The importance of loneliness in psychotic-like symptoms: Data from three studies

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ABSTRACT

Poor social connection or loneliness is a prominent feature of schizotypy and may exacerbate psychosis risk. Previous studies have examined the inter-relationships between loneliness and psychosis risk, but critically, they have largely been conducted in non-clinical samples or exclusively used laboratory questionnaires with limited consideration of the heterogeneity within schizotypy (i.e., positive, negative, disorganized factors). The present study examined links between loneliness and psychotic-like symptoms across the dimensions of schizotypy through cross-sectional, laboratory-based questionnaires (Study 1; $N = 160$), ambulatory assessment (Study 2; $N = 118$) in undergraduates, and ambulatory assessment in inpatients in a substance abuse treatment program (Study 3; $N = 48$). Trait positive schizotypy consistently predicted cross-sectional and state psychotic-like symptoms. Loneliness, assessed via cross-sectional and ambulatory means, was largely linked with psychotic-like symptoms. Importantly, psychotic-like symptoms were dynamic: psychotic-like symptoms largely increased with loneliness in individuals with elevated positive and disorganized schizotypal traits, though there were some inconsistency related to disorganized schizotypy and state psychotic-like symptoms. Negative schizotypy and loneliness did not significantly interact to predict psychotic-like symptoms, suggesting specificity to positive schizotypy. Ambulatory approaches provide the opportunity for ecologically valid identification of risk states across psychopathology, thus informing early intervention.

1. Introduction

Schizotypy is defined as a range of personality traits associated with a predisposition to schizophrenia-spectrum pathology (Lenzenweger, 2006). These traits exist along a psychosis continuum (Lenzenweger, 2006), ranging from subclinical and potentially adaptive experiences to severely debilitating clinically clustered symptoms (i.e., schizophrenia). Findings of social dysfunctions across the psychosis continuum are robust and manifest a broad set of functional systems, including basic perceptual abilities (e.g., theory of mind, social skills; Barragan et al., 2011) and quantity/quality of social motivation and behavior (i.e., depleted social networks, decreased rates of intimate relations; Badcock et al., 2016; Brown et al., 2007). Particularly important are the perceived poor subjective social connectedness and isolation from family, friends, and/or the general community – which

converges heavily with the construct of "loneliness". Capioppo and Patrick (2008) defined loneliness as a complex and distressing feeling that stems from the perception that one's social needs are not being met by quality of one's social relationships. Generally speaking, loneliness has been associated with poor mental and physical health, decreased subjective well-being, and myriad psychiatric states and disorders such as depression (Gerst-Emerson and Jayawardhana, 2015). Recent literature also indicates that up to 94% of individuals with schizophrenia report loneliness (Badcock et al., 2015). This is not surprising as loneliness may be intrinsically linked with any (or all) of three core symptom clusters of schizophrenia (Eglit et al., 2018). For example, delusional beliefs related to suspiciousness, social anhedonia and asociality, and unusual speech/behavior leading to social distancing behaviors from public can lead to social disconnectedness in individuals with schizophrenia. Loneliness in psychometrically-assessed schizotypy

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(i.e., defined using self-reported questionnaires) is prominent (Badcock et al., 2016) and is further associated with several maladaptive outcomes including poor academic and recreational functioning (Cohen and Davis, 2009; Raynal et al., 2016) and substance use (Barrantes-Vidal et al., 2010; Esterberg et al., 2009). The present study examined links between loneliness and psychotic-like symptoms in schizotypy using both cross-sectional (i.e., laboratory-based questionnaires) and ambulatory data collection methods in both clinical and non-clinical samples.

Beyond links between loneliness and poor functioning in schizotypy, loneliness may also be an important component in the exacerbation of psychotic symptoms. According to the 'social regulatory cycle' theory (Reeck et al., 2016), a mutual process of regulating negative affect takes place when people are amongst others (i.e., social buffer). However, in the absence of sufficient social resources, negative affective states may be insufficiently regulated, increasing the likelihood that psychotic-like or psychotic symptoms will occur. There are other links between social factors and psychotic symptoms. Social dysfunction has been linked with poor internal/external reality testing – a mechanism likely underlying hallucinations – in schizophrenia (Divilbiss et al., 2011). Relatedly, Millman et al. (2018), among others (Bentall and Fernyhough, 2008; Mizrahi, 2016), have observed that subjective social stress was associated with psychotic-like symptoms in both clinical high risk and healthy control samples, assessed through cross-sectional laboratory questionnaires and clinical interviews. Moreover, social connectedness and psychosis, assessed using ambulatory data collection methods, are interrelated and both wax and wane over time in neurotypical populations (Schlier et al., 2018), individuals with high schizotypal traits (Kwapil et al., 2012), and patients with schizophrenia spectrum disorders (Ben-Zeev et al., 2012). These studies suggest that state loneliness may moderate the likelihood that psychotic-like symptoms will occur in those with schizotypal traits. Indeed, state social disconnection was a moderator between trait schizotypal traits and psychotic-like symptoms in a non-clinical sample (Barrantes-Vidal et al., 2013). Importantly, interactions between objective social variables (i.e., frequency of social contact) and schizotypy were non-significant, signifying the value of subjective appraisals of social experiences (Barrantes-Vidal et al., 2013). However, there are null findings as well. Chun et al. (2017) observed associations between state loneliness and psychotic-like symptoms a in college sample, but moderation was not found with schizotypy scores derived from clinical interview. This is an important issue to resolve, in that loneliness is a malleable psychological state, and hence, a viable intervention target (Masi et al., 2011).

