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# Loneliness and Psychotic Symptoms: The Mediating Role of Depression

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**Abstract** Psychotic symptoms have been shown to be associated with numerous social factors, such as migration and urban upbringing, of which one plausible common component is loneliness. This suggests a relationship between loneliness and positive psychotic symptoms. According to current cognitive models of psychosis, the relationship between loneliness and positive symptoms is likely to be explained by affective states. The current study examined the cross-sectional relationship between loneliness, depression, and positive symptoms in four separate community samples (combined $N = 766$) with regression based mediation analysis and network analysis. The results showed that depression completely mediated the relationship between loneliness and positive symptoms in three out of four samples. Partial mediation was found in one sample. Network analysis revealed that loneliness, depression, and positive symptoms clustered separately and that there was a unique connection between loneliness and items that assess paranoid beliefs, in the sense that loneliness was not found to be connected to other psychotic symptoms, such

as hallucinations. As expected, loneliness is related to positive symptoms and depression played a strong role in explaining the association. Thus, early interventions of psychosis that target loneliness are likely to be beneficial, especially if these interventions additionally target depression. Furthermore, the specific connection of loneliness and paranoid beliefs supports the theory that specific adversity leads to specific psychotic symptoms.

**Keywords** Loneliness · Depression · Psychotic symptoms · Mediation · Network analysis

## Introduction

Psychotic symptoms have been shown to be associated with numerous social factors such as being discriminated (Anglina et al. 2013; Janssen et al., 2003), being bullied (Wolke et al. 2014), living in urban areas (Kelly et al. 2010), living alone (Morgan et al. 2008), being a migrant (Cantor-Graae and Selten 2005), having low socioeconomic status (Boydell et al. 2013), and having smaller social networks and support (Gayer-Anderson and Morgan 2013). One common component of these factors has been argued to be social defeat (Selten et al. 2013), a theory which has spurred its own line of research (e.g. Gevonden et al. 2014). Another plausible common component, which has received less attention, is perceived social isolation or alienation, which is likely to result in a sense of loneliness.

Loneliness is not necessarily the same as objective social isolation; a person can feel lonely even when surrounded by other people (Hawkley and Cacioppo 2010). It is also different from solitude, which is a voluntary state (Cacioppo et al. 2010). Rather, loneliness can be described as a negative affective state that results from the perceived

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discrepancy of a persons' need for social relationships with their actual social relationships (Hawkley and Cacioppo 2010). Because of its intuitive link to the most relevant social risk factors associated with psychosis it seems reasonable to expect loneliness to be a prominent feeling in people with psychotic disorders (Deniro 1995). Moreover, feeling lonely may even precede and contribute to the development and maintenance of psychotic symptoms (Gayer-Anderson and Morgan 2013).

A causal role of loneliness to psychotic symptoms might be expected in particular for persecutory beliefs and hallucinations. Paranoia has been suggested to originate from social evaluative concerns (Freeman et al. 2005), therefore a strong commonalty with loneliness seems intuitive. Also, both paranoid symptoms and hallucinations are more likely to arise from a lack of meaningful or corrective social input. This is suggested by the social deafferentation hypothesis put forward by Hoffman (2007), who—in analogy to the phantom limb phenomenon—argued that the "social brain" of humans tends to generate meaningful social contacts in forms of hallucinations and delusions if it lacks input from real social experience. In support of this notion, both hallucinations (Nayani and David 1996) and delusions (Myin-Germeys et al. 2001) have been shown to occur more frequently when people are alone.

The hypothesized association between loneliness and psychotic symptoms is likely to be explained partially by affective states, in particular by depression. Although loneliness has been shown to be associated with a variety of mental health disorders, its association seems to be the strongest with depression (Meltzer et al. 2012; Neeleman and Power 1994). Moreover, loneliness predicted depressive symptoms in a five-year longitudinal study with cross-lagged panel analysis (Cacioppo et al. 2010) and depression preceded psychotic symptoms in several longitudinal (Fowler et al. 2012; Häfner et al. 2005) and ecological momentary assessment studies (e.g. Kramer et al. 2013). Thus, it seems reasonable to expect depression to mediate the relationship between loneliness and positive psychotic symptoms.

Recognizing loneliness as a relevant issue in psychosis, Sündermann et al. (2014) studied the relationship between social networks, loneliness, and psychotic symptoms in a sample of 38 first-episode psychotic patients. They found that participants reported high levels of loneliness. Moreover, loneliness was correlated with positive and negative symptoms. Furthermore, they found the association between loneliness and paranoid symptoms to be partially explained by anxiety. Although this study focused on anxiety rather than depression, it supports the assumption that loneliness and related affective states are associated with psychosis. Given that the sample consisted of first-episode psychotic patients of whom one third did not have a confidant, loneliness does not seem to be merely a consequence of the disorder as has been shown in previous patient studies (Neeleman and Power 1994). Rather, feelings of loneliness are likely to have already been present before the disorder and possibly contributed to it.

