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Socio-neuro risk factors for suicidal behavior in criminal offenders with psychotic disorders

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Abstract

Relative to the general population, individuals with psychotic disorders have a higher risk of suicide. Suicide risk is also elevated in criminal offenders. Thus, psychotic-disordered individuals with antisocial tendencies may form an especially high-risk group. We built upon prior risk analyses by examining whether neurobehavioral correlates of social cognition were associated with suicidal behavior in criminal offenders with psychotic disorders. We assessed empathic accuracy and brain structure in four groups: (i) incarcerated offenders with psychotic disorders and past suicide attempts, (ii) incarcerated offenders with psychotic disorders and no suicide attempts, (iii) incarcerated offenders without psychotic disorders and (iv) community non-offenders without psychotic disorders. Established suicide risk variables were examined along with empathic accuracy and gray matter in brain regions implicated in social cognition. Relative to the other groups, offenders with psychotic disorders and suicide attempts had lower empathic accuracy and smaller temporal pole volumes. Empathic accuracy and temporal pole volumes were significantly associated with suicide attempts independent of other risk variables. The results indicate that brain and behavioral correlates of social cognition may add incremental value to models of suicide risk.

Key words: empathic accuracy; temporal poles; suicide; psychosis

Introduction

Psychotic disorders, such as schizophrenia and bipolar disorder with psychotic features, are associated with an 8- to 12-fold risk of suicide compared with the general population (Roy, 1986; Caldwell and Gottesman, 1990; Breier *et al.*, 1991; Harris and Barraclough, 1997; Dutta *et al.*, 2010; Nordentoft *et al.*, 2011). It is difficult to assess which psychotic individuals are at higher risk than others, though certain risk variables have been identified (e.g. comorbid psychiatric disorders, substance abuse, family history of suicide, medication discontinuation, insight into illness) (Potkin *et al.*, 2003; Hawton *et al.*, 2005a,b; Hor and Taylor, 2010). While some of these variables contribute to suicide risk assessment, they may be difficult to predict (e.g. medication discontinuation) or may represent static variables that cannot be modified (e.g. family history). There is thus a need for research to characterize dynamic risk variables that can be identified early and modified with treatment.

Disturbances in social behavior are a core feature of psychotic disorders. Underlying these disturbances are impairments in the production and interpretation of appropriate social signals such as facial and vocal emotion recognition (Getz *et al.*, 2003; Kohler *et al.*, 2010), emotional and mental state attribution (Brüne, 2005; Olley *et al.*, 2005; Langdon *et al.*, 2006; Leitman *et al.*, 2006), and empathic accuracy (Derntl *et al.*, 2009; Shamay-Tsoory *et al.*, 2009; Lee *et al.*, 2011b; Smith *et al.*, 2015). Patients with schizophrenia tend to show greater deficits compared those with bipolar disorder (Lee *et al.*, 2013). These deficits are associated with poor outcomes (Fett *et al.*, 2011) including impaired interpersonal skills and social functioning (Hooker and Park, 2002; Pinkham and Penn, 2006), and mediate the relationship between neurocognitive impairment and overall functioning (Green and Horan, 2010; Couture *et al.*, 2011; Horan *et al.*, 2012; Schmidt *et al.*, 2011). They may also affect family and peer relationships, causing feelings of social disconnection. Although lack of social connectedness is an often-cited risk factor for suicide (Durkheim, 1897; Shneidman, 1998; Joiner *et al.*, 2009; Van Orden *et al.*, 2010; O'Connor, 2011), to date there has been little direct examination of the association between social cognitive impairment and suicidal behavior.

The neuroanatomical underpinnings of social cognition have been well established (Cacioppo and Decety, 2011). For example, mental state attribution, or mentalizing, reliably engages the medial prefrontal cortex (mPFC), posterior superior temporal cortex (posterior ST) and temporal poles (Frith and Frith, 2003; Amodio and Frith, 2006; Olson *et al.*, 2007; Assaf *et al.*, 2009). Individuals with psychotic disorders show aberrant functional responses in these regions when performing social cognitive tasks, which are related to overall social functioning (Brunet-Gouet and Decety, 2006; Malhi *et al.*, 2008; Benedetti *et al.*, 2009; Kim *et al.*, 2009; Dodell-Feder *et al.*, 2014). Furthermore, anatomical MRI studies have reported gray matter volume reductions in some of these regions, most consistently posterior ST, among psychotic-disordered individuals with a history of suicide attempts (Aguilar *et al.*, 2008; van Heeringen *et al.*, 2011; Giakoumatos *et al.*, 2013). This finding has been attributed to altered social perception (inferred perceptions of oneself by others which lead to negative affect) (Giakoumatos *et al.*, 2013).

Most of the patient research summarized above has been conducted in psychotic-disordered individuals who reside in the community. Another group of individuals at high risk for suicide is prisoners. Individuals who become imprisoned at some point show increased suicidal thoughts and behaviors throughout their lives, with a rate of almost six times the general population among males (Fruehwald *et al.*, 2004; Jenkins *et al.*, 2005). Thus, criminal offenders with psychotic disorders may represent an especially high-risk group (Baillargeon *et al.*, 2009; Haglund *et al.*, 2014). It is challenging to conduct neuroimaging studies of criminal offenders due to incarceration and the practical challenges associated with bringing imaging capabilities to prisons (or transporting prisoners to outside imaging facilities, which is often not possible or permissible). In this study, we used a mobile MRI scanner that was situated on prison grounds, enabling us to recruit and scan psychotic-disordered offenders.

