency performance, in order to relate the cognitive constructs to more traditional neuropsychological constructs. Forty-six schizophrenia inpatients were administered JTC, ToM, verbal fluency, executive functioning, and verbal memory tasks. A principal component analysis resulted in three components interpreted as Memory, Elaboration and Flexibility. ToM loaded with verbal fluency on the Elaboration component, whereas JTC loaded with executive functioning on the Flexibility component. The negative subscale of the Positive and Negative Syndrome Scale (PANSS) correlated with the Elaboration component, but no other component-subscale correlations reached significance. Implications of these results are that impairments in elaboration may underlie the commonly observed correlation between ToM and negative symptoms, but argue against a common neurocognitive system for JTC, ToM and positive symptoms.

© 2008 Elsevier Ireland Ltd. All rights reserved.

1. Introduction

Research in the field of cognitive neuropsychiatry in schizophrenia typically employs a univariate group-study approach, whereby measures from one experimental task are compared between patients and controls, and/or patient subgroups. In this fashion the cognitive neuropsychiatry literature has gradually evolved to a state where multivariate associations are implied by the pattern of univariate results. Frequently these interrelationships involve associations with the symptomatology of schizophrenia, such that several cognitive/neuropsychological tasks can be linked to the symptoms of schizophrenia in complementary patterns, potentially providing insight into the nature of the underlying neurocognitive systems if empirically supported.

For example, tasks measuring social cognition and reasoning biases have been applied to the study of schizophrenia in order to shed light on the cognitive underpinnings of positive symptoms (Black-

wood et al., 2001; Garety and Freeman, 1999). With respect to social cognition, it was initially speculated that impairments in understanding the mental states of others would lead to a misinterpretation of social cues, possibly resulting in paranoia and other delusions (Corcoran et al., 1995; Frith and Corcoran, 1996). However, the empirical evidence for these associations is often not well founded. Some schizophrenia studies have shown associations between measures of social cognition and delusions (Corcoran et al., 2007; Pickup and Frith, 2001; Pousa et al., 2008), but others have shown associations with negative symptoms (Bell and Mishara, 2006; Brüne, 2005; Harrington et al., 2005; Mazza et al., 2001; Shamay-Tsoory et al., 2007) or disorganization (Sarfati et al., 1997; Sprong et al., 2007). With respect to reasoning biases, it was hypothesized that impairments in reasoning, such as early termination of information gathering, could also result in paranoia and other delusions (Garety et al., 1991; Huq et al., 1988); however, the empirical evidence for whether or not reasoning biases correlate with positive symptoms is mixed (Corcoran et al., 2007; Garety and Freeman, 1999; McKay et al., 2007; Menon et al., 2006; Moritz and Woodward, 2005; Woodward et al., 2008; Young and Bental, 1997).

Negative symptoms are typically found to be associated with standardized neuropsychological measures such as verbal fluency, memory and executive functioning (Liddle and Morris, 1991; Moritz

* Corresponding author. BC Mental Health & Addictions Research Institute, Room 116, 3rd Floor, 938 W. 28th Avenue, Vancouver, B.C., Canada, V5Z 4H4. Tel.: +1 604 875 2000x4724; fax: +1 604 875 3871.

E-mail address: toddswoodward@gmail.com (T.S. Woodward).

et al., 2001b; Norman et al., 1997; Woodward et al., 2003; Woodward et al., 2004), and this has been largely confirmed in meta-analytic reviews (Aleman et al., 1999; Johnson-Selfridge and Zalewski, 2001). However, associations between positive symptoms and executive measures have also emerged in meta-analytic reviews (Johnson-Selfridge and Zalewski, 2001). Moreover, these associations are sometimes not replicated (Green and Walker, 1985; Liddle, 1987; Norman et al., 1997).

Thus, while reasoning biases and social cognition are theorized to associate with positive but not negative symptoms, and memory, executive and fluency performance are theorized to associate with negative but not positive symptoms, this pattern of association and dissociation is not particularly well supported by the empirical evidence from univariate studies. Advancement of these theoretical accounts would benefit from multivariate studies, whereby measures of reasoning biases, social cognition, verbal fluency, memory and executive functioning could be administered to a single sample, and factor analytic techniques used to explore how these measures share variance. Shared variance between these measures suggests that they may be underpinned by a common cognitive operation. Factor or component scores can then be computed and saved, and correlated with positive and negative symptoms.