These relationships become even more potentially complex given the multidimensional nature of schizotypy (i.e., positive, negative, disorganized). The majority of studies to date examining the relationship between schizotypy, psychotic-like symptoms and loneliness have almost exclusively examined positive schizotypy traits, or related phenomenon such as psychosis proneness or attenuated positive symptoms (Barrantes-Vidal et al., 2013; Cicero and Kerns, 2010; Laloyaux et al., 2016). Schizotypy is heterogeneous construct with each superordinate factor comprising of disparate social and emotional experiences. It is possible that loneliness and psychotic-like symptoms occur via different mechanisms across different schizotypy facets. For example, positive schizotypy is marked with elevations in social anxiety and general distrust of the public despite a desire for closer social relations (Barrantes-Vidal et al., 2010). Thus, loneliness may intensify feelings of negative affective states and psychotic-like symptoms in those with a propensity towards increased beliefs of social rejection such as individuals with elevated positive schizotypal traits. In contrast, negative schizotypy is often associated with heightened social anhedonia, decreased positive affect during social interactions, and a general apathy towards social interactions (Brown et al., 2007; Kemp et al., 2018). Therefore, social contact may not be the desired emotion regulation or reality testing technique in negative schizotypy; as such, loneliness may

not be a sufficient stressor for the onset of psychiatric like symptoms. In the case of these constructs within disorganized schizotypy, little research has been conducted, especially in regards with ambulatory techniques. However, disorganized schizotypy has previously been characterized by increased negative affect and emotional ambivalence (Kemp et al., 2018), both of which are associated with social dysfunction (Kimhy et al., 2016) and psychosis in schizophrenia (Serper and Berenbaum, 2008). Thus, it is imperative to disentangle the dynamic relationships between the varying schizotypal traits, social dysfunction, and psychotic-like symptoms.

The current studies explored relationships between schizotypy, loneliness, and psychotic-like symptoms. This was explored using two separate samples of non-clinical (i.e., college) and one clinical (i.e., dual-diagnosed inpatients) adult sample combining cross-sectional, laboratory questionnaires and ambulatory techniques. Importantly, ambulatory technology can account for some limitations associated with cross-sectional data collection (e.g., retrospective recall errors, recall bias, shared-method variance; see Trull and Ebner-Priemer, 2009). With regards to our clinical sample, all of whom met criteria for a substance use disorder, previous studies have linked positive schizotypal traits to increased substance use both concurrently and prospectively (Kwapil et al., 2013, 2012). We hypothesized that schizotypy will predict psychotic-like symptoms and loneliness will moderate this relationship such that loneliness would be associated with psychotic-like symptoms only in those with high schizotypal traits. We also examined how these relationships differed across positive, negative, and disorganized schizotypy.

2. Study 1 methods

2.1. Participants

Undergraduates ($n = 160$) completed an online survey which included a consent form, basic demographic questions, and several cross-sectional, laboratory-based questionnaires (see Table 1 for Study 1, 2, and 3 sample demographic and descriptive characteristics). Appropriate ethic boards approved the research protocols for all studies presented in this report.

2.2. Trait Schizotypy

Trait schizotypy was assessed with the Schizotypal Personality

Table 1
Characteristics of demographics across three studies.

Variable	Study 1 ($n = 160$)	Study 2 ($n = 118$)	Study 3 ($n = 48$)
Demographics			
Age [M (SD)]	19.9 (1.5)	19.9 (1.9)	37.7 (10.8)
Sex (% male)	17%	22%	100%
Education [M (SD)]	N/A[a]	N/A[a]	12.26 (0.44)
Ethnicity (% Caucasian)	77%	75%	48%
SPQ-BR			
Positive	1.16 (0.69)	1.21 (0.65)	1.29 (0.73)
Negative	1.25 (0.80)	1.32 (0.81)	1.66 (0.83)
Disorganized	1.75 (0.81)	1.80 (0.76)	1.65 (0.76)
Loneliness			
UCLA Loneliness	2.86 (0.38)	–	–
State Loneliness	–	15.31 (23.90)	31.57 (38.08)[b]
Psychotic-like Symptoms			
BSI Psychoticism	1.72 (0.74)	–	–
State Psychotic-like Symptoms	–	2.77 (7.64)	9.50 (22.50)

Note.
[a] All participants were current undergraduate students;.
[b] This score reflects the average of the Study 3 state loneliness item ("How close do you feel…") *after* reverse coding; SPQ-BR = Schizotypal Personality Questionnaire – Brief Revised; BSI = Brief Symptoms Inventory.