Following the assumption that loneliness is a risk factor for psychosis and that both psychotic symptoms and their risk factors occur on a continuum (Linscott and van Os 2013; Zavos et al. 2014) we hypothesize that people from the general population who feel lonely will score higher on subclinical positive psychotic symptoms. We argue that investigating a sample of healthy participants, rather than patients, can provide insight into basic mechanisms on the pathway from vulnerability to psychosis. Thus, the present study examined the relationship between loneliness and positive psychotic symptoms in several community samples and tested whether depression mediates this relationship. Regression-based mediation analyses were complemented by a network analysis to investigate the type of positive psychotic symptoms that would be most closely related to loneliness.

Network analysis utilizes a network framework of understanding psychopathology in the sense that relationships between constructs are not explained by interacting latent factors (e.g. underlying entity of positive symptoms is related to another underlying entity of loneliness), but as a complex system in which individual indicators (e.g. feeling lonely and paranoid thoughts) are connected with—and possibly influence—each other (Borsboom and Cramer 2013; Costantini et al. 2015; Hofmann et al. 2016). Several studies have used this approach to uncover specific connections, for example studies have shown that losing a partner is primarily linked to loneliness before spreading to other depression symptoms (Fried et al. 2015). Thus, the rationale for using a network framework is to uncover possible specific connections between loneliness and certain positive psychotic symptoms.

## Methods

### Participants and Procedure

Participants were recruited in four separate surveys that took place from September 2014 to March 2015 through Amazon's Mechanical Turk (MTurk). We repeated the survey several times to confirm the replicability of the findings as replicability of research findings is an issue in this field (i.e. psychology, Pashler and Wagenmakers 2012). MTurk is an online crowdsourcing website, on which users can do tasks in exchange for monetary compensation (Buhrmester et al. 2011). The advantages

of using MTurk for studying clinical phenomena have been convincingly described (see Shapiro et al. 2013) and include the fact that prevalence rates of clinical symptoms match those in the general population and the complete anonymity that facilitates disclosure of symptoms.

The inclusion criteria were being over 18 years old, living in the United States, having demonstrated high-quality work on previous tasks, and having reported to be fluent in English. Participants completed several self-report questionnaires that took approximately 15 min to complete. The participants who completed the questionnaires (approximately 8 min) were compensated with US $1.00.

To test the credibility of participation, we included an attention check item ("People vary in the amount they pay attention to these kinds of surveys. Some take them seriously and read each question, whereas others go very quickly and barely read the questions at all. If you have read this question carefully, please write the word yes in the blank box below labeled other. There is no need for you to respond to the scale below.").

The survey in the first sample was completed by 344 participants, the second by 180, the third by 169, and the fourth by 185. Of these, 55, 25, 18, and 14 participants respectively were excluded because they did not pass the attention check item or reported to be less than fluent in English (less than 4 in a scale of $1 = Not\ fluent$ to $5 = Very\ fluent$). The final samples consisted of 289, 155, 151, and 171 participants respectively.

The participants' characteristics in each of the sample are presented in Table 1. We found statistically significant differences across samples of gender, $\chi^2(3, N = 766) = 34.91$, $p < .001$, age, $F(3, 761) = 2.88$, $p = .035$, marital status, $\chi^2(12, N = 766) = 29.17$, $p < .001$, educational level, $\chi^2(21, N = 766) = 114.88$, $p < .001$, and family income level, $\chi^2(12, N = 766) = 43.30$, $p < .001$.

## Measures

### Loneliness

Loneliness was measured by a 3-item scale that was specifically constructed for large survey studies (Hughes et al. 2004) based on the R-UCLA Loneliness scale (Russell 1996). The scale measured the frequency of loneliness experience with a 5-point Likert scale ($1 = hardly\ ever$, $5 = often$). The items are "How often do you feel that you lack companionship?", "How often do you feel left out?", and "How often do you feel isolated from others?" The scale has demonstrated good internal consistency and validity (Hughes et al. 2004). The inter-item reliability ($\alpha$) of the loneliness scale varied between .88 and .92 in the four samples.