In the current study we were primarily interested in two of the most commonly studied reasoning and social cognition paradigms: jumping to conclusions (JTC; Garety et al., 1991) and theory of mind (ToM; Frith and Corcoran, 1996). JTC paradigms typically involve the beads task, where the subject is presented with jars containing beads of two colours (e.g. red and white beads divided 60–40 in one jar and 40–60 in the other) and asked from which jar beads are being drawn when the jars have been hidden from view. Schizophrenia patients tend to request fewer beads before deciding on which one of the jars is the source of the beads. The JTC response pattern on probabilistic reasoning studies is thought to be caused by a “data gathering bias” (Garety and Freeman, 1999) whereby patients with delusions arrive at hasty conclusions using less information than healthy controls. This JTC response pattern has been widely replicated in patient groups (Garety et al., 1991; Huq et al., 1988; Menon et al., 2008; Menon et al., 2006; Moritz and Woodward, 2004; Woodward et al., 2008), and some studies have concluded that this response pattern might be associated with positive symptoms as a whole (Menon et al., 2008).

ToM is perhaps the most commonly investigated aspect of social cognition in schizophrenia, for which consideration of situational variables is required in order to determine the perspectives and intentions of other people. This has been of interest for the study of positive symptoms, because delusions can involve a misunderstanding of what is on the mind of others (e.g., paranoid delusions). The Hinting task (Corcoran et al., 1995) is a widely used ToM task, and measures the ability to infer the real intentions behind indirect speech (e.g., what did the child really mean when they said “Mom I’m hungry” when passing the candy aisle). The need to relate ToM measures to other aspects of cognition has been mentioned in reviews, as this has been identified as an important future direction for schizophrenia research (Harrington et al., 2005, p. 282). These relationships have been investigated in other fields of research; for example, in developmental psychology associations have been observed between ToM and inhibitory control (Carlson et al., 2002) and in autism associations have been observed between ToM and set shifting (Ozonoff et al., 1991).

Based on theory, and the original motivation for applying JTC and ToM cognitive challenge tasks to the study of schizophrenia, JTC and ToM may be expected to share variance with each other and with positive symptoms, whereas verbal fluency, memory and executive functions may be expected to share variance with each other and with negative symptoms. The objective of the current project was to use a multivariate approach to assess whether this pattern of associations and dissociations would emerge from an empirical multivariate

analysis. This involved two steps: a data-driven factor analytic approach to investigate the pattern of inter-relationships among the cognitive and clinical neuropsychological measures, followed by correlating the resulting factors with the positive and negative aspects of schizophrenia.

2. Methods

2.1. Participants

Forty-six patients were recruited from the inpatient and outpatient services of the Centre for Addiction and Mental Health (CAMH), Toronto. The study and the recruitment procedures were approved by the Research Ethics Board of CAMH and the University of Toronto, and all subjects provided written, informed consent prior to their participation. Thirty-five patients had a current diagnosis of schizophrenia, nine of schizoaffective disorder, and two of schizophreniform disorder. All clinical diagnoses were confirmed by a trained psychiatrist (RM) using the Mini-International Neuropsychiatric Interview (M.I.N.I.; Sheehan et al., 1998). Thirty-five patients were receiving atypical antipsychotics (clozapine $n=5$, olanzapine $n=16$, quetiapine $n=3$, risperidone $n=8$, fluphenazine $n=1$, loxapine $n=1$, modicate $n=1$), seven were medication-free at the time of testing, and medication information was not available for four patients. Patients had no significant medical or neurological illness, and no current substance abuse or dependence. Details of the participants and recruitment are published elsewhere (Mizrahi et al., 2006a).

The mean age at testing was 33.35 years (S.D. = 10.26), the mean years of education was 13.44 years (S.D. = 2.72), and the mean length of illness was 10.35 years (10.24). The mean number of previous hospitalizations was 2.83 (S.D. = 3.74), and the mean estimated Wechsler Adult Intelligence Scale IQ (WAIS; Wechsler, 1997), derived from the digit symbol and information subtest scores, was 97.50 (10.75). In and out-patients at various stages of illness participated in the study, as is reflected by the high standard deviations for age (min = 19, max = 60 yrs) and length of illness (min = 0, max = 40 yrs). Number of previous episodes ranged from 0 to 15 ($M=3.39$; S.D. = 3.75) and number of previous hospitalizations ranged from 0 to 15 ($M=2.83$, S.D. = 3.74). Five patients were experiencing their first episode. The heterogeneity of this sample resulted in substantial variation in symptomatology, as is required for an individual-difference-based correlational study.

2.2. Measures

2.2.1. Psychopathology

Symptom severity was assessed with the Positive and Negative Syndrome Scale (PANSS; Kay et al., 1989), designed to measure severity of psychopathology in adult subjects with schizophrenia, schizoaffective disorder and other psychotic illnesses, emphasizes positive and negative symptoms dimensions. It includes three scales and 30 items: seven items make up the Positive Scale (examples are delusions, conceptual disorganization, and hallucinatory behaviour), and seven items make up the Negative Scale (examples are blunted affect, emotional withdrawal, poor rapport, and passive/apathetic social withdrawal). Positive and Negative syndrome scores were computed as recommended by the PANSS developers ($M=16.91$, S.D. = 5.44; $M=15.64$, S.D. = 4.56, for positive and negative syndrome scores, respectively).