Questionnaire – Brief Revised (SPQ-BR; Cohen et al., 2010). The SPQ-BR is comprised of 32 Likert-scale items (1 = *Strongly Disagree* through to 5 = *Strongly Agree*) and derived from the full Schizotypal Personality Questionnaire (SPQ; Raine, 1991). The SPQ-BR has a three-factor structure (positive, negative, and disorganized) and has displayed strong psychometric properties (see Cohen et al., 2010). The negative (i.e., interpersonal) schizotypy factor of the original SPQ was comprised of constricted affect, no close friends, and social anxiety subordinate factors. Social anxiety however is more strongly related to positive than negative symptoms and can be conceptualized as secondary to negative schizotypal traits. The SPQ-BR addresses this by parceling out social anxiety from negative schizotypy (Callaway et al., 2014; Cohen et al., 2010). The SPQ-BR was to assess trait schizotypy throughout all studies presented in this report. Correlations among the three superordinate factors (e.g., positive, negative, disorganized) for each study can be found in supplemental materials.

2.3. Cross-sectional loneliness

The UCLA Loneliness Scale, Version 3 (UCLA-3; Russell, 1996) was used to measure the subjective appraisals of social connectedness and how people perceive their social situation rather than focus on the quantity of friends an individual has (e.g., How often do you feel…that your relationships with others are not meaningful?). The UCLA-3 has good psychometric properties (Lasgaard, 2007; Russell, 1996) and is comprised of 20 Likert-scale items (1 = *Never* through to 4 = *Often*). Average score across the 20 items was used for analyses, with higher scores indicating elevated loneliness. The mean score on this scale was 2.86 (SD = 0.38) indicating that participants endorsed loneliness between "Rarely" and "Sometimes".

2.4. Cross-sectional psychotic-like symptoms

The Brief Symptom Inventory (BSI; Derogatis and Melisaratos, 2009) is a commonly used measure of psychiatric symptomatology (e.g., depression, anxiety, somatization, etc.) and evaluated on a 5-point Likert scale (1 = Not at all; 5 = Extremely). The BSI covers endorsed experiences within the prior four weeks with increasing scores reflecting increased symptom severity. The BSI has demonstrated good reliability and convergent validity (see Derogatis and Melisaratos, 2009). For the purposes of this study, the Psychoticism scale was used as our measure of psychotic-like symptoms [M (SD) = 1.72(0.74) indicated that participants endorsed psychotic-like symptoms between the 1 = "*Not at all*" and 2 = "*A little bit*" anchors]. Approximately 24% of participants endorsed psychotic-like symptoms greater than the 2 = "*A little bit*".

2.5. Analyses

First, associations between potential demographic (e.g., age, gender, ethnicity) variables and study variables that might inform subsequent analyses were computed. Demographic variables did not substantially influence any of the subsequent analyses. Moderation and simple slope analyses were assessed using PROCESS for SPSS (Hayes, 2013). Schizotypal traits and cross-sectional loneliness were centered and entered along with their cross product as predictors for cross-sectional psychotic-like symptoms. Three separate linear regression models testing moderation were used with each model consisting of one distinct component of schizotypy (e.g., positive schizotypy, loneliness, and their cross product). Simple slope coefficients were used to evaluate the association between trait schizotypy and psychotic-like symptoms at low (< −1 SD below the mean), moderate (between 1 SD below and 1 SD above the mean) and high (> 1 SD above the mean) levels of loneliness for any significant interactions (Aiken and West, 1991). For graphic illustrations of interaction effects, two subgroups based on low and high loneliness scale scores were created and

Table 2
Multiple regression for the prediction of cross-sectional psychotic-like symptoms by trait schizotypy, cross-sectional loneliness, and their interaction (Undergraduate sample; $N = 160$).

| | Cross-sectional Psychotic-like Symptoms | | |
	R^2	F	B (SE)
Positive Schizotypy, Full Model	.50	52.8	
Trait Schizotypy – Positive			.52 (0.07)**
Loneliness			.55 (0.15)**
Interaction			.55 (0.16)**
Negative Schizotypy, Full Model	.37	52.8	
Trait Schizotypy – Negative			.33 (0.06)**
Loneliness			.79 (0.16)**
Interaction			.26 (0.17)
Disorganized Schizotypy, Full Model	.39	33.5	
Trait Schizotypy – Disorganized			.35 (0.06)**
Loneliness			.80 (0.15)**
Interaction			.36 (0.16)*

* $p < .05$.
** $p < .01$.

the associations between schizotypy and psychotic-like symptoms variables were graphed for each subgroup. All tests were two-tailed and all variables normally distributed (skew < 1.5).