The goal of this study was to compare the behavioral and brain correlates of social cognition in psychotic offenders with and without a history of suicide attempts. Although not all suicide attempters go on to complete suicide, past attempts are among the strongest predictors of future suicide (Gunnell and Lewis, 2005). We chose to examine empathic accuracy, defined here as the ability to infer others' emotions in social contexts. The empathic accuracy task we used presented video clips to study participants in which people (not actors) described autobiographical events, and participants indicated which types of emotions the people most likely experienced during the event (Ickes, 1997; Brook and Kosson, 2013). This task was chosen for its interpersonal and dynamic features, which resembles the types of social cognitive abilities that individuals use in real-life social interactions. Additionally, difficulty inferring specific types of emotions in others could be expected to escalate interpersonal conflict and feelings of social alienation (for example, misinterpreting nervousness or shyness as irritation or anger).

We compared task performance and brain structure between psychotic offenders with and without a history of suicide attempt/s, and also compared performance with nonpsychotic offenders and community non-offenders. The community non-offender group was used to provide standard measures of empathic accuracy and brain structure. However, because this group was likely to differ from the psychotic offenders on characteristics other than psychosis or suicidal behavior (e.g. substance abuse, criminal behavior, impoverished environments), we also included a non-psychotic offender comparison group. We hypothesized that psychotic offenders with a history of suicide attempts would show lower empathic accuracy and smaller posterior superior temporal (posterior ST) gray matter volume. Although the posterior ST was our primary region of interest, we also included the temporal poles and mPFC, which have been implicated in studies of mental state attribution in schizophrenia and bipolar disorder (Benedetti *et al.*, 2009; Kim *et al.*, 2009; Lee *et al.*, 2010; Lee *et al.*, 2011a; Dodell-Feder *et al.*, 2014). We hypothesized that empathic accuracy and gray matter volumes would add incremental value to the discrimination of psychotic offenders with and without past suicide attempts, independent of other established risk variables for suicide (e.g. depression).

Method

Participants

The total sample included 126 participants: (a) male criminal offenders ($n = 41$) who met DSM-IV criteria for schizophrenia ($n = 19$), schizoaffective disorder ($n = 11$), bipolar disorder with psychotic features ($n = 9$), major depressive disorder with psychotic features ($n = 1$) or psychotic disorder not otherwise specified ($n = 1$); (b) male criminal offenders with no history of a psychotic disorder ($n = 59$) and (c) male community non-offenders ($n = 26$). Incarcerated offenders were recruited from state psychiatric/ treatment and prison facilities in Wisconsin and New Mexico.

Table 1. Demographic and clinical characteristics of study groups

	Community non-offender (n = 26)	Non-psychotic offender (n = 59)	Psychotic no suicide attempt (n = 25)	Psychotic suicide attempt (n = 18)			Post hoc
	M (s.d.)	M (s.d.)	M (s.d.)	M (s.d.)	F	P	
Age	32.5 (11.16)	33.0 (9.49)	40.2 (10.23)	38.9 (11.73)	4.23	0.01	CN/NO < PN/PS
IQ estimate	114.8 (14.69)	98.1 (13.22)	94.9 (14.45)	93.8 (18.61)	10.66	< .001	CN > NO/PN/PS
PCL-R	–	22.5 (7.65)	21.4 (7.30)	21.1 (6.26)	0.34	0.71	–
					t	P	
Illness duration	–	–	15.8 (12.33)	17.8 (13.36)	0.50	0.62	–
Olanzapine equiv.	–	–	19.8 (14.76)	23.4 (16.34)	0.74	0.47	–
PANSS positive	–	–	15.0 (5.86)	14.7 (5.99)	0.16	0.88	–
PANSS negative	–	–	12.6 (5.07)	12.7 (5.78)	0.02	0.98	–
PANSS general	–	–	26.0 (9.70)	28.35 (5.60)	0.90	0.38	–
BIS	–	–	60.6 (12.06)	60.6 (12.95)	0.00	1.00	–
	%	%	%	%	χ^2	P	
Race (CA:AA:OT)	61.5:11.5:27	47:47:5	60:32:8	50:39:11	20.3	0.06	–
Handedness (R:L:B)	73:8:19	88:5:7	88:8:4	78:17:5	7.45	0.28	–
Psychotic disorder (SZ:SZA:BP:OT)	–	–	40:32:24:4	61:17:17:5	2.24	0.52	–
Anxiety disorder	–	2	16	17	0.00	0.95	–
Early adverse experiences	–	–	44	47	0.04	0.98	–
Serious violence	–	87[a]	57.7	76.5	1.85	0.17	

IQ, intelligence quotient estimate from the vocabulary and matrix reasoning subtests of the WAIS; PCL-R, psychopathy checklist-revised; PANSS, positive and negative symptom scale; BIS, Barratt impulsiveness scale; CA, Caucasian; AA, African American; OT, other; R, right; L, left; B, both (no dominant hand); SZ, schizophrenia; SZA, Schizoaffective disorder; BP, bipolar disorder; OT, other psychotic disorder.
[a]Five participants were excluded from this analysis due to insufficient detail available regarding the degree of injury or use of weapons related to assault.