2.2.2. Clinical neuropsychology measures

The clinical measures for this study were derived from the Toronto Brief Inventory of Cognition developed by the fourth author (TBC; Christensen, 2002). This battery was developed to provide a short bedside neuropsychological battery that would be easily administered in the clinical setting. These tests were developed to represent shortened versions of standard neuropsychological measures that span the range of typically employed clinical neuropsychological test batteries. These measures have been shown to have test re-test reliability and validity comparable to the standard neuropsychological measures (Christensen, 2002).

2.2.2.1. Word list memory test. The verbal memory test involved recall of a list of 9 words composed of three categories of three words each. The word list was presented twice with free recall of the list after each presentation. The Acquisition measure was computed as the sum of words recalled from both trials (Trial 1 + Trial 2). Approximately 15–30 min after the acquisition phase, participants were asked to recall as many of the words as they can remember from the original list. The total number of words recalled constitutes the Free Recall Score. Subjects were then presented with a recognition list which consisted of 24 words: 9 target words, 9 related foils from the categories in the recall list (3 words from each category), and 6 distractor words. The foils and distractor words were comparable on frequency, imageability and category potency to the target words. The correct number of words correctly recognized minus the number of false positives comprised the Recognition score.

2.2.2.2. Rule extraction test. The Rule Extraction Test was designed to be conceptually similar to the Intra/Extradimensional Shift subtest of the CANTAB (Robbins et al., 1994), in that participants are presented with a series of paired drawings, and must determine which of the two stimuli presented contains the target element (e.g., black triangle, gray X, or gray angled line). The rules of the task are not explicitly conveyed to the

participants during this task; however, they are told whether they are correct or incorrect after each trial. There are 3 parts to this test, with the second and third parts corresponding to particular types of rule changes—intradimensional and reversal shifts respectively. The rules of the task change after the participant either scores 6 consecutive correct trials, or completes all 20 of the trials presented. The total number of correct responses is referred to as a Rule Extraction Score, and represents the participants' ability to ascertain rules and apply them appropriately.

2.2.2.3. Verbal and category fluency tests. The verbal and category fluency tests are widely used to evaluate a participant's ability to spontaneously generate words under restricted search conditions. For verbal fluency, participants were asked to generate as many words as possible that begin with a given letter of the alphabet (L, S, or F) in 30 s. These letters were derived from two commonly used and highly correlated sets of verbal fluency letter stimuli (F-A-S, C-F-L) (Spreen and Benton, 1969, 1977). The category fluency test is also a word-generation task in which participants are required to name as many items as they can from a particular category (furniture, vegetables, vehicles) in 30 s.

2.2.3. Cognitive neuropsychology measures

2.2.3.1. Theory of Mind (ToM). Theory of mind was assessed with the Hinting task as described by Corcoran et al., in which an individual is required to infer real intentions behind indirect speech (Corcoran et al., 1995). The task comprises 10 short passages presenting an interaction between two characters ending with one of the characters dropping an obvious hint. The subject is then asked what the character really meant when he/she said this. If the subjects failed to give the correct response, an even more obvious hint is added to the story. A correct response is therefore scored as 2 or 1 depending on when the response was given.

2.2.3.2. Jumping to Conclusions (JTC). Two versions of the standard probabilistic reasoning task were used—the neutral beads task (which is also the most commonly used version), and an emotionally salient version of the task, which has been shown to be more sensitive to the JTC response pattern (Dudley et al., 1997). Both versions required self-termination. In the neutral version, participants are presented with two jars containing beads of two colours mixed together in opposite ratios (one contains 60 red and 40 black beads, while the other contains 60 black and 40 red beads; Garety et al., 1991). The participants are told that the beads will be drawn from one of the jars, and the jars are hidden from view. The beads are drawn in a seemingly random but actually predetermined sequence, and are replaced after being shown. Participants are told to respond as soon as they know from which jar the beads are being drawn.

In the “emotional” version of the task (Dudley et al., 1997), participants are presented with positive and negative trait adjectives in the same ratio and sequence as the beads task. They are told that these are the results of two surveys conducted about a person. They are presented the words one at a time and told to respond when they know whether the words are from the “mostly good” or “mostly bad” survey. Details of task administration have been published elsewhere (Menon et al., 2008). Due to the limited number of trials, in order to increase reliability of the JTC measure, these JTC measures were summed to provide one JTC measure.