### Depression

The Center for Epidemiologic Studies Depression scale (CES-D, Radloff 1977) measures current depression and its frequency over the past week (e.g. "I felt depressed"). The CES-D scale has been shown to be reliable and valid in community and clinical samples (Weissman et al. 1977). The scale consists of 20 items with 5-point Likert scale ($1 = rarely\ or\ none\ of\ the\ time$, $5 = most\ or\ all\ the\ time$). However, following the procedure in other studies on loneliness (e.g. Cacioppo et al. 2006, 2010; VanderWeele et al. 2012) we excluded item 14 ("I felt lonely") to ensure that any association between loneliness and depression is not the result of item overlap. We used the average total score. Higher scores indicate more frequent depressive symptoms. The inter-item reliability ($\alpha$) of the CES-D scale varied between .93 and .94 in the four samples.

### Positive Symptoms

The positive symptoms frequency subscale of the Community Assessment of Psychic Experiences (CAPE, Stefanis et al. 2002) was used to measure the frequency of experiencing positive symptoms. Specifically, the positive symptoms subtypes are hallucinations, bizarre experiences, paranoia, and other delusions (Schlier et al. 2015). The scale consists of 20 items with a 4-point Likert scale ($1 = never$, $4 = nearly\ always$). Higher scores indicate more frequent experiences of positive symptoms. The CAPE has shown good internal consistency, construct validity, and predictive validity in community and clinical samples (Brenner et al. 2007; Konings et al. 2006; Mossaheb et al. 2012; Schlier et al. 2015). The inter-item reliability ($\alpha$) of the CAPE positive symptoms frequency scale varied between .90 and .95 in the four samples.

### Statistical Analyses

First, a mediation analysis was conducted following the Baron and Kenny procedure (Baron and Kenny 1986). This was computed with PROCESS Macro version 2.13 by Hayes (www.processmacro.org) on SPSS version 22 (Hayes 2013). The PROCESS Macro uses an ordinary least squares regression-based path analytic framework for mediation analysis. The unstandardized regression coefficient was reported, along with the bias-corrected and accelerated bootstrapped 95 % confidence interval (CI) based on 1000 bootstrap draws. According to Cohen, effect sizes in the form of percentage of variance explained ($R^2$) of 0.01, 0.06, and 0.14 are considered small, medium, and large, respectively (Cohen 1988). The predictor variable was loneliness, the outcome variable was positive symptoms, and the mediator variable was depression. The

**Table 1** Participants' characteristics

|  | First sample (n = 289) | Second sample (n = 155) | Third sample (n = 151) | Fourth sample (n = 171) |
|---|---|---|---|---|
| Gender |  |  |  |  |
| Male | 94 (32.5 %) | 83 (53.5 %) | 89 (58.9 %) | 73 (42.7 %) |
| Female | 195 (67.5 %) | 72 (46.5 %) | 62 (41.1 %) | 98 (57.3 %) |
| Age | 37.61 (SD = 12.77) | 36.50 (SD = 11.62) | 34.07 (SD = 11.39) | 37.06 (SD = 12.65) |
| Marital status |  |  |  |  |
| Single | 127 (43.9 %) | 50 (32.3 %) | 58 (38.4 %) | 82 (48.0 %) |
| Married | 125 (43.3 %) | 98 (63.2 %) | 85 (56.3 %) | 77 (45.0 %) |
| Divorced | 27 (9.3 %) | 7 (4.5 %) | 5 (3.3 %) | 9 (5.3 %) |
| Separated | 3 (1.0 %) | 0 (0.0 %) | 1 (0.7 %) | 1 (0.6 %) |
| Widowed | 7 (2.4 %) | 0 (0.0 %) | 2 (1.3 %) | 2 (1.2 %) |
| Educational level |  |  |  |  |
| High-school, no diploma | 2 (0.7 %) | 1 (0.6 %) | 1 (0.7 %) | 3 (1.8 %) |
| High-school diploma | 40 (13.9 %) | 6 (3.9 %) | 9 (6.0 %) | 22 (12.9 %) |
| Some college | 84 (29.2 %) | 13 (8.4 %) | 9 (6.0 %) | 47 (27.5 %) |
| Associate degree | 30 (10.4 %) | 7 (4.5 %) | 12 (7.9 %) | 16 (9.4 %) |
| Bachelor's degree | 85 (29.5 %) | 85 (54.8 %) | 81 (53.6 %) | 63 (36.8 %) |
| Master's degree | 35 (12.2 %) | 41 (26.5 %) | 37 (24.5 %) | 16 (9.4 %) |
| Professional or doctorate degree | 12 (4.2 %) | 2 (1.3 %) | 2 (1.3 %) | 4 (2.3 %) |
| Family income level |  |  |  |  |
| Under US$25,000 | 62 (21.5 %) | 56 (36.1 %) | 64 (42.4 %) | 43 (25.1 %) |
| Between US$25,000 and US$50,000 | 90 (31.1 %) | 57 (36.8 %) | 51 (33.8 %) | 55 (32.2 %) |
| Between US$50,000 and US$100,000 | 96 (33.2 %) | 29 (18.7 %) | 27 (17.9 %) | 57 (33.3 %) |
| Between US$100,000 and US$250,000 | 36 (12.5 %) | 12 (7.7 %) | 7 (4.6 %) | 15 (8.8 %) |
| More than US$250,000 | 5 (1.7 %) | 1 (0.6 %) | 2 (1.3 %) | 1 (0.6 %) |