2.6. Results and discussion

All three schizotypy factors and loneliness were related to cross-sectional psychotic-like symptoms using questionnaire-based assessment in a non-clinical sample (see supplemental tables). The interaction term for two of the schizotypy components and laboratory measured loneliness (e.g., positive schizotypy x loneliness; disorganized schizotypy x loneliness) accounted for significant variance in cross-sectional, psychotic-like symptoms (see Table 2). For the group endorsing moderate or high levels of loneliness, scores of positive schizotypy were significantly related to psychotic-like symptoms [moderate: B(SE) = 0.52(0.07); p < .001; high: BE(SE) = 0.69(0.08); p < .001], but this relationship was weaker, though still significant, for participants endorsing low levels of loneliness [B(SE) = 0.35(0.09); p < .01; see Fig. 1]. The significant moderating effects of loneliness on the association between disorganized schizotypy and psychotic-like symptoms yielded a similar pattern. Individuals endorsing moderate and high levels of cross-sectional loneliness [moderate: B(SE) = 0.35(0.06); p < .001; high: B(SE) = 0.46(0.08); p < .001] exhibited stronger linear relationships between disorganized schizotypy and psychotic-like symptoms. This relationship showed a weaker, though still significant, linear relationship for individuals at low levels of loneliness [B(SE) = 0.23(0.07); p < .01]. Importantly, the cross product for negative schizotypy and cross-sectional loneliness did not significantly predict cross-sectional psychotic-like symptoms.

Regarding our primary analyses, cross-sectional psychotic-like symptoms varied as a function of loneliness in non-clinical individuals with elevated positive and disorganized schizotypal traits. More specifically, in individuals endorsing elevations on these positive and disorganized schizotypal traits, psychotic-like symptoms were elevated with increased loneliness. Associations between loneliness and psychotic-like symptoms did not vary as a function of negative schizotypal traits in these traditional questionnaires, indicating specificity. Findings for significant interaction of loneliness with positive, but not negative, schizotypy are consistent with our hypotheses.

3. Study 2 methods

3.1. Participants

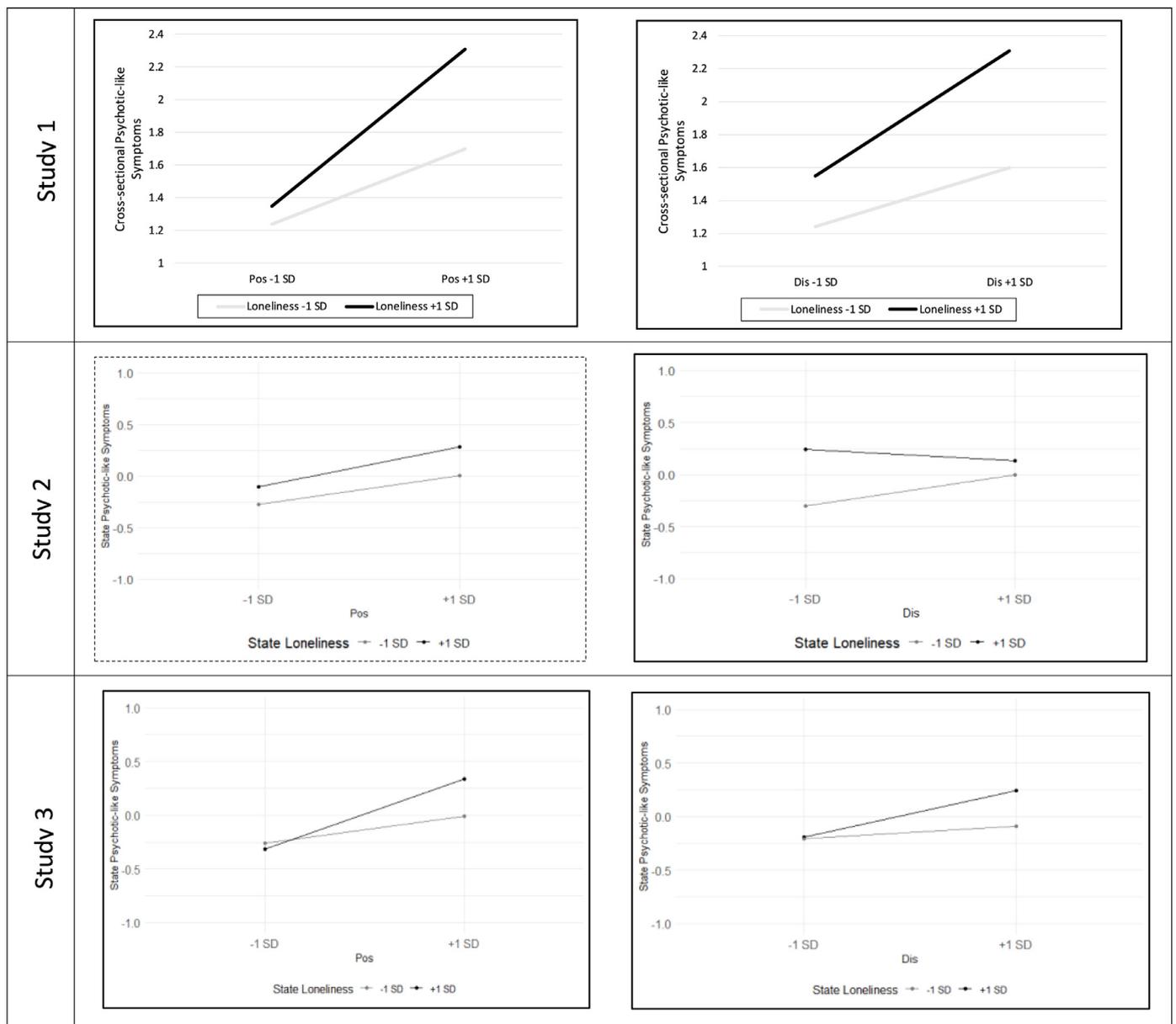Undergraduate students (*n* = 118; distinct from Study 1) completed