Non-offenders were recruited from the NM community. All participants were scanned using the same mobile MRI scanner. Inclusion criteria for the psychotic offender group were: (i) age between 18 and 60, (ii) native English speaker, (iii) reading level fourth grade or higher, (iv) no history of epilepsy or seizures, (v) no history of serious head injury with loss of consciousness longer than 1 h, (vi) no history of mental retardation or developmental disability. These criteria were also applied to both control groups, in addition to: (i) no lifetime psychotic disorder in self or first-degree relative or recurrent major mood Axis I disorder, (ii) no history of paranoid, schizotypal or schizoid Axis II disorder. Community non-offenders were additionally required to have no history of drug use or alcohol use disorder and no criminal offenses. Written informed consent was obtained from all participants at the initial study session after a complete description of the study procedures, which were approved by the University of New Mexico Institutional Review Board. Participants were paid at a rate commensurate to work assignments at their facility. No prior studies have reported on the psychotic or non-offender participants. A subset of the non-psychotic offender group has been included in prior studies (Motzkin *et al.*, 2011; Ly *et al.*, 2012; Motzkin *et al.*, 2014; Pujara *et al.*, 2013; Philippi *et al.*, 2015; Wolf *et al.*, 2015).

Of the 41 psychotic offenders, 18 had a history of suicide attempt/s and 23 did not. Psychotic offenders were consecutively enrolled in the study (rather than being selected based on history of suicidal behavior). Classification of suicide attempts was based on criteria outlined in the Colombia Suicide Severity Rating Scale (C-SSRS) (Posner *et al.*, 2011): a potentially self-injurious act committed with at least some wish to die as a result of the act. Relevant life history details were obtained via interviews and file review. Specifically, we reviewed participant institutional files that contained medical records with annual psychiatry reports, psychosocial history summaries dating back to childhood and interval reports regarding adjustment to the

facility and treatment progress. Usually, these were sufficient to determine whether the individual had a history of a suicide attempt. In rare cases where file content was insufficient, information was obtained from the Structured Clinical Interview for DSM-IV Disorders (SCID-IV) and/or Hare Psychopathy Checklist-Revised (PCL-R) interviews (see below). Demographic and clinical characteristics of the four groups are provided in Table 1.

Assessments

Past and present DSM-IV Axis I and II disorders were evaluated in all participants using the research version of the Structured Clinical Interview for DSM-IV Disorders (SCID-IV) (First *et al.*, 1997). Psychotic disorder diagnoses in incarcerated offenders were confirmed with additional file reviews of previous evaluations by facility psychologists or physicians. Current symptoms were evaluated in psychotic offenders using the Positive and Negative Symptom Scale (Kay *et al.*, 1987). All except six psychotic offenders were taking antipsychotic medications at the time of the study. Medication dosages were converted to daily olanzapine equivalents (Gardner *et al.*, 2010) (see Supplementary data for additional information). Intelligence was assessed with the vocabulary and matrix reasoning subtests of the Wechsler Adult Intelligence Scale (WAIS) (Wechsler, 1997; Ryan *et al.*, 1999). Psychopathy, which is more prevalent among offenders (Hare, 2003) and associated with lower empathic accuracy (Brook and Kosson, 2013), was assessed using the Hare Psychopathy Checklist-Revised (PCL-R) (Hare, 2003).

Established risk variables for suicide in psychotic individuals (Potkin *et al.*, 2003; Hawton *et al.*, 2005a; Hor and Taylor, 2010) were examined. Positive and negative symptoms, as well as insight, were scored from relevant PANSS items. Because studies have found that high levels of positive symptoms and low levels of negative symptoms are associated with the highest risk for suicide (Hor and Taylor, 2010), we separated participants into groups based on whether their positive and negative symptom scores

were above or below the group median (i.e. High Positive + High Negative, High Positive + Low Negative, Low Positive + High Negative and Low Positive + Low Negative), and created a binary measure (HP + LN *vs* other groups). Participants with a symptom score equal to the median ($n = 13$) were excluded from analysis with this variable. Depression was defined as having a history of at least one major depressive episode. Relevant clinical information was obtained from the SCID and file review. Information regarding substance use disorders was obtained from the SCID (see Supplementary data for additional information).

We also evaluated variables associated with increased suicide risk in the general population: impulsivity, anxiety, aggression and early adverse experiences (e.g. physical and/or or sexual abuse) (Sareen *et al.*, 2005; Nock and Kessler, 2006; Stein *et al.*, 2010; Swann *et al.*, 2005). Impulsivity was measured using the Barratt Impulsiveness Scale (Patton *et al.*, 1995). History of anxiety disorder was evaluated with the SCID. Early abuse was assessed using a modified version of the Traumatic Life Events Questionnaire (Kubany *et al.*, 2000; http://www.bhevolution.org). For aggression, we assessed the individuals' history of violent acts. Participants were assigned to one of the two categories: no violence or minor violence (e.g. assault without injury or weapon use) and serious violence (e.g. sexual offense, homicide) (Swanson *et al.*, 2006). Violence information was obtained via an interview in which participants were asked if they had ever committed each of several different classes of crime (e.g. robbery, homicide, DUI, minor assault). Self-report was checked against file/criminal records. None of these variables significantly differed between psychotic offenders with and without past suicide attempts (Table 1).