Gender $\chi^2(3, N = 766) = 34.91$, $p < .001$; Age $F(3, 761) = 2.88$, $p = .035$; Marital status $\chi^2(12, N = 766) = 29.17$, $p < .001$; Educational level $\chi^2(21, N = 766) = 114.88$, $p < .001$; Family income level $\chi^2(12, N = 766) = 43.30$, $p < .001$

mediation analysis was conducted separately for each sample.

Second, in order to visualize the proximity between items within each construct and the proximity between the constructs at the item level, a network analysis was conducted based on a polychoric correlation matrix with an extended Bayesian information criterion (EBIC) minimization procedure in the combined sample ($N = 766$). The EBIC procedure has been shown to produce accurate network estimations (Foygel and Drton 2010; van Borkulo et al. 2014). Furthermore, we used the least absolute shrinkage and selection operator (LASSO) regularization technique developed by Tibshirani (1996), specifically the graphical LASSO variant that directly estimates the inverse of the covariance matrix that is developed by Friedman et al. (2008). The partial correlation based network is particularly useful to investigate specific relationships between constructs as it stringently controls for other relationships (Borsboom and Cramer 2013). As centrality

parameters and clustering coefficients are often provided in studies using network analysis (for example see Curtiss and Klemanski 2016), we have provided them as additional figures in the supplementary material (see Supplementary Figure 2 for the strength centrality plot and Supplementary Figure 3 for the clustering centrality plot of this network). The network was visualized using Qgraph version 1.3.3. package (Epskamp et al. 2012) in R version 3.2.2.

## Results

### Mean, Standard Deviation, and Score Range

The means, standard deviations, and score ranges for loneliness, depression, and positive symptoms are presented in Table 2. The mean scores of loneliness, depression, and positive symptoms (Choi et al. 2014; Hanssen et al. 2003; Hughes et al. 2004) are comparable to previous

**Table 2** Mean, standard deviations, and score range of the first, second, third, and fourth sample

|  | First sample ($n = 289$) | | | Second sample ($n = 155$) | | | Third sample ($n = 151$) | | | Fourth sample ($n = 171$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | M | SD | Range | M | SD | Range | M | SD | Range | M | SD | Range |
| Loneliness | 2.47 | 1.21 | 1.00–5.00 | 2.62 | 1.06 | 1.00–5.00 | 2.43 | 1.10 | 1.00–5.00 | 2.68 | 1.27 | 1.00–5.00 |
| Depression | 2.32 | 0.59 | 1.63–4.21 | 2.43 | 0.55 | 1.63–3.79 | 2.44 | 0.61 | 1.63–4.16 | 2.43 | 0.61 | 1.63–4.26 |
| Positive symptoms | 1.39 | 0.39 | 1.00–3.11 | 1.72 | 0.63 | 1.00–3.68 | 1.82 | 0.63 | 1.00–3.32 | 1.46 | 0.46 | 1.00–3.16 |

studies on community samples. We found statistically significant mean score differences between the samples for positive symptoms, $F(3, 762) = 31.42$, $p < .001$, but not for loneliness, $F(3, 762) = 1.86$, $p = .135$, nor depression, $F(3, 762) = 1.96$, $p = .118$.

## Mediation Analyses

The mediation analysis is illustrated in Fig. 1. We found statistically significant associations of loneliness and positive symptoms ($c$) in the four samples. We also found statistically significant associations of loneliness with depression ($a$), and depression with positive symptoms ($b$) in all four samples. Entering depression in the model reduced the strength of the previously statistically significant association between loneliness and positive symptoms ($c'$) to non-significance in the first, second, and fourth sample, and a reduction of the strength of the association was observed in the third sample. There was a full mediation effect in the first (standardized indirect effect = 0.31, Bootstrap SE = 0.06, 95 % CI [0.21, 0.43]), second (standardized indirect effect = 0.45, Bootstrap SE = 0.07, 95 % CI [0.30, 0.59]), and fourth sample (standardized indirect effect = 0.31, Bootstrap SE = 0.06, 95 % CI [0.20, 0.43]). A partial mediation effect was observed in the third sample (standardized indirect effect = 0.29, Bootstrap SE = 0.07, 95 % CI [0.16, 0.43]). When age, sex, marital status, education level, and family income level were entered as covariates, a similar pattern was found: full mediation was observed in the first, second, and fourth sample, and partial mediation in the third sample. The unstandardized (B) estimate, 95 % CI, and $R^2$ are presented in Table 3. Loneliness accounted for medium to large amounts of variance in positive symptoms, range of $R^2$ from .10 to .32, and large amounts of variance in depression, range of $R^2$ from .45 to .51. Loneliness together with depression accounted for large amounts of variance of positive symptoms, range of $R^2$ from .22 to .41.