Fig. 1. Interaction effect of trait schizotypy and loneliness on psychotic-like symptoms.
Note. Pos = Trait Positive Schizotypy; Dis = Trait Disorganized Schizotypy; Dashed border indicates non-significant interaction.

the SPQ-BR and a series of tasks via a mobile application (the delta Mental Status Exam or *d*MSE; see (Chandler et al., 2019; Cohen et al., 2019a; Cowan et al., 2019; Holmlund et al., 2019b, 2019a; Le et al., 2018) over a five-day window. Participants downloaded the *d*MSE to their mobile device and were instructed to complete one app-based session (~20 min) per day for five days in a quiet, secluded environment (average sessions per participant = 4.63). The *d*MSE includes a range of tasks, including self-report, cognitive, and speaking (to procure speech and language features), for examining and tracking correlates of various risks states associated with serious mental illness. All self-report tasks consisted of probes that were presented visually with an analogue scale and audio voice.

3.2. State loneliness

State loneliness was assessed using a self-report digital slider scale with the following probe: "Do you feel lonely or isolated?" A visual analogue scale with anchors 0 = "*not lonely*" to 100 = "*very lonely*" was

used [M(SD) = 15.31(23.9); ICC = 0.62].

3.3. State psychotic-like symptoms

State psychotic-like symptoms were assessed using a composite score of the following two self-report digital slider scales: "Are you seeing things that others can't see"; "Are you hearing voices that others can't hear?". Visual slider scales with anchors 0 = "*no visions/voices*" through to 100 = "*often see visions/hear voices*" were used [M (SD) = 2.77(7.64)]; scores indicate that state psychotic-like symptoms were low in frequency and intensity overall with notable variability. Approximately 10% of participants endorsed higher instances or intensity of psychotic-like symptoms (i.e., average psychotic-like symptoms per participant across five-day window = >10.0). This composite psychotic-like symptom score showed good reliability across sessions (ICC = 0.64) which highlights the dynamic nature of this construct. Of note, PLS is a broad construct that encompasses hallucinations/perceptual aberration (queried in these ambulatory studies) along with

various forms of magical ideations and ideas of reference. Hallucinations do compromise a core component of PLS in ambulatory (Barrantes-Vidal et al., 2013) and self-report (Kline et al., 2016) instruments of psychosis risk states and predict conversion to psychosis (Lehembre-Shiah et al., 2017). Moreover, our replication of the findings across clinical and non-clinical samples using varied assessment methods increases confidence that our state PLS items tapped into the psychotic-like symptoms construct. However, this narrow focus of PLS is a limitation and future studies would be benefit indexing multiple aspects of PLS in their relationship to loneliness.

3.4. Analyses

Demographic variables did not influence subsequent analyses. Multi-level modelling (MLM) was used as data points in each session (Level 1) were nested within participants (Level 2). Participants was set as a random factor. Cross-level interactions tested whether the Level 1 predictor (state loneliness) moderated the associations between Level 2 predictors (trait schizotypy) and Level 1 criterion (state psychotic-like symptoms). All predictors (e.g., trait schizotypy, state loneliness, interaction term) were entered simultaneously. Like Study 1, three separate MLM models were used with each model consisting of a different schizotypy component. Schizotypal traits were grand mean centered, and state loneliness and state psychotic-like symptoms were group mean centered (by testing session). Significant interactions were probed using simple slope and intercept analysis of coefficient values and were evaluated for statistical significance (via t-tests) at two levels: low (-1 SD) and high ($+1$ SD) levels of state loneliness. Extreme scores (>3.5 SD) were trimmed (i.e., replaced with values 3.5 SD). Similar procedures from Study 1 were used for graphic illustrations of interaction effects. The analyses were computed using the R "Lme4" package (Bates et al., 2014).

3.5. Results and discussion

State loneliness emerged as a significant, independent predictor of state psychotic-like symptoms in all three models (see Table 3) while of the schizotypy facets, only trait positive schizotypy emerged as an independent predictor of state psychotic-like symptoms in this non-clinical sample. Significant cross-level interactions exclusively involved state loneliness and disorganized schizotypy. However, an unexpected pattern emerged: for the group endorsing *low* levels of state loneliness, scores of disorganized schizotypy were related to state psychotic-like symptoms [BE(SE) = 0.14(0.08); $p < .05$]; this relationship was not significant for participants endorsing *high* levels of state loneliness [B (SE) = $-0.08(0.08)$]; see Fig. 1]. The cross-level product for positive

and negative schizotypy and state loneliness did not significantly predict state psychotic-like symptoms.