Empathic accuracy task

Participants viewed 13 brief video clips in which the 'target' individual described an affectively laden social situation they had previously experienced. The target was a volunteer relating an event they had actually experienced (not an actor). Target volunteers were diverse in age, race and ethnicity and included both males and females. The target was situated/angled in the video to simulate an interpersonal interaction with the participant. Following each clip the participant completed an answer sheet which listed 25 emotions comprising the tripartite hierarchical inventory of emotion words (Parrott, 2001). They were instructed to select which emotions they believed the target had experienced, and to rank the selected emotions in order (#1 being the most relevant). Empathic accuracy was operationalized as the degree of correspondence (0–2 Likert scale) between the participant rating of the most salient emotion (i.e. the emotion ranked #1) and the target rating of the most salient emotion. The total possible score was 26/26 (i.e. score of 2 for each of the 13 scenarios), thus a range of 0–100% accuracy. The task has shown high construct validity with other empathic accuracy measures (Brook and Kosson, 2013).

MRI acquisition

High-resolution T1-weighted structural MRI scans were collected on a Siemens 1.5T Avanto mobile scanner, stationed at the correctional facility, using an MPRAGE pulse sequence on a 32-channel head coil (repetition time = 2400 ms, echo times = 2.41 ms, inversion time = 1000 ms, flip angle = 8°, slice thickness = 1.2 mm, matrix size = 240 × 240) yielding 160 sagittal slices with an in-plane resolution of 1.3 mm × 1.3 mm. Data were preprocessed and analyzed using the Statistical Parametric

Mapping software (SPM12; http://www.fil.ion.ucl.ac.uk/spm). T1 images were manually inspected by an operator blind to subject identity and realigned to ensure proper spatial normalization. Data were then spatially normalized into the standard Montreal Neurological Institute space, resampled to $2 \times 2 \times 2$ mm voxels and segmented into white matter, gray matter and cerebrospinal fluid. The segmented maps were modulated to preserve total cerebral volume (Ashburner and Friston, 2005) and voxels with values < 0.15 were removed. The segmented images were then smoothed using a Gaussian kernel with a full-width at half-maximum of 10 mm. Five psychotic offenders (three from the non-suicide attempt group) did not complete the MRI scan due to MRI incompatibility ($n = 3$), withdrawing from the study prior to the MRI scan ($n = 1$), or being unavailable while the MRI scanner was stationed at the facility ($n = 1$).

MRI analysis

Regional gray matter volumes in *a priori* regions of interest were calculated in SPM12 for each participant. Mean GMVs were extracted from anatomical image masks defining the posterior superior temporal cortex [Brodmann Area (BA) 22], temporal poles (BA 38) and mPFC (BA 9). Image masks were obtained from the Wake Forest University Pick Atlas Toolbox in SPM12 based on automated anatomical labeling (aal) defined regions. Group differences in each region were then analyzed using ANCOVA in SPSS 20.0 (www.spss.com) with planned *t*-tests comparing the suicide attempt group to the no suicide attempt, non-psychotic offender and non-offender groups. Alpha was set to $P < 0.05$ (two-tailed) for all analyses. Additionally, we conducted a whole-brain analysis to investigate whether regions other than those hypothesized differed between groups. A Monte Carlo simulation conducted using

ClustSim (Forman *et al.*, 1995) determined that an 831 voxel extent at $P < 0.001$ uncorrected yielded a corrected threshold of $P < 0.05$, accounting for spatial correlations between GMVs in neighboring voxels. Total brain volume (GMV + WMV), age and IQ estimate were included as covariates in all of the above analyses.

Behavioral data analysis

All analyses were conducted using SPSS. Empathic accuracy performance across groups was analyzed using one-way analysis of variance. Age and IQ estimate, which were negatively and positively correlated with empathic accuracy scores, respectively [$r(124) = -0.22$, $P = 0.017$; $r(122) = 0.25$, $P = 0.005$], were included as covariates. None of the other variables in Table 1 were significantly correlated with empathic accuracy. One-way ANCOVA was conducted across groups with planned follow-up *t*-tests to compare performance between the suicide attempt group and the no suicide attempt, nonpsychotic offender and non-offender comparison groups. Alpha was set to $P < 0.05$ (two-tailed) for all analyses.

