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Social Deafferentation and the Relation Between Loneliness and Hallucinations

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Background and Hypothesis: The social deafferentation hypothesis (SDA) has been proposed as an explanatory mechanism of hallucinations, based on the theory that social withdrawal triggers the initial phase of schizophrenia. The current study tests the SDA by assessing how loneliness is associated with different types of hallucinations. Under the SDA, increased loneliness is hypothesized to affect the occurrence of hallucinations that carry social meaning, but not of nonsocial hallucinations. **Study Design:** As part of an online survey, 2038 adolescents and young adults from the general population (median age 21 years; 75% female) filled out the Questionnaire for Psychotic Experiences, and the shortened De Jong Gierveld Loneliness Scale. Binomial logistic regression was used to investigate the effects of loneliness severity on past month prevalence of hallucinations, and on the presence of social versus nonsocial hallucinations. **Study Results:** Loneliness increased the prevalence of hallucinations across modalities in the past month. Moreover, stronger degree of loneliness increased the likelihood of hearing voices or laughter, and of hallucinating being touched. Conversely, loneliness decreased the likelihood of experiencing the nonsocial hallucination of a tingling feeling. As expected, loneliness did not increase the prevalence of experiencing nonsocial hallucinations. Surprisingly, neither was loneliness associated with experiencing felt presence. **Conclusions:** Our results are novel in showing that loneliness specifically increases the likelihood of hearing human sounds such as voices or laughter, or feeling a human touch. Hallucinations without social meaning were not more likely to be experienced with increasing loneliness. This forms a confirmation of the SDA.

Key words: social deafferentation/loneliness/hallucinations/adolescents/young adults

Introduction

Engaging in strongly bonded relationships is a principal characteristic of humans and other primates, highlighting the importance of social networks to our species' survival.¹ It is, therefore, unsurprising that social isolation can come at great costs, including a decrease in physical and mental well-being, and even development of psychiatric disorders.² Recognizing the vulnerability of the socially developing brain, Hoffman³ proposed the social deafferentation hypothesis (SDA) as an explanatory mechanism for psychotic experiences such as hallucinations. Specifically, the SDA states that social withdrawal during critical brain development triggers the onset of the initial phase of schizophrenia by way of neuroplastic reactivity. Akin to sensory deafferentation, where visual and auditory impairment can lead to hallucinations in these perceptual modalities, loneliness is hypothesized to cause spurious activation of social schema—resulting in hallucinations with a social connotation.^{4,5}

At the time the SDA was proposed, its empirical support was limited. More recently, the relation between loneliness and the occurrence of hallucinations in psychosis has been shown to be substantial.⁶ Furthermore, this relation has been replicated beyond the context of psychotic disorders. For example, Slotema et al. found that patients with borderline personality disorder experience more hallucinations with increasing loneliness.⁷ Dodell-Feder et al. showed that also in the general population, having smaller

social networks is associated with an increased occurrence of hallucinations.⁸ However, in such studies it is difficult to disentangle cause and effect, as people with a schizotypal tendency tend to be less social and also carry a predisposition for hallucinations.^{7,9,10} Hence, their hallucinations may merely reflect their genetic predisposition and not result from their lack of human contacts per se. It is also known that people with psychotic experiences will become more socially isolated as a result of symptoms like paranoid tendency.¹¹ In previous studies, the exact content of the hallucinations (ie, social or nonsocial) was not examined or not specified, leaving it unclear whether the reported hallucinations can indeed be interpreted as social deafferentation (ie, spurious socially-related brain activity). An exception is a study by Lincoln et al.,¹² which showed that loneliness does not affect the proneness to hallucinate music (ie, a nonsocial hallucination) in a white-noise paradigm, which is consistent with the SDA.

While the SDA forms a compelling explanation for the occurrence of social hallucinations, its support is still scarce. To test the SDA, a distinction should be made between social (eg, hearing voices, feeling touch) and nonsocial (eg, hearing music, feeling formication) hallucinations. The aim of the current study, therefore, is to form a more rigorous test of the SDA by assessing whether increasing loneliness is associated with hallucinations that carry social meaning, but not with hallucinations that lack any social connotation. The SDA specifies that the adverse effect of loneliness on neuroplastic reactivity should only take place during the so-called vulnerable period for the initial phase of schizophrenia. For this reason, in the current study we limit our investigation to participants in adolescence and early adulthood, aligning with the age range during which the earliest signs of mental disturbances and first psychotic symptoms emerge preceding the onset of schizophrenia.¹³ We examine loneliness and hallucinations in a large nonclinical sample, additionally overcoming known confounding factors often associated with research in clinical samples (eg, social isolation as a result of a psychiatric disorder and presence of schizotypal personality).

Methods and Materials

Participant Recruitment

Participants were recruited from the general Dutch population between September 2016 and May 2017, and were eligible to take part if they were 14 years of age or older and able to understand Dutch. In order to reach a broad participant population, the study was promoted via national television, online news, online scientific lectures, popular scientific events, and websites.