Replicating previous literature and Study 1, trait positive schizotypy was associated with state psychotic-like symptoms. Interestingly, while trait negative and disorganized schizotypy were highly associated with cross-sectional reports of psychotic-like symptoms in Study 1, these relationships were non-significant when tracking psychotic-like symptoms in daily life. State loneliness was related to momentary psychotic-like symptoms, further substantiating the maladaptive influence of loneliness even among non-clinical adults. With regards to interactions, results from this study were largely inconsistent with findings from Study 1. More specifically, findings that state psychotic-like symptoms increased as a function of disorganized traits in *low* state loneliness rather than *high* state loneliness were contrary to our hypothesis. Previous studies have found that disorganized schizotypy is uniquely associated with poorer cognitive control, heightened emotional confusion (Kerns and Becker, 2008), and greater maladaptive reactivity following emotional duress (Minor and Cohen, 2010). It may be that increased loneliness caused a disorganization of affect and cognitive-behavioral links within this specific factor of schizotypy (Kemp et al., 2018) thereby potentially contributing to our unexpected findings. A more notable finding is that individuals who endorsed low disorganized schizotypal traits, thus presumably "healthy" individuals, were more likely to experience state psychotic-like symptoms as loneliness increased.

4. Study 3 methods

4.1. Participants

Male psychiatric inpatients ($n = 48$) recruited from a community-based substance use treatment facility completed the SPQ-BR and a series of tasks (similar to Study 2) via the *d*MSE four times per week for the duration of their inpatient residency (max = 28 days; average sessions per participant = 9.79). All patient [mean age (SD) = 37.7 (10.8); predominantly with high school degree or equivalent] met criteria for a substance use disorder per chart review and due to entry requirements to the substance use treatment facility. There was a high degree of co-morbidity in this sample. Approximately 54% also met criteria for an affective disorder, 8% met criteria for anxiety-spectrum disorder, 4% met criteria for post-traumatic stress disorder, and a further 3% met criteria for schizophrenia based on chart diagnoses. Patients were free from major medical or other neurological disorders that would be hinder compliance with the research protocol (per medical records and staff report). Participants were given a mobile device with the *d*MSE application pre-installed and received extensive instruction on usage.

Table 3
Multi-level modeling for the prediction of state psychotic-like symptoms by trait schizotypy, state loneliness, and their interaction.

	Study 2 (Undergraduate sample; $N = 118$)		Study 3 (Inpatient sample; $N = 48$)	
	Fit Statistic - X^2	B(SE)	Fit Statistic - X^2	B(SE)
Positive Schizotypy, Full Model	22.8**		14.4**	
Trait Schizotypy – Positive		.17 (0.07)*		.23 (0.10)*
State Loneliness		.11 (0.04)*		.06 (0.05)
Interaction		.03 (0.04)		.10 (0.05)*
Negative Schizotypy, Full Model	18.4**		7.5^t	
Trait Schizotypy – Negative		.09 (0.07)		.07 (0.10)
State Loneliness		.14 (0.04)*		.08 (0.05)*
Interaction		-0.03 (0.03)		.07 (0.05)
Disorganized Schizotypy, Full Model	24.7**		9.5*	
Trait Schizotypy – Disorganized		.05 (0.07)		.14 (0.10)
State Loneliness		.17 (0.04)*		.07 (0.05)
Interaction		-0.10 (0.04)*		.09 (0.05)*

^{t} $p < .10$.
* $p < .05$.
** $p < .01$.

They were asked to find a quiet place to complete testing at a time and place of their choosing.

4.2. State loneliness

State loneliness was assessed using a self-report slider scale with the following probe: "How close do you feel to your family and friends?" This probe is similar to items that are found on the UCLA Loneliness Scale (e.g., "I am no longer close to anyone" and "There are people I feel close to"; Russell, 1996). Furthermore, the UCLA Loneliness Scale has been previously used in inpatient studies (Schlauch et al., 2015; Trémeau et al., 2016). A visual analogue scale with anchors 0 = "not close" through to 100 = "very close" was originally used [M (SD) = 68.43(38.08); ICC = 0.71]. This item was reversed coded before analyses (see Table 1, Table 3, and Fig. 1) in order to make the direction of effect comparable across all studies. Therefore, higher scores reflect increased loneliness.

4.3. State psychotic-like symptoms

State Psychotic-like symptoms were assessed using the same procedures (i.e., composite score of two hallucination probes) listed in Study 2 [M(SD) = 9.50(22.50)]. Study 3 composite PLE score showed good reliability across sessions (ICC = 0.59), again indicating the dynamic nature of psychotic-like symptoms.

4.4. Analyses

Demographic confounds were not observed for the analyses listed next. Data analytic procedures mirrored those conducted in Study 2 (i.e., MLM with cross-level interactions). Similar procedures from Study 1 and 2 were used for graphic illustrations of interaction effects.

4.5. Results and discussion

State loneliness only emerged as a significant, independent predictor of state psychotic-like symptoms in the negative schizotypy model, while only trait positive schizotypy again emerged as an independent predictor of state psychotic-like symptoms (see Table 3). Significant cross-level interactions exclusively involved state loneliness with positive schizotypy and disorganized schizotypy for the prediction of state psychotic-like symptoms. For the group endorsing high levels of state loneliness, scores of positive schizotypy were related to state psychotic-like symptoms [B(SE) = 0.33(0.11); *p* < .05], but this relationship was not significant for participants endorsing low levels of state loneliness [B(SE) =0.13(0.10); see Fig. 1]. This pattern was consistent for disorganized schizotypy as scores of disorganized schizotypy were related to momentary psychotic-like symptoms [B (SE) = 0.22(0.12); *p* < .05] in high levels of state loneliness, but this relationship was not significant for participants endorsing low levels of state loneliness [B(SE) =0.05(0.11); see Fig. 1]. Importantly, the cross product for negative schizotypy and state loneliness did not significantly predict state psychotic-like symptoms.