Suicide group analysis

We used logistic regression to examine the effects of established suicide risk variables for psychotic disorders (depression, positive + negative symptoms, substance use disorder, insight), empathic accuracy and brain volumes on suicide attempt group status (yes/no) of psychotic offenders. In order to retain the participants that did not complete MRI scans (thus keeping the participant group consistent across regressions), GMV values for these participants were generated using iterative Markov chain
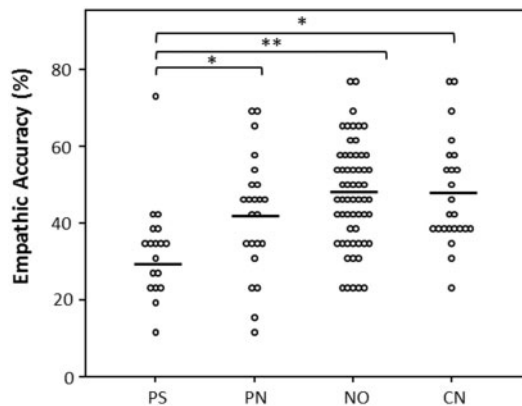
Fig. 1. Target (% accuracy) scores across groups. PS, psychotic offenders with suicide attempts; PN, psychotic offenders without suicide attempts; NO, nonpsychotic offenders; CN, community non-offenders. *$P < 0.05$, **$P < 0.005$.

Monte Carlo fully conditional specification imputation in SPSS, which is appropriate for arbitrary pattern missing data (all results remained significant when the analysis was repeated without these subjects.).

Results

Group differences in empathic accuracy

Participants showed moderate empathic accuracy performance (% accuracy $M = 44.3$, s.d. $= 14.64$), consistent with prior research in criminal offenders (Brook and Kosson, 2013). Psychotic offenders with a history of suicide attempts had lower empathic accuracy compared with psychotic offenders without suicide attempts ($P = 0.032$), nonpsychotic offenders ($P = 0.001$) and community non-offenders ($P = 0.036$); main effect of group [$F_{(3,122)} = 3.67$, $P = 0.014$; Figure 1]. There were no significant differences among the three comparison groups on empathic accuracy [$F_{(2,104)} = 0.48$, ns].

Group differences in brain volume

Psychotic offenders with a history of suicide attempts had lower right and left temporal pole volumes compared with psychotic offenders without suicide attempts (right: $P = .004$; left: $P = 0.005$), nonpsychotic offenders (right: $P = 0.015$; left: $P = 0.017$) and community non-offenders (right: $P = 0.009$; left: $P = 0.004$); main effect of group [right: $F_{(3,119)} = 3.33$, $P = 0.022$; left: $F_{(3,119)} = 3.63$, $P = .015$; Figure 2]. There were no significant group effects in the mPFC [$F_{(3,119)} = 0.54$, $P = 0.65$], or posterior ST [right: $F_{(3,119)} = 0.91$, $P = 0.44$; left: $F_{(3,119)} = 2.04$, $P = 0.11$]. There were no significant differences among the three comparison groups (psychotic offender—no suicide attempt, non-psychotic offender, healthy control) in any region of interest (all P's > 0.30).

The results of the whole-brain analysis revealed a main effect of group in right primary auditory cortex (BA 41; $x = 44$, $y = -15$, $z = 8$; $F_{(3,115)} = 10.56$; $k = 4700$) and left temporal pole (BA 38; $x = -45$, $y = 21$, $z = -18$; $F_{(3,115)} = 9.50$; $k = 3915$). Between-group comparisons indicated that the group effect in primary auditory cortex was explained by reduced volume in both psychotic offender groups relative to nonpsychotic offenders (suicide attempters: $x = 44$, $y = -15$, $z = 9$, $P < 0.0001$, $k = 102$, non-attempters: $x = 44$, $y = -16$, $z = 9$, $P < 0.001$, $k = 270$) and non-offenders (suicide attempters: $x = 44$, $y = -14$, $z = 8$, $P < 0.00001$, $k = 15$; non-attempters: $x = 45$, $y = -9$, $z = 2$, $P < 0.001$, $k = 3664$),

The effect in the left temporal pole was explained by reduced volume in the psychotic—suicide attempt group relative to non-psychotic offenders ($x = -46$, $y = 18$, $z = -15$; $P < 0.001$; $k = 7384$) and non-offenders ($x = -46$, $y = 21$, $z = -18$; $P < 0.001$; $k = 27\,964$).

Association between empathic accuracy, brain volumes and suicide attempts

We used logistic regression to examine the effects of established suicide risk variables for psychotic disorders (depression, positive + negative symptoms, substance use disorder, insight), empathic accuracy and brain volumes on suicide attempt group status (yes/no) of psychotic offenders. Zero-order regressions with each variable are presented in Table 2. Depression and positive + negative symptom groups were significant predictors of past suicide attempt/s, while substance use disorder and insight were not. Examining alcohol and drug use disorders separately also did not yield significant results.

We retained all variables for the hierarchical logistic regression with three steps: (1) Established risk variables, (2) Empathic accuracy, (3) Left or right temporal pole volume, except for the positive + negative symptom variable so that the 13 participants that did not meet criteria for 1 of the positive + negative symptom groups could be included. There were no significant differences in empathic accuracy or left and right temporal pole volumes between the psychotic symptom groups ($P = 0.52$, $P = 0.35$, $P = 0.39$, respectively). A separate hierarchical logistic regression analysis without the 13 participants and including the positive + negative symptom variable, the results of which were substantively the same with regard to the significance of empathic accuracy and brain volumes in predicting suicide attempt group, is provided in Supplementary data, Table S1.