## Network Analysis

The network is shown in Fig. 2, where only absolute partial correlations above 0.05 are shown to improve the interpretation and visibility (please see Supplementary Figure 1
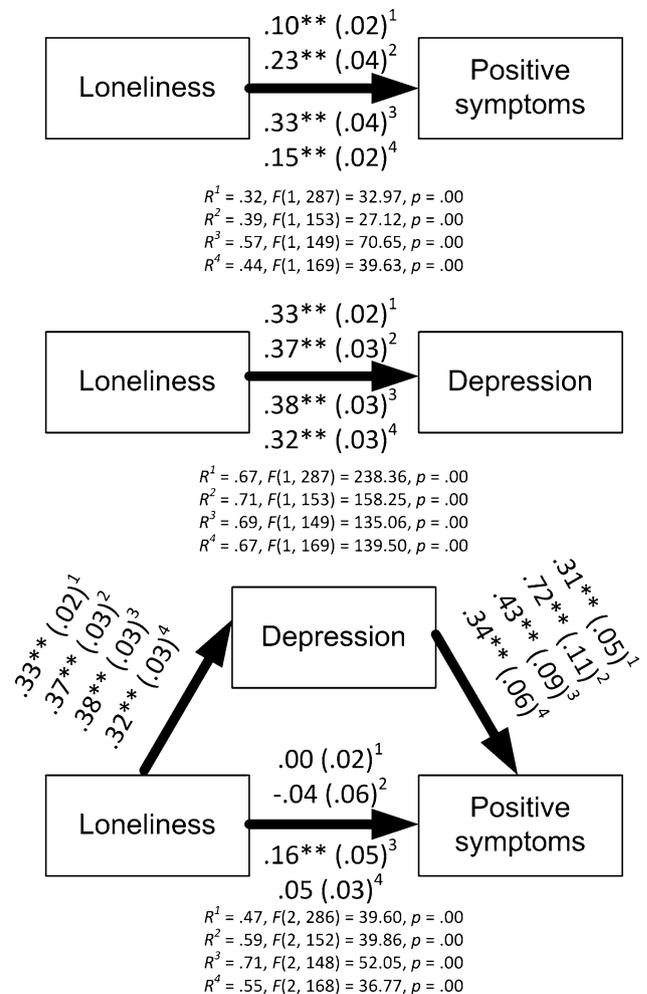


$R^1 = .32$, $F(1, 287) = 32.97$, $p = .00$
$R^2 = .39$, $F(1, 153) = 27.12$, $p = .00$
$R^3 = .57$, $F(1, 149) = 70.65$, $p = .00$
$R^4 = .44$, $F(1, 169) = 39.63$, $p = .00$

$R^1 = .67$, $F(1, 287) = 238.36$, $p = .00$
$R^2 = .71$, $F(1, 153) = 158.25$, $p = .00$
$R^3 = .69$, $F(1, 149) = 135.06$, $p = .00$
$R^4 = .67$, $F(1, 169) = 139.50$, $p = .00$

$R^1 = .47$, $F(2, 286) = 39.60$, $p = .00$
$R^2 = .59$, $F(2, 152) = 39.86$, $p = .00$
$R^3 = .71$, $F(2, 148) = 52.05$, $p = .00$
$R^4 = .55$, $F(2, 168) = 36.77$, $p = .00$

**Fig. 1** Mediation analysis on the relationship of loneliness and positive symptoms mediated by depression. *Note* superscript numbers ([1,2,3,4]) indicate first, second, third, and fourth sample; **$p < 0.01$; unstandardized regression coefficient is reported with standard error in brackets

for a network without any form of cut-off). As can be seen, loneliness, depression, and positive symptoms items were clustered separately. The network also revealed that the loneliness items—rather than indirectly through depression—were only directly connected with the CAPE's P3 item (false appearance: "Do you ever feel that some people are not what they seem to be?") and P11 item (odd looks: "Do you ever feel that people look at you oddly because of