Trait positive schizotypy once again emerged as the only trait schizotypy factor to predict state psychotic-like symptoms. State loneliness was linked with state psychotic-like symptoms only in the model including negative, but not positive or disorganized, schizotypy. This may be due to negative schizotypy accounting for a small amount of the variance in state psychotic-like symptoms. Moderation effects from this ambulatory patient study are largely consistent with findings from the non-clinical sample in Study 1. More specifically, in patients endorsing elevations on these positive and disorganized schizotypal traits, momentary psychotic-like symptoms were elevated with increased state loneliness. Links between loneliness and psychotic-like symptoms did not vary as a function of negative schizotypal traits, indicating that the impact of subjective appraisals of social experiences vary across the dimensions of schizotypy.

5. General discussion

The current studies evaluated how associations between psychotic-like symptoms and multidimensional schizotypy (i.e., positive, negative, and disorganized) varied as a function of loneliness. We extend previous literature by examining these constructs using varied assessments techniques. All three schizotypy factors were related to cross-sectional (i.e., laboratory-based questionnaires) psychotic-like symptoms, but only positive schizotypy remained a significant independent predictor of momentary psychotic-like symptoms in the two ambulatory studies. More simply, trait positive schizotypy was the only schizotypy factor consistently related to cross-sectional and state psychotic-like symptoms for participants with an average level of loneliness (i.e., due to mean-centered predictors). Findings across our studies largely indicated that loneliness, assessed via cross-sectional and ambulatory means, is linked with psychotic-like symptoms independent of schizotypal traits. Importantly, psychotic-like symptoms were largely dynamic as a function of loneliness in individuals with overall elevated positive and disorganized schizotypal traits in our studies. More specifically, in individuals elevated loneliness, psychotic-like symptoms covaried with increased positive and disorganized traits. No interactions between negative schizotypy and loneliness significantly predicted psychotic-like symptoms in our studies, suggesting specificity and further delineating the disparate social experiences captured by the multidimensional components of schizotypy. Results from these studies have ecological validity for the experiences encountered in daily life given that multiple assessments techniques were utilized across clinical and non-clinical adults.

Findings that psychotic-like symptoms fluctuate are consistent with prior literature (Schlier et al., 2018). While positive schizotypy is defined in part by a trait- and state-like tendency to experience psychotic-like symptoms, individuals with elevated negative and disorganized schizotypal traits also experience psychotic-like symptoms in daily life (Barrantes-Vidal et al., 2013; Chun et al., 2017). Due to their dynamic nature, it important to understand their contextual risk factors such as loneliness in schizotypy. Multiple neurobiological mechanisms underlie psychotic symptoms (e.g., hallucinations, delusions) including the dopaminergic network (Polner et al., 2016) and abnormal prefrontal-limbic neural activity (Ford et al., 2014; Juckel et al., 2012). Loneliness, and related objective social disconnectedness, may act as a social stressor to disrupt prefrontal cortex functions and interactions with dopaminergic pathways as observed in previous studies (Kong et al., 2014; Nakagawa et al., 2015). Moreover, loneliness has been found to be associated with key cognitive mechanisms including executive and inhibitory control dysfunction in older adults (Ellwardt et al., 2013; Oluanaigh et al., 2012) which may underlie auditory hallucinations (Badcock et al., 2015). This may explain significant interactions between loneliness and positive schizotypy as the latter has been uniquely associated with disruptions in dopamine functioning during reward processing (Mohr and Ettinger, 2014), executive control (Kane et al., 2016), and heightened sensitivity to rejection (Chun et al., 2017). Of note, neurophysiological and neuropsychological concomitants of loneliness and their influences toward psychotic-like symptoms were not assessed in our studies and represent a future research avenue. Social connections play a key role in individuals regulating each other's emotions (Reeck et al., 2016). Limited social resources may disrupt abilities in downregulating negative affective states and attenuating neural substrates that exacerbate propensity to experience psychotic-like symptoms. Both positive and disorganized schizotypy have been uniquely linked with increased negative affect and emotion dysregulation (Kemp et al., 2018; Kerns and Becker, 2008); thus, poor emotion dysregulation is likely linked with greater vulnerability to the maladaptive effects of loneliness. Replication of the findings across clinical and non-clinical samples using varied assessment methods increases

confidence in these pathways. However, further clarification on the pathways among loneliness, psychotic-like symptoms, and positive schizotypy with emotion regulation and physiological reactivity are warranted.