3. Results

Using Statistical Package for the Social Sciences (SPSS) 16.0 for Windows, the following measures were submitted to a principal component analysis with varimax rotation: Acquisition ($M=10.52$, $S.D.=2.93$), Free recall ($M=4.41$, $S.D.=2.02$) Recognition ($M=7.02$, $S.D.=1.72$), Verbal Fluency ($M=8.72$, $S.D.=2.59$), Category Fluency ($M=7.17$, $S.D.=2.08$), Rule Extraction ($M=48.35$, $S.D.=9.39$), ToM ($M=16.76$, $S.D.=3.40$), and JTC ($M=7.04$, $S.D.=5.35$). The eigenvalue-greater-than-one rule and scree plot converged on a three component solution that accounted for 60% of the total variance, with extraction eigenvalues of 2.34, 1.34, and 1.11. The component loadings

are listed in Table 1, with all loadings greater than 0.50 set in bold font. The first component was dominated by loadings on acquisition, free recall and recognition, and accounted 25% of the total variance (rotated). This component was labelled Memory. The second component had high loadings on verbal and category fluency, but also on the ToM task, and accounted for 19% of the total variance (rotated). We labelled this component Elaboration, reflecting the elaboration on selected mental sets required for successful performance on fluency tests (referred to as clustering; Troyer et al., 1998), and for the production of a wide variety of possible responses for success on the Hinting (ToM) task. The third component was dominated by high loadings on rule extraction (executive functioning) and the JTC task, and accounted for 16% of the total variance (rotated). It was labelled Flexibility, due to the shared cognitive operation of not over-committing to the presently viewed stimuli, and considering alternative solutions. The orthogonally rotated component scores were saved as variables and taken forward to compute correlations with the cognitive and neuropsychological measures.

With respect to the positive and negative syndrome scores derived from the PANSS, the negative syndrome score correlated significantly with the Elaboration component, $r(44)=-0.35$, $P<0.05$, but not with the Memory or Flexibility components, $r(44)=-0.20$, $P=0.18$ and $r(44)=0.05$, $P=0.77$, respectively. In contrast, the positive syndrome score did not correlate significantly with any of the components (Elaboration, Memory, and Flexibility, $r(44)=-0.09$, $P=0.56$, $r(44)=-0.23$, $P=0.13$, $r(44)=-0.15$, $P=0.33$, respectively). Exploratory correlations between each individual positive and negative PANSS item were also computed. The only correlation that would be considered significant after a conservative Bonferroni correction for multiple exploratory comparisons was between the Elaboration component and Difficulty in Abstract Thinking, $r(44)=-0.50$, $P<0.001$. Two other correlations to pass the uncorrected α level and give more detail regarding the association between the Elaboration component and negative symptoms: that between the Elaboration component and Emotional Withdrawal, $r(44)=-0.32$, $P<0.05$ and between the Elaboration component and Lack of Spontaneity, $r(44)=-0.30$, $P<0.05$.

In order to determine whether the variance unique to each construct (and therefore not reflected by the component scores) shared variance with the positive and negative subscales, a multiple regression analysis was carried out. The three component scores were forced into a regression equation, and the potential contribution of all univariate measures was assessed over and above that of the component scores. Using positive symptoms as the dependent measure, none of the individual variables accounted for variance over and above the three component scores (all $P_s>0.13$). Using negative symptoms as the dependent measure, two of the individual variables accounted for significant variance over and above the three component scores: JTC, $t(42)=2.44$, $P<0.05$, and ToM $t(42)=-2.03$, $P<0.05$ (all remaining $P_s>0.09$), but none of these would be considered significant after a Bonferroni correction.

4. Discussion

Based on theory, and the original motivation for applying cognitive challenge tasks to the study of schizophrenia, JTC and ToM may be expected to share variance with each other and with positive symptoms, whereas verbal fluency, memory and executive functions may be expected to share variance with each other and with negative symptoms. The objective of the current project was to use a multivariate approach to assess whether this pattern of associations and dissociations would emerge from an empirical analysis. A principal component analysis resulted in three components interpreted as Memory, Elaboration and Flexibility. In contrast with the association of ToM and JTC implied in the literature, ToM loaded with verbal fluency measures on the Elaboration component, whereas JTC

Table 1
Varimax rotated loading matrix ($N=46$).

	Memory	Elaboration	Flexibility
Acquisition	0.824	0.072	0.200
Free recall	0.815	0.030	0.213
Recognition	0.715	0.067	-0.080
Letter fluency	0.219	0.761	-0.166
Categories fluency	-0.019	0.704	0.108
Hinting (ToM)	0.006	0.613	0.183
Rule Extraction (Executive)	0.028	-0.034	0.910
Jumping to Conclusions (JTC)	0.246	0.239	0.562

Note. Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. All loadings 0.50 and above are set in bold font.

loaded with executive functioning on the Flexibility component. With respect to symptomatology, the negative syndrome score correlated significantly with the Elaboration component, but no other correlations were significant. Thus, although the JTC task and ToM tasks may be theorized to reflect brain systems that underpin positive symptoms, these current data do not provide support for such a common cognitive system.