**Table 3** Mediation analysis of loneliness, depression, and positive symptoms

| Mediation steps | Outcome | Predictor | $B$ | | | | 95 % CI | | | | $R^2$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| 1 | Positive | Loneliness | .10** | .23** | .33** | .15** | [.07, .14] | [.14, .32] | [.25, .40] | [.11, .20] | .10 | .15 | .32 | .19 |
| 2 | Depression | Loneliness | .33** | .37** | .38** | .32** | [.29, .37] | [.31, .43] | [.32, .45] | [.27, .38] | .45 | .51 | .48 | .45 |
| 3 | Positive | Depression | .31** | .72** | .43** | .34** | [.21, .40] | [.51, .93] | [.25, .61] | [.21, .46] | .22 | .34 | .41 | .31 |
| 4 | | Loneliness | .00 | −.04 | .16** | .05 | [−.04, .05] | [−.15, .08] | [.06, .26] | [−.02, .11] | | | | |

Positive means positive symptoms

CI = bias-corrected and accelerated confidence interval for B; 1 = first sample ($n = 289$), 2 = second sample ($n = 155$), 3 = third sample ($n = 151$), 4 = fourth sample ($n = 171$)

** $p < 0.01$

your appearance?"), which both load on the paranoia factor of the CAPE (Schlier et al. 2015). In addition, the network generally positioned items related to paranoia and grandiosity in the outer section of the positive symptoms cluster and near the depression cluster. This pattern was particularly clear with P3 (false appearances) and P11 (odd looks) representing paranoia, as well as P7 (being special) and P6 (being important) representing grandiosity.

### Additional Analysis

Because the network showed that the loneliness cluster lies in between the depression and positive symptoms cluster, we also explored the hypothesis that loneliness mediates the relationship between depression and positive symptoms. However, as to be expected from the set of regressions already conducted (see Sect. 3.2.), we found that loneliness did not act as a mediator because its relationship with positive symptoms was not significant in the third step of the mediation, after taking depression into account (first sample, $B = 0.00$, $p = .85$; second sample, $B = −0.04$, $p = .53$; fourth sample, $B = 0.05$, $p = .14$). However, in the third sample we found that loneliness significantly mediated the relationship between depression and positive symptoms (standardized indirect effect = 0.19, Bootstrap SE = 0.06, 95 % CI [0.07, 0.32]). Therefore, the results mostly do not support the hypothesis that loneliness mediates the relationship between depression and positive symptoms.

### Discussion

Overall, the findings were in line with our expectations. In all four samples loneliness was strongly associated with positive symptoms and this was largely explained by

depression. The clear association of loneliness and positive symptoms corroborates the findings of the study in first-episode sample (Sündermann et al. 2014). The fact that we found the same association in the general population speaks for a high external validity of the association and further emphasizes the role of loneliness to mental well-being (Hawkley and Cacioppo 2010).

Depression consistently explained the relationship of loneliness and positive symptoms. This adds to the accumulating evidence for the role of affective states in the development and maintenance of positive symptoms that is emphasized in psychological models (e.g. Freeman et al. 2005; Morrison 2001). The alternative interpretation that loneliness and depression are essentially the same construct is ruled out in this study by the separate clustering of depression and loneliness items in the network analysis. Furthermore, a possible alternative model of loneliness mediating the relationship between depression and positive symptoms was not clearly supported by our additional analyses.