Loneliness did not appear to alter the relationship between negative schizotypy and psychotic-like symptoms in our studies. Negative schizotypy is defined, in part, by decreased interest and approach toward social relationships. This is not unlike the social communication/interaction deficits seen in those with autism spectrum disorders (ASD). Indeed, several reviews have documented the social dysfunction overlap among ASD and schizophrenia spectrum disorders and related subtypes (i.e., deficit syndrome; see Buchanan, 2007; Chisholm et al., 2015). Hence, a paucity of social affiliation may not elicit sufficient stress to induce symptoms like hallucinations in negative schizotypy as opposed to the other schizotypy factors. Negative schizotypy has previously been shown to be broadly related to loneliness (Badcock et al., 2016), but a granular understanding of how individuals with elevated negative schizotypal traits view/understand loneliness is needed with future research. While some have suggested that negative schizotypy can also reflect a variant of depression (Campellone et al., 2016), negative schizotypy and associated psychometrically-defined social anhedonia remain a particularly important vulnerability marker for transition of schizophrenia spectrum disorders and psychosis (Blanchard et al., 2011).

These studies contained some inconsistencies. Specifically, Study 2 yielded unexpected moderation results in that state loneliness significantly interacted with disorganized, but not positive, to predict momentary psychotic-like symptoms. Such unexpected findings may be explained with respect to temporal resolution (i.e., assessment time windows) and sample characteristics. Study 2 examined these dynamic constructs (e.g., loneliness and psychotic-like symptoms) using ambulatory assessments over a relatively brief time window within some of the highest functioning individuals on the psychosis continuum, thus potentially leading to insufficient variability. When extending these daily ambulatory methods to 28 days and in a clinical population (Study 3), where rates of psychosis-related phenomenon increase even in patients without a schizophrenia-spectrum diagnosis (Thirthalli and Benegal, 2006), an expected pattern of results emerged that is consistent with Study 1 and previous ambulatory studies (Barrantes-Vidal et al., 2013). Consideration of temporal resolution will also be an important facet for future research and clinical assessments as "biobehavioral" measures (e.g., portable electroencephalography, eye-tracking and facial and speech analysis) which yields continuous, digital, and scalable data become more prevalent (Cohen et al., 2019b; Elvevåg et al., 2016). Alternatively, this unexpected finding may be relevant and expand our understanding of disorganized schizotypy in nonclinical populations. As noted earlier, current theoretical understanding and empirical findings suggest that disorganized schizotypy is defined in part by emotional, cognitive, and behavioral confusion, especially during times of elevated negative affect (Kerns, 2006; Minor and Cohen, 2010). The relatively brief time window within Study 2 (five days) may have captured these characteristics of disorganized schizotypy leading to inconsistent findings. This inconsistent finding warrants further replication in ambulatory studies.

Several limitations and subsequent recommendations are worth mention. Our data analytic plan did not permit for a causal interpretation (i.e., that loneliness caused psychotic-like symptoms). Future research would benefit increased sampling (i.e., multiple daily assessments over numerous weeks) to conduct lagged analyses. Increased sampling would also permit the use of advanced statistical analyses such as group iterative multiple model estimation (GIMME model; Lane et al., 2019), which models significant multivariate associations (i.e., loneliness and other contextual vulnerability factors) for everyone in a given sample (i.e., group-level) and person-specific associations (i.e., individual-level). Also, prompting participants with repeated questions, as is typical in ambulatory studies, may change their behavior/perceptions in the constructs of interest. In this case, there may have been a lagged effect (either increasing or decreasing) on loneliness via repeated queries. Another limitation is that ambulatory data on loneliness and psychotic-like symptoms were not collected at random intervals, thus potentially reducing generalizability to experiences in daily life. The current studies also used subjective feelings of loneliness as our contextual vulnerability risk factor for psychotic-like symptoms. Future research would benefit from incorporating digital phenotyping of social connectedness, which indexes phone call logs, text messaging, and geo-location (Ben-Zeev et al., 2017). Lastly, two of our studies were comprised of convenience (i.e., college) samples, who potentially may have more adaptive beliefs and other resiliency characteristics compared to the general public, or clinical populations. Also, our inpatient sample was comprised of male participants; studies have shown differential gender effects related to loneliness (i.e., male tends report less loneliness; Cramer and Neyedley, 1998) and schizotypal traits (i.e., females tend to endorse greater positive schizotypal traits; Raine, 1992). Future research should attempt to replicate our findings in individuals with more severe functional deficits (i.e., Cluster A personality disorders, schizophrenia) and diverse populations from schizotypy.

Overall, our findings contribute to the extant literature on the influential role of social dysfunction such as loneliness on psychotic-like symptoms. The present studies provided consistent evidence that psychotic-like symptoms are influenced by loneliness, yet largely with respect to positive and disorganized schizotypal traits. The emergence of consumer-grade, biobehavioral, and ambulatory technologies promise to provide unprecedented opportunity for ecological valid and time-efficient detection of risk states across psychopathology and thus informing early intervention (Cohen et al., 2019b; Niendam et al., 2018).

Contributors

TL performed the literature search, conducted data analyses, and wrote the bulk of the manuscript. TC, ES, and AC aided with data interpretation. All other authors helped interpret the findings and provided conceptual material to the planning and presentation of this project. All authors contributed to the writing of the manuscript.

Declaration of Competing Interest

The authors report no conflict of interest.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.psychres.2019.112625.

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