The inclusion of the ToM task on the Elaboration component suggests that in order to perform well on the Hinting (ToM) task, it may be important to elaborate on the set of possible responses, a cognitive ability also required for success in verbal fluency (i.e., for producing expansive clusters of responses). We previously observed that for verbal fluency, clustering was associated with negative symptoms (Woodward et al., 2003), implicating elaboration on a selected mental set as an important cognitive underpinning of negative symptoms. This is congruent with previous accounts stating that an impaired ability to self-initiate mental activity underlies negative symptoms (Liddle, 2001, p. 135).

From this perspective it is interesting to note that the Elaboration component also correlated with the Difficulty in Abstract Thinking item ($r = .50$) from the PANSS, suggesting that ToM and Difficulty in Abstract Thinking may share an underlying cognitive construct (in fact the two individual items were correlated at -0.41 in these data, $P = 0.005$). Abstract thinking and social cognitive skills such as ToM may be enhanced by elaboration on cognitive sets by generating “alternative” views of the current situation, such as possible alternate meanings to the literal meaning of proverbs (e.g., “he has a chip on his shoulder”), non-literal interpretations of utterances, such as those that imply sarcasm (e.g., “you are sure working hard today”) and/or context-based understanding of social situations (e.g., “she is subdued today not because of what she thinks of me, but because she just went through a difficult breakup”). The correlation of the Elaboration component with negative symptoms also fits with literature suggesting a correspondence between ToM and negative symptoms (Bell and Mishara, 2006; Brüne, 2005; Harrington et al., 2005; Langdon et al., 2001; Mizrahi et al., 2006b), and supporting this is an observed high correlation between the individual ToM item and the PANSS negative score (-0.43 in the current data, $P < 0.005$).

ToM has empirically been demonstrated to correlate with a variety of neurocognitive measures, such as memory (Murphy, 1998) working memory (Bora et al., 2006), IQ (Brüne, 2003; Corcoran et al., 1995; Murphy, 1998), and executive functions (Bora et al., 2007; Langdon et al., 2001); however, the independence of ToM performance from the rule extraction measures in the current study fails to support this. The discrepancy of the results relating ToM to executive functions may be attributable to use of a variety of tasks to measure ToM, with the two most common being the Hinting task (used here) and the false belief task (Corcoran et al., 1995). In addition to the importance of the specific ToM measure used, associations may also depend on chronicity (Pousa et al., 2008).

The overlap between JTC and executive functions (i.e., rule extraction) may be attributable to common cognitive operations promoting flexibility. Performing normally on the JTC and the rule extraction task requires the ability to avoid over-committing to the currently processed stimulus. Put simply, avoiding over-commitment to the currently processed stimulus would lead to requesting more “beads” before deciding, resulting in conservative behaviour on the JTC test, and switching rules, leading to greater success on the rule extraction task. Relatedly, Garety et al. (2005) suggested that “cognitive flexibility” underlies performance on the JTC task.

The distinction between elaboration and flexibility is a subtle one, because some conceptualizations of cognitive flexibility and executive functioning propose that generating alternatives is important for both these aspects of cognition. Although there is validity to this perspective when executing functions are considered as a whole, elaboration and flexibility are fundamentally distinct cognitive operations. Notably, a clear distinction between elaboration and

flexibility has previously been put forward and operationalized as the distinction between clustering and switching mental sets in verbal fluency (Troyer et al., 1998). In our previous work on verbal fluency and schizophrenia (Woodward et al., 2003), in accordance with the work presented here, we observed that clustering, but not switching, was associated with negative symptoms. The absence of an association between switching mental set and negative symptoms was also observed in the current multivariate analysis, and is consistent with previous work reporting an absence of an association between negative symptoms and tests assessing mental flexibility, such as the Wisconsin Card Sorting Test (Liddle and Morris, 1991; Moritz et al., 2001a; O'Leary et al., 2000). Thus, this finding is congruent with the proposal that impairment in elaboration on a selected mental set, not switching between mental sets, underlies negative symptoms.

Using negative symptoms as the dependent measure, JTC and ToM accounted for significant (at the uncorrected level) proportions of variance over and above the three component scores, but only null results were observed when positive symptoms were used as the dependent variable. This suggests that variance unique to these two univariate measures, and not common to the components, are may also be important for understanding negative symptoms. For example, in addition to elaboration on a mental set, performance on the Hinting task may be affected by awareness of social cues and context, which may also be impaired when negative symptoms are present (Bora et al., 2006). Performance on the JTC task, in addition to flexibility and avoidance of overcommitment to the stimulus at hand (which JTC shares with the Rule Extraction task), involves setting a cutoff for when sufficient information is available to decide (Moritz et al., 2007), and this may in turn be related to negative symptoms.

An important limitation of this study is that the sample size is considered relatively small for a multivariate study. With 8 variables and 46 subjects the subject to variable ratio was 5.75:1. Although this ratio meets the recommended minimum criterion of 5:1 for factor analysis (Gorusch, 1983), it falls short of the more conservative and widely cited 10:1 ratio (Nunnally, 1978). The component structure reported in Table 1 is a good demonstration of simple structure (Yates, 1987), making it less likely to have arisen due to spurious correlations between items; however, future multivariate studies may involve larger sample sizes and more comprehensive test batteries in order to increase the reliability and generalizability of the findings.