Additionally, as expected, the network analysis identified a unique connection between loneliness and symptoms of paranoia, specifically the impression that other people are giving odd looks and that other people are not what they seem to be. Other than expected, however, we did not find a connection between loneliness and hallucinations. Rather, hallucinations seemed to be associated with loneliness through a complex web of other positive symptoms. This finding does not support the notion that hallucinations arise directly from a lack of meaningful or corrective social input as suggested by the social deafferentation hypothesis (Hoffman 2007). Nevertheless, the different patterns of associations between loneliness and subtypes of positive symptoms support Bentall et al. (2014) theory on the heterogeneity of etiology in psychotic symptoms. Specifically, feeling lonely is associated with and might be a unique risk-factor for paranoid symptoms.
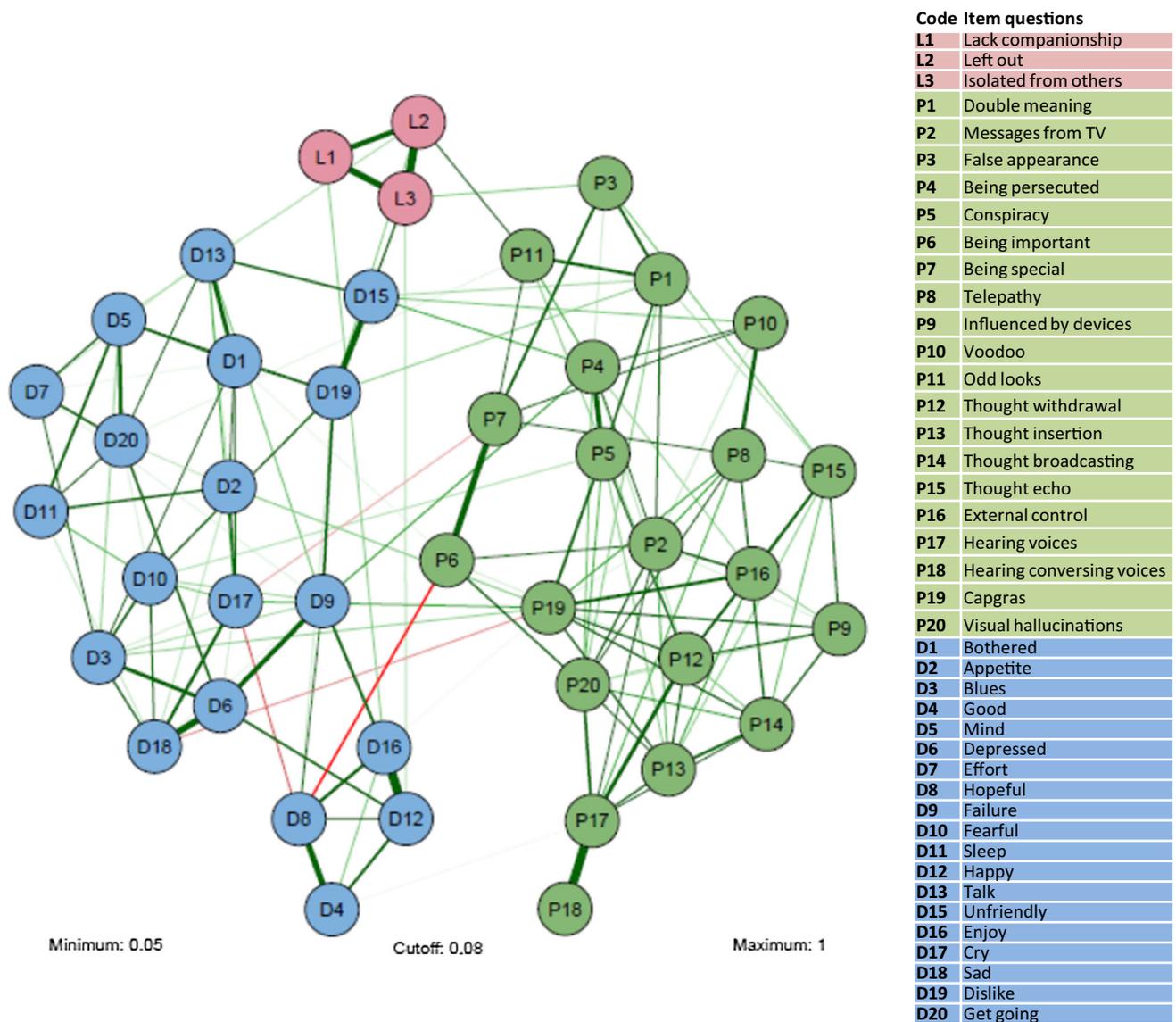
| Code | Item questions |
|------|----------------|
| L1 | Lack companionship |
| L2 | Left out |
| L3 | Isolated from others |
| P1 | Double meaning |
| P2 | Messages from TV |
| P3 | False appearance |
| P4 | Being persecuted |
| P5 | Conspiracy |
| P6 | Being important |
| P7 | Being special |
| P8 | Telepathy |
| P9 | Influenced by devices |
| P10 | Voodoo |
| P11 | Odd looks |
| P12 | Thought withdrawal |
| P13 | Thought insertion |
| P14 | Thought broadcasting |
| P15 | Thought echo |
| P16 | External control |
| P17 | Hearing voices |
| P18 | Hearing conversing voices |
| P19 | Capgras |
| P20 | Visual hallucinations |
| D1 | Bothered |
| D2 | Appetite |
| D3 | Blues |
| D4 | Good |
| D5 | Mind |
| D6 | Depressed |
| D7 | Effort |
| D8 | Hopeful |
| D9 | Failure |
| D10 | Fearful |
| D11 | Sleep |
| D12 | Happy |
| D13 | Talk |
| D15 | Unfriendly |
| D16 | Enjoy |
| D17 | Cry |
| D18 | Sad |
| D19 | Dislike |
| D20 | Get going |