Results revealed that lower empathic accuracy was associated with an increased likelihood of a past suicide attempt, above and beyond the effects of the other risk variables (depression, substance use, insight) [$\chi^2(1) = 8.84$, $P < 0.05$] (Table 3). Additionally, reduced left and right temporal pole volumes were associated with an increased likelihood of a past suicide attempt, above and beyond the effects of the other risk variables (depression, substance use, insight) and empathic accuracy [left: $\chi^2(1) = 15.99$, $P < 0.001$; right $\chi^2(1) = 12.57$, $P < 0.001$] (Table 3). The inclusion of empathic accuracy increased the amount of variance explained from 0.29 to 0.50, and the additional inclusion of left or right temporal pole volumes increased the variance to 0.78 and 0.73, respectively. While the addition of empathic accuracy to established risk variables did not increase the percent of correctly classified cases (74.4% in both steps), the addition of left or right temporal pole volumes increased correct classification to 89.7 and 87.2%, respectively.

Associations with psychopathy

Because psychopathic traits exist at clinical levels in incarcerated populations (Hare, 2003), and have been associated with lower empathic accuracy (Brook and Kosson, 2013), we examined associations between psychopathy and relevant variables in the current study. Psychopathy scores did not significantly differ between any of the incarcerated groups, including suicide attempters *vs* non-attempters (Table 1). There were no significant correlations between psychopathy scores and empathic accuracy among all incarcerated participants [$r(98) = -0.02$, $P = 0.83$], nonpsychotic offenders [$r(59) = 0.02$, $P = 0.91$] or psychotic offenders [$r(39) = -0.16$, $P = 0.34$]. There were also no significant correlations between psychopathy scores and right
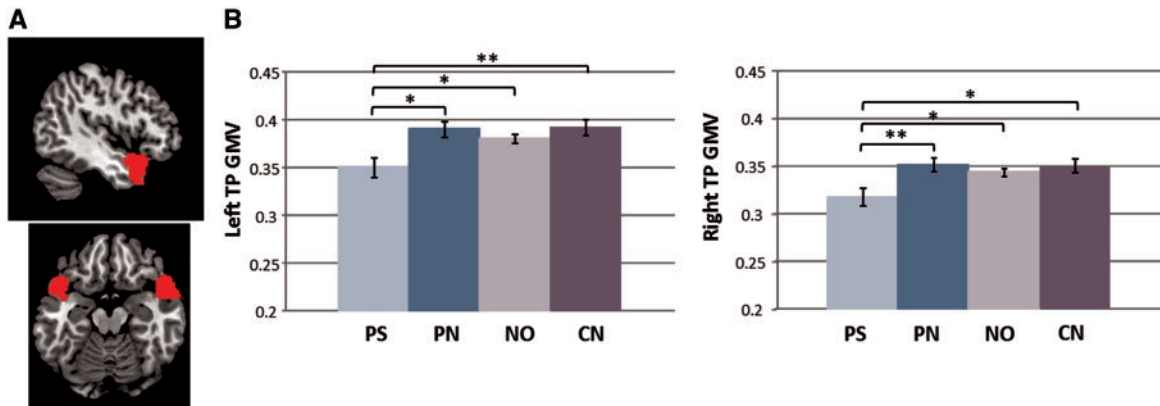
Fig. 2. (A) Anatomical image mask defining the temporal pole ROI. (B) Group differences in bilateral temporal lobe volumes. Bars represent standard error. Means adjusted for age, IQ estimate and TBV. PS, psychotic offenders with suicide attempts; PN, psychotic offenders without suicide attempts; NO, nonpsychotic offenders; CN, community non-offenders. *$P < 0.05$, **$P < 0.005$.

Table 2. Logistic regression analysis evaluating suicide attempt history (yes/no) in psychotic offenders based on established risk variables, empathic accuracy and temporal pole volumes

Risk variable	β	SE (β)	P value	OR (95% CI)
Depression	1.52	0.71	0.03	4.55 (1.14–18.15)
Positive + negative symptoms	2.30	1.19	0.05	10.00 (0.97–102.87)
Substance use disorder	0.62	0.72	0.38	1.87 (0.46–7.60)
Insight	0.05	0.33	0.89	0.96 (0.50–1.81)
Empathic accuracy	−0.72	0.38	0.06	0.49 (0.23–1.02)
Left temporal pole	−1.10	0.43	0.01	0.33 (0.14–0.78)
Right temporal pole	−0.89	0.39	0.02	0.41 (0.19–0.88)

temporal pole volumes [$r(98) = -0.16$, $P = 0.13$, $r(59) = -0.17$, $P = 0.20$, $r(39) = -0.22$, $P = 0.18$], left temporal pole volumes [$r(98) = -0.19$, $P = 0.06$, $r(59) = -0.20$, $P = 0.12$, $r(39) = -0.25$, $P = 0.12$], mPFC volumes [$r(98) = -0.15$, $P = 0.16$, $r(59) = -0.15$, $P = 0.25$, $r(39) = -0.23$, $P = 0.19$], left posterior ST volumes [$r(98) = -0.14$, $P = 0.19$, $r(59) = -0.19$, $P = 0.15$, $r(39) = -0.16$, $P = 0.34$] or right posterior ST volumes [$r(98) = -0.14$, $P = 0.19$, $r(59) = -0.22$, $P = 0.10$, $r(39) = -0.12$, $P = 0.48$].