Multivariate analyses of the cognitive and neuropsychological measures that are theorized to underlie the symptoms of schizophrenia are important for understanding the relationships between these constructs, and whether this overlap is associated with symptomatology. This multivariate approach allows assessment of associations and dissociations that are implied by the patterns of univariate results currently available in the cognitive neuropsychiatry literature. For example, the measures of JTC and ToM are two of the most commonly studied cognitive paradigms in cognitive neuropsychiatry, consistently mentioned in reviews of the literature (Bell et al., 2006; Blackwood et al., 2001; Davies et al., 2001; Garety and Freeman, 1999), but are typically not included together in batteries of cognitive and neuropsychological tests (for an exception see Corcoran et al., 2007). When each test is studied in isolation, and conclusions based on group comparisons, patterns of interrelations between the involved tests and symptoms are implied, but cannot be empirically determined. Therefore, multivariate studies are important for advancing our understanding of the associations and dissociations among the cognitive operations that underlie the symptoms of schizophrenia.

Acknowledgements

The authors thank Sandy Richards, RN, CMHPN(c), CCRC and Ivana Furimsky, RN, MN, CPMHN(c), CCRC for their recruitment efforts, and Pablo Rusjan, PhD for software development. TSW is supported by a Scholar award from the Michael Smith Foundation for Health Research, and a New Investigator Award from the Canadian Institutes of Health Research. RM is supported by a New Investigator Award from the Canadian Institutes of Health Research.