**Fig. 2** Network of loneliness, depression, and psychotic symptoms. The *green lines* indicate positive associations, *red lines* negative associations, and the *thickness of the lines* indicates the strength of the association. *Lines* representing below a 0.05 correlation coefficient were not shown, the cut-off for a normal line was set at 0.08, and the maximum line thickness was set at 1.00 (Color figure online)

## Strengths and Limitations

We acknowledge that there would have been alternative ways of analyzing the data, such as using a Bayesian framework (Nuijten et al. 2014) that allows for the combination of results into one coefficient. However, we chose—and consider a strength—a frequentist inference replication approach and found consistent support for our hypotheses across four samples that differed significantly in age, gender, educational level, and family income. Furthermore, although it would have been interesting to conduct the network analysis on each of the samples, it would have been difficult to compare them due to unequal sample sizes. The method of network analyses in psychopathology is novel and rigorous methods to assess reliability are yet to be developed. We conducted the network analysis on the aggregated sample in order to provide the most accurate network. Thus, the results can be considered as a stable finding that can form a basis for future research.

However, some limitations need to be taken into account. First, causal inferences are limited due to the cross-sectional nature of the study. Although the findings from longitudinal studies seem to justify arguing for a causal pathway from loneliness to depression (e.g. Cacioppo et al. 2010, 2006) and from depression to positive symptoms (e.g. Kramer et al. 2013; van Rossum et al.

2011), the causal effect of loneliness on positive symptoms is less clear. While loneliness is likely to increase paranoid thoughts, these thoughts may in turn lead to increased loneliness due to the lack of corrective feedback and the social withdrawal that typically results from increased paranoia. Thus, it seems intuitive to assume that both causal directions play a role. Another limitation is that all of the four samples were collected via MTurk users. The advantage of such method of recruitment is that it allows us to conduct exact replications with participants coming from diverse socio-demographic background (e.g. from people with no high school certificate to people with a professional or doctorate degree), but the findings may not be representative of people who do not have access to the Internet (e.g. people living below poverty line).

In the four samples the CAPE positive symptom scores were within the range of the mean scores found in previously reported epidemiological non-clinical samples ($M = [1.3, 1.4]$) and lower than in samples of patients such as schizophrenia patients ($M = 2.13$, Konings et al. 2006; Moritz and Larøi 2008). Moreover, the broad range of scores in the study's samples ($M = [1.00, 3.68]$) corresponds to previous findings in community samples (e.g. Hanssen et al. 2003). Therefore, the CAPE scores across the four samples can be considered representative of the general population.

### Clinical Implications

The results add to the accumulating evidence indicating that the evaluation of one's social situation (Freeman et al. 2014), interpersonal self-concept (Kesting and Lincoln 2013), and affective processing (Freeman and Garety 2014; O'Driscoll et al. 2014) are relevant risk factors on the pathway from external stressors' to psychosis. Our findings further extend this understanding by pointing specifically to the relevance of loneliness. One implication of the result is that interventions targeting loneliness are likely to be an effective adjunct to early interventions for psychosis as they could improve both depression and psychotic symptoms. So far however, early interventions have not been successful in increasing social integration and social connectedness (Marshall and Rathbone 2011). Thus, refinement or a new conceptualization of interventions targeting loneliness seems warranted.

Depending on whether the nature of loneliness lies in a lack of social relationships or a lack of meaning in these relationships, or both, there are a variety of interventions that have the potential to reduce feelings of loneliness. For example, an adapted version of behavioral activation therapy (Lejuez et al. 2011) which focuses specifically on social activities could be used to promote new opportunities to make social contacts. Maladaptive interpersonal beliefs could be targeted by cognitive therapy (Mehl 2015) and feelings of connectedness with others could be increased by imagery-based techniques, such as suggested in compassion-focused therapy (Lincoln et al. 2012) or loving-kindness meditations (Hutcherson et al. 2008).

However, our findings also indicate that treating depression alone might suffice for improving subclinical psychotic experiences and could possibly prevent full-blown clinical psychosis. Focusing solely on depression is a prominent component of existing early intervention programs. It has the advantage that patients do not have to be confronted with a label of psychosis which may lead to stigmatization (Schlier et al. 2014) in the first place and thus be more readily acceptable to people at risk.

### Summary

Overall, the findings underline the importance of loneliness and depression in explaining psychotic symptoms. This indicates that early intervention would benefit from targeting both loneliness and depression. In line with our assumption that paranoid beliefs arise from social evaluative concerns and a lack of meaningful social input, we found that, within the full range of psychotic experiences, loneliness was particularly related to paranoid beliefs. Targeting social affiliative processes may thus hold particular potential for people with paranoid symptomatology.

#### Compliance with Ethical Standards

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