Discussion

Psychotic disorders are associated with increased suicide risk, social cognitive impairments and aberrant brain volumes in regions that are integral components of social cognitive networks. We explored the hypothesis that lower empathic accuracy and smaller brain volumes in regions implicated in social cognition would be related to past suicide attempts in a psychotic-disordered offender population. We found that psychotic offenders with a history of suicide attempts had lower empathic accuracy and reduced gray matter in bilateral temporal poles. These results were significant above and beyond the effects of other suicide risk variables (depression, substance abuse, insight). The inclusion of empathic accuracy with other risk variables increased the amount of variance explained from 29% to 50%, while the inclusion of temporal pole volumes further increased this to 73–78%. Thus, empathic accuracy and temporal pole volumes contributed substantially to the discrimination of psychotic offenders with and without past suicide attempts.

The higher incidence of a past depressive episode among individuals with psychotic disorders and past suicide attempt/s is consistent with prior research, as is the finding of higher positive and lower negative PANSS symptom scores (Potkin *et al.*, 2003; Hawton *et al.*, 2005a,b; Hor and Taylor, 2010). We did not observe group differences in alcohol or drug use, contrary to prior findings. This is likely because prior studies have been conducted in community non-offenders. Criminal offenders have higher rates of substance use than non-offenders (Kessler *et al.*, 1994; Compton *et al.*, 2005). Thus there may have been less variability among offenders and consequently fewer group differences. We also did not observe group differences in insight, which could be related to our measurement of this variable with the PANSS. Prior studies that found higher insight among suicidal psychotic individuals used measures that focused on insight into illness (Kim *et al.*, 2003; Schwartz and Smith, 2004; Crumlish *et al.*, 2005). The PANSS combines insight into illness and need for treatment, the latter of which is not related to suicidal behavior (Crumlish *et al.*, 2005). It is also important to note that the PANSS was not administered near the time of a suicide attempt, and participants were undergoing continual treatment and supervision, which could impact current insight levels and other characteristics.

Psychotic offenders with past suicide attempts were impaired in empathic accuracy relative to all comparison groups. This suggests a reduced ability to identify emotions in social context. While in line with prior studies showing impaired social cognition in schizophrenia (Green *et al.*, 2015), we found that impairment was specific to those with suicide attempts. Those without attempts were generally unimpaired relative to non-psychotic offenders or community controls. There are several possible explanations for this result, which are also the reasons why we did not hypothesize psychotic *vs* nonpsychotic group differences. First, most prior studies have focused on schizophrenia, whereas we included individuals with any psychotic disorder. Second, some types of social cognitive abilities may be generally impaired in psychotic disorders while other social cognitive impairments are associated with suicide risk. For example, whether non-affective (e.g. cognitive perspective taking/theory of mind) social cognitive abilities known to be impaired in psychotic disorders are associated with suicide risk has not been studied. Even within the domain of empathic accuracy, differences in assessment methods could affect the association with functional outcomes. Some prior studies

Table 3. Hierarchical logistic regression analysis evaluating suicide attempt history (yes/no) based on established risk variables, empathic accuracy and temporal pole volumes

Step and variable	β	SE (β)	Wald	OR (95% CI)	χ^2	R^2
Step 1					$\chi^2(3) = 9.37^*$	0.29
Depression	2.28	0.86	6.93	9.72 (1.79–52.88)**		
Substance use disorder	0.86	0.83	1.08	2.37 (0.47–12.09)		
Insight	0.31	0.40	0.59	1.36 (0.62–2.97)		
Step 2					$\chi^2(1) = 8.84^{***}$	0.50
Empathic accuracy	−1.48	0.60	6.10	0.23 (0.07–0.74)*		
Step 3a					$\chi^2(1) = 15.99^{****}$	0.78
Left temporal pole	−3.17	1.28	6.17	0.04 (0.003–0.51)*		
Step 3b					$\chi^2(1) = 12.57^{****}$	0.73
Right temporal pole	−2.16	0.86	6.39	0.65 (0.46–0.91)*		

$^*P < 0.05.$ $^{**}P < 0.01.$ $^{***}P < 0.005.$ $^{****}P < 0.001.$

examining empathic accuracy in schizophrenia used a task in which participants rated the degree of positive or negative emotion that a person was experiencing during an autobiographical event (Zaki *et al.*, 2009; Lee *et al.*, 2011b; Harvey *et al.*, 2013). We asked participants to select specific emotions that the person experienced during an autobiographical event. These tasks may engage different cognitive and affective processes such as semantic knowledge (e.g. social-emotional terms and concepts). It seems plausible that misinterpreting levels of positive or negative emotion in others could lead to interpersonal conflict, and consequently feelings of social isolation and suicidal ideation/ behavior. However, until suicidal behavior is studied in relation to a variety of social cognitive abilities and their measurement, such suggestions are speculative. Third, it is possible that certain social cognitive impairments are uniquely related to suicide attempt history in offender populations. It is important to identify which types of social cognition predict suicide risk in which populations, so that interventions can be tailored appropriately.