References

- Aleman, A., Hijman, R., de Haan, E.H.F., Kahn, R.S., 1999. Memory impairment in schizophrenia: a meta-analysis. *American Journal of Psychiatry* 156, 1358–1366.
- Bell, M.D., Mishara, A.L., 2006. Does negative symptom change relate to neurocognitive change in schizophrenia? Implications for targeted treatments. *Schizophrenia Research* 81, 17–27.
- Bell, V., Halligan, P.W., Ellis, H.D., 2006. Explaining delusions: a cognitive perspective. *Trends in Cognitive Sciences* 10, 219–226.
- Blackwood, N.J., Howard, R.J., Bentall, R.P., Murray, R.M., 2001. Cognitive neuropsychiatric models of persecutory delusions. *American Journal of Psychiatry* 158, 527–539.
- Bora, E., Erayavuz, A., Kayahan, B., Sungu, G., Veznedaroglu, B., 2006. Social functioning, theory of mind and neurocognition in outpatients with schizophrenia; mental state decoding may be a better predictor of social functioning than mental state reasoning. *Psychiatry Research* 145, 95–103.
- Bora, E., Sehitoğlu, G., Aslier, M., Atabay, I., Veznedaroglu, B., 2007. Theory of mind and unawareness of illness in schizophrenia: is poor insight a mentalizing deficit? *European Archives of Psychiatry and Clinical Neuroscience* 257, 104–111.
- Brüne, M., 2003. Theory of mind and the role of IQ in chronic disorganized schizophrenia. *Schizophrenia Research* 60, 57–64.
- Brüne, M., 2005. Emotion recognition, 'theory of mind,' and social behavior in schizophrenia. *Psychiatry Research* 133, 135–147.
- Carlson, S., Moses, L., Breton, C., 2002. How specific is the relation between executive function and theory of mind? Contributions of inhibitory control and working memory. *Infant and Child Development* 11, 73–92.
- Christensen, B., 2002. Toronto Brief Inventory of Cognition (TBIC). Copyright Bruce Christensen, Toronto.
- Corcoran, R., Mercer, G., Frith, C.D., 1995. Schizophrenia, symptomatology and social inference: investigating "Theory of mind" in people with schizophrenia. *Schizophrenia Research* 17, 5–13.
- Corcoran, R., Rowse, G., Moore, R., Blackwood, N., Kinderman, P., Howard, R., Cummins, S., Bentall, R.P., 2007. A transdiagnostic investigation of 'theory of mind' and 'jumping to conclusions' in patients with persecutory delusions. *Psychological Medicine* 1–7.
- Davies, D.R., Coltheart, M., Langdon, R., Breen, N., 2001. Monothematic delusions: towards a two-factor account. *Philosophy, Psychiatry, & Psychology* 8, 133–158.
- Dudley, R.E., John, C.H., Young, A.W., Over, D.E., 1997. The effect of self-referent material on the reasoning of people with delusions. *British Journal of Clinical Psychology* 36 (Pt 4), 575–584.
- Frith, C.D., Corcoran, R., 1996. Exploring 'theory of mind' in people with schizophrenia. *Psychological Medicine* 26, 521–530.
- Garety, P.A., Freeman, D., 1999. Cognitive approaches to delusions: a critical review of the evidence. *British Journal of Clinical Psychology* 38, 113–154.
- Garety, P.A., Hemsley, D.R., Wessely, S., 1991. Reasoning in deluded schizophrenic and paranoid patients: biases in performance on a probabilistic inference task. *Journal of Nervous and Mental Disease* 179, 194–201.
- Garety, P.A., Freeman, D., Jolley, S., Dunn, G., Bebbington, P.E., Fowler, D.G., Kuipers, E., Dudley, R., 2005. Reasoning, emotions, and delusional conviction in psychosis. *Journal of Abnormal Psychology* 114, 373–384.
- Gorusch, R.L., 1983. *Factor Analysis* (2nd ed.). Lawrence Erlbaum Associates, Hillsdale, NJ.
- Green, M., Walker, E., 1985. Neuropsychological performance and positive and negative symptoms in schizophrenia. *Journal of Abnormal Psychology* 94, 460–469.
- Harrington, L., Siegert, R.J., McClure, J., 2005. Theory of mind in schizophrenia: a critical review. *Cognitive Neuropsychiatry* 10, 249–286.
- Huq, S.F., Garety, P.A., Hemsley, D.R., 1988. Probabilistic judgments in deluded and non-deluded subjects. *Quarterly Journal of Experimental Psychology* 40, 801–812.
- Johnson-Selfridge, M., Zalewski, C., 2001. Moderator variables of executive functioning in schizophrenia: meta-analytic findings. *Schizophrenia Bulletin* 27, 305–316.
- Kay, S.R., Opler, L.A., Lindenmayer, J.P., 1989. The positive and negative syndrome scale (PANSS): rationale and standardisation. *British Journal of Psychiatry* 155, 59–65.
- Langdon, R., Coltheart, M., Ward, P.B., Catts, S.V., 2001. Mentalising, executive planning and disengagement in schizophrenia. *Cognitive Neuropsychiatry* 6, 81–108.
- Liddle, P.F., 1987. Schizophrenic syndromes, cognitive performance and neurological dysfunction. *Psychological Medicine* 17, 49–57.
- Liddle, P.F., 2001. *Disordered Mind and Brain: The Neural Basis of Mental Symptoms*. Gaskell, London.
- Liddle, P.F., Morris, D.L., 1991. Schizophrenic syndromes and frontal lobe performance. *British Journal of Psychiatry* 158, 340–345.
- Mazza, M., De Risio, A., Surian, L., Roncone, R., Casacchia, M., 2001. Selective impairments of theory of mind in people with schizophrenia. *Schizophrenia Research* 47, 299–308.
- McKay, R., Langdon, R., Coltheart, M., 2007. The defensive function of persecutory delusions: an investigation using the implicit association test. *Cognitive Neuropsychiatry* 12, 1–24.
- Menon, M., Pomarol-Clotet, E., McKenna, P., McCarthy, R., 2006. Probabilistic reasoning in schizophrenia: a comparison of the performance of deluded and nondeluded schizophrenic patients and exploration of possible cognitive underpinnings. *Cognitive Neuropsychiatry* 11, 521–536.
- Menon, M., Mizrahi, R., Kapur, S., 2008. 'Jumping to conclusions' and delusions in psychosis: relationship and response to treatment. *Schizophrenia Research* 98, 225–231.