Psychotic offenders with suicide attempts had smaller bilateral temporal pole volumes relative to the comparison groups. The critical involvement of the temporal poles in social and emotional processing has been demonstrated in lesion and neuroimaging studies of humans and non-human primates (Olson *et al.*, 2007). Damage to this region impairs the ability to recognize and produce appropriate social signals (e.g. facial expressions) and causes changes in personality including social withdrawal. Functional imaging studies have shown that tasks involving thinking about other people's thoughts and emotions consistently engage the temporal poles (Olson *et al.*, 2007). The temporal poles also support multi-sensory integration and top-down modulation of sensory regions during social cognitive processing (Pehrs *et al.*, 2015, Cerebral Cortex). Prior neuroimaging studies of suicidal behavior in schizophrenia and other psychotic disorders have not typically implicated the temporal poles, but instead posterior superior temporal cortex—particularly within the left hemisphere (Aguilar *et al.*, 2008; Giakoumatos *et al.*, 2013). We did observe reduced left posterior ST volumes in attempters, but the result fell short of significance. It is also possible that temporal pole volumes are uniquely related to suicide attempts in offender populations. A recent study found that youth homicide offenders had smaller temporal pole volumes relative to youth offenders who had not

committed homicide (Cope *et al.*, 2014). Thus, the temporal poles may be associated with risk of harm to self and others. However, there is some evidence of temporal pole involvement in suicide in non-forensic, non-psychotic populations. Reduced norepinephrine receptor binding in the temporal poles has been found in depressed suicide victims (De Paermentier *et al.*, 1990, 1991).

These results also highlight biobehavioral markers that could be targeted for treatment intervention. Social cognitive abilities are being increasingly viewed as treatment targets in schizophrenia and related psychotic disorders. Recent studies have implemented techniques such as social cognitive skills training, oxytocin administration, and transcranial direct current stimulation to enhance social cognition in schizophrenia (Kurtz and Richardson, 2012; Pedersen *et al.*, 2011; Davis *et al.*, 2013; Fischer-Shofty *et al.*, 2013; Lindenmayer *et al.*, 2013; Guastella *et al.*, 2015; Rassovsky *et al.*, 2015). The results suggest that, depending on the technique used, improvements are specific to certain types of social cognition. For example, enhancing effects of oxytocin are usually observed for higher-order social cognitive abilities, such as mentalizing and empathy. Given the substantial variability among types of higher-order social cognitive abilities, as discussed earlier, it will be important to identify which are related to suicidal behavior and can be modified by specific interventions. It is also possible that certain interventions have observable effects on brain structure or function but not behavior.

There are some limitations to this study. First, our prediction of suicide attempts group was retrospective. While studies have shown that that suicide risk is measurable up to 37 years after the initial attempt (Dahlgren, 1977; Suominen *et al.*, 2004; Angst *et al.*, 2005; Brådvik *et al.*, 2008), prospective studies in which social cognitive variables are recorded at baseline (prior to suicidal behavior) will provide a more stringent test of their applicability as risk variables. Second, although having a history of suicide attempts is a strong indicator of future suicide, many attempters will not go on to complete. Prospective studies are needed to determine whether the current results extend to suicide completion. Third, we did not include a comparison group of non-psychotic offenders with past suicide attempts. As such, the question of whether the current results are generalizable to non-psychotic populations cannot be addressed. Additionally, because there have been no prior studies of social cognition and

suicide in psychotic disorders (to our knowledge), and no prior studies of empathic accuracy in psychotic disorders using our specific task, whether the results are generalizable to psychosis and/or suicidal behavior in non-forensic (i.e. community) psychotic samples remains to be determined. We did, however, assess a number of variables which tend to be elevated in forensic populations and have been associated with reduced empathic accuracy and/or frontal and temporal brain volumes (e.g. psychopathy, aggression, impulsivity) to ensure that our results were not attributable to these factors. Fourth, we did not have a large enough sample to compare the results across different diagnostic groups (e.g. schizophrenia *vs* bipolar disorder). Finally, all participants were taking an antipsychotic or other psychotropic medication. Although there were no significant differences in the number of participants who were currently using these medications in the suicide attempt and no-attempt groups, other potential influences (e.g. effects of long-term medication use) cannot be ruled out.

The current results also do not demonstrate causality between impaired empathic accuracy and suicidal behavior. The results identify one type of social cognitive skill that is related to suicide behavior in psychotic criminal offenders, as well as demonstrating reduced brain volume in a region implicated in social cognition. They also lend support to theories of suicide that posit thwarted belongingness and social disaffiliation as major risk factors (Joiner *et al.*, 2009), and the notion that accuracy measures of social cognition are important for evaluating functional outcomes in general (Zaki and Ochsner, 2011). Although replication is needed, the current results are of clinical interest in demonstrating the incremental value of social cognition to the cumulative evaluation of suicide risk and in identifying a potential neurobehavioral target for treatment and risk management.

Supplementary data

Supplementary data are available at *SCAN* online.

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