- Mizrahi, R., Kiang, M., Mamo, D.C., Arenovich, T., Bagby, R.M., Zipursky, R.B., Kapur, S., 2006a. The selective effect of antipsychotics on the different dimensions of the experience of psychosis in schizophrenia spectrum disorders. *Schizophrenia Research* 88, 111–118.
- Mizrahi, R., Korostil, M., Starkstein, S.E., Zipursky, R.B., Kapur, S., 2006b. The effect of antipsychotic treatment on theory of mind. *Psychological Medicine* 1–7.
- Moritz, S., Woodward, T.S., 2004. Plausibility judgement in schizophrenic patients. Evidence for a liberal acceptance bias. *German Journal of Psychiatry* 7, 66–74.
- Moritz, S., Woodward, T.S., 2005. Jumping to conclusions in delusional and non-delusional schizophrenic patients. *British Journal of Clinical Psychology* 44, 1–16.
- Moritz, S., Andresen, B., Jacobsen, D., Mersmann, K., Wilke, U., Lambert, M., Krausz, M., Naber, D., 2001a. Neuropsychological correlates of schizophrenic syndromes in patients treated with atypical neuroleptics. *European Psychiatry* 16, 354–361.
- Moritz, S., Heeren, D., Andresen, B., Krausz, M., 2001b. An analysis of the specificity and the syndromal correlates of verbal memory impairments in schizophrenia. *Psychiatry Research* 101, 23–31.
- Moritz, S., Woodward, T.S., Lambert, M., 2007. Under what circumstances do patients with schizophrenia jump to conclusions? A liberal acceptance account. *British Journal of Clinical Psychology* 46, 127–137.
- Murphy, D., 1998. Theory of mind in a sample of men with schizophrenia detained in a special hospital: its relationship to symptom profiles and neuropsychological tests. *Criminal Behaviour and Mental Health* 8, 13–26.
- Norman, R.M.G., Malla, A.K., Morrison-Stewart, S.L., Helmes, E., Williamson, P.C., Thomas, J., Cortese, L., 1997. Neuropsychological correlates of syndromes in schizophrenia. *British Journal of Psychiatry* 170, 134–139.
- Nunnally, J.C., 1978. *Psychometric Theory*, 2nd ed. McGraw Hill, New York.
- O'Leary, D.S., Flaum, M., Kesler, M.L., Flashman, L.A., Arndt, S., Andreasen, N.C., 2000. Cognitive correlates of the negative, disorganized, and psychotic symptom dimensions of schizophrenia. *Journal of Neuropsychiatry and Clinical Neurosciences* 12, 4–15.
- Ozonoff, S., Pennington, B., Rogers, S., 1991. Executive function deficits in high-functioning autistic individuals: relationship to theory of mind. *Journal of Child Psychology and Psychiatry* 32, 1081–1105.
- Pickup, G.J., Frith, C.D., 2001. Theory of mind impairments in schizophrenia: symptomatology, severity and specificity. *Psychological Medicine* 31, 207–220.
- Pousa, E., Duno, R., Brebion, G., David, A.S., Ruiz, A.I., Obiols, J.E., 2008. Theory of mind deficits in chronic schizophrenia: evidence for state dependence. *Psychiatry Research* 158, 1–10.
- Robbins, T.W., James, M., Owen, A.M., Sahakian, B.J., McInnes, L., Rabbitt, P., 1994. Cambridge neuropsychological test automated battery (CANTAB): a factor analytic study of a large sample of normal elderly volunteers. *Dementia* 5, 266–281.
- Sarfati, Y., Hardy-Bayle, M.C., Besche, C., Widlocher, D., 1997. Attribution of intentions to others in people with schizophrenia: a non-verbal exploration with comic strips. *Schizophrenia Research* 25, 199–209.
- Shamay-Tsoory, S.G., Shur, S., Barcai-Goodman, L., Medlovich, S., Harari, H., Levkovitz, Y., 2007. Dissociation of cognitive from affective components of theory of mind in schizophrenia. *Psychiatry Research* 149, 11–23.
- Sheehan, D.V., Lecrubier, Y., Sheehan, K.H., Amorim, P., Janavs, J., Weiller, E., Hergueta, T., Baker, R., Dunbar, G.C., 1998. The mini-international neuropsychiatric interview (m.I.N.I.): the development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. *Journal of Clinical Psychiatry* 59 (Suppl 20), 22–33.
- Spreen, O., Benton, A.L., 1969, 1977. *Neurosensory Center Comprehensive Examination for Aphasia (NCCCA)*. University of Victoria Neuropsychology Laboratory, Victoria.
- Sprong, M., Schothorst, P., Vos, E., Hox, J., van Engeland, H., 2007. Theory of mind in schizophrenia: meta-analysis. *British Journal of Psychiatry* 191, 5–13.
- Troyer, A.K., Moscovitch, M., Winocur, G., Alexander, M.P., Stuss, D., 1998. Clustering and switching on verbal fluency: the effects of focal frontal- and temporal-lobe lesions. *Neuropsychologia* 36, 499–504.
- Wechsler, D., 1997. *Wais-III. Wechsler Adult Intelligence Scale, third edition*. The Psychological Corporation, San Antonio.
- Woodward, T.S., Ruff, C.C., Thornton, A.E., Moritz, S., Liddle, P., 2003. Methodological considerations regarding the association of Stroop and verbal fluency performance with the symptoms of schizophrenia. *Schizophrenia Research* 61, 207–214.
- Woodward, T.S., Thornton, A.E., Ruff, C.C., Moritz, S., Liddle, P.F., 2004. Material-specific episodic memory associates of the psychomotor poverty syndrome in schizophrenia. *Cognitive Neuropsychiatry* 9, 213–227.
- Woodward, T.S., Munz, M., LeClerc, C., Lecomte, T., 2008. Change in delusions is associated with change in "jumping to conclusions". *Psychiatry Research*, doi:10.1016/j.psychres.2008.10.020.
- Yates, A., 1987. *Multivariate Exploratory Data Analysis: A Perspective on Exploratory Factor Analysis*. State University of New York Press, Albany.
- Young, H.F., Bentall, R.P., 1997. Probabilistic reasoning on deluded, depressed and normal subjects: effects of task difficulty and meaningful versus non-meaningful material. *Psychological Medicine* 27, 455–465.