Procedures

Eligible respondents who gave digital written informed consent participated by filling out an online survey, consisting of questions pertaining to demographic information (eg, age and sex), recreational drug use, and a number of questionnaires. Among these were the Questionnaire for Psychotic Experiences (QPE)—filled out by all participants, and the De Jong Gierveld Loneliness Scale (DJGLS)—presented as an optional follow-up questionnaire, and hence filled out by a subset of the participants.^{14,15} An elaborate description of the entire survey procedure is provided elsewhere.¹⁶ The current study discusses the outcomes of the survey data acquired with the QPE and DJGLS, and demographic information. The study was approved by the ethical review board of the University Medical Center Utrecht (IRB number 16-408).

Questionnaire for Psychotic Experiences

The QPE is a validated questionnaire examining psychotic-like experiences, among which hallucinations.¹⁴ The QPE includes a range of questions about hallucinations in different perceptual modalities, including the auditory (AH), visual (VH), and tactile (TH), which form the focus of the current study. Of importance for the study aim, the QPE gathers information about the specific content of hallucinatory experiences.

De Jong Gierveld Loneliness Scale

The degree of loneliness was assessed by the shortened version of the DJGLS, which is a validated scale that measures overall loneliness using six statements that are to be rated.¹⁵ Participants could indicate how well the statements (eg, “I often feel rejected”, “I miss people in my life on whom I can rely”) applied to them by indicating “no”, “more or less”, or “yes”. The corresponding coding of 0, 1, 2 resulted in a total loneliness score ranging between 0 and 12.

Statistical Analyses

Participants were included in the current study if they were between the ages of 14 and 25 years old, and had completed the QPE and DJGLS. As some recreational drugs are known to be potent triggers for hallucinations, and substance use can be a form of social behavior, a preliminary analysis of only those participants who had not used any recreational drugs (ie, cannabis, MDMA, cocaine, GHB, amphetamines, 4FA, nitrous oxide, ketamine, psilocybine, or LSD) in the past month was carried out to examine possible differences with the sample at large.¹⁷ To assess any effects of sex and age on hallucination prevalence and loneliness score, we used chi-square tests, Mann-Whitney *U* tests, and logistic regression analyses.

As part of the QPE, participants who had experienced a hallucination in the past month were asked to specify the type of hallucination.¹⁶ From these, we selected those that have a clear social connotation (ie, that would signal the presence of other humans and could prompt social interaction, had they been externally generated percepts: hearing voices or laughter, seeing people, feeling touch, feeling a human presence), and those clearly without social connotation (ie, not signaling human presence: hearing music or environmental sounds, seeing animals, feeling formication, or tingling) in the same perceptual modalities and with roughly the same complexity, for comparison. For our analyses of interest, therefore, we selected those participants who had indicated to have had experienced an AH, VH, and/or TH in the past month.

The QPE also gathers information about olfactory hallucinations. Smell, like any sensory modality in social animals, can be very important in terms of relaying social information.¹⁸ However, in humans, smelling other people can be hypothesized to be less likely to prompt social interaction in the way that, for example, seeing other people would, although studies on the role of olfaction in triggering social actions are as of yet missing.¹⁹ In addition, smells created by the presence of a person (eg, perfume) may linger, sometimes still being present long after the person has left. For these reasons, we considered olfactory hallucinations to lack the clear social connotation that hearing voices and laughter, seeing people, feeling touch, and a presence do have, and did not include them in our analyses.

To compare social and nonsocial hallucinations, we performed binary logistic regression analyses on the prevalence of these different types of hallucinations with loneliness score as explanatory variable. To control for effects of age and sex, these factors were included in the models. Beta-weights are reported, indicating the increment in likelihood of experiencing the specific hallucination for each unit increase of the loneliness score (ranging from 0 to 12). Reported *P*-values are those after correcting for the false discovery rate, when pertaining to the analyses of interest (comparing social and nonsocial hallucinations).²⁰ Reported *P*-values for the general results and demographics are uncorrected. All analyses were run using RStudio version 1.4.1717.

Results

Demographics and General Outcomes

Of the survey respondents, 2038 were between the ages of 14 and 25 years old and had completed both the DJGLS and QPE. Results of the analyses for the subsample of participants who had not used recreational drugs in the past month ($n = 1607$) can be found in the [Supplementary Results](#). The results of this subsample do not differ from the results of the entire sample in terms of direction and significance of effects. All reported analyses in the following sections, therefore, pertain to the entire sample of 2038 participants.

Median age of the participants in this sample was 21 years (interquartile range [IQR] = 5), and 75% were women. Lifetime prevalence of hallucinations was 83%, with 65% having experienced an AH, 49% a VH, and 50% a TH. During the past month, 58% of the participants had experienced a hallucination, with 40% experiencing an AH, 27% a VH, and 28% a TH. The median loneliness score was 3 (IQR = 5).

Female participants more often experienced a hallucination in the past month (65%) than males (55%) ($\chi^2 = 14.1$, $P < .001$). This pattern held for AH (females: 42%; males: 34%; $\chi^2 = 10.1$, $P = .002$), VH (females: 28%; males: 23%; $\chi^2 = 10.1$, $P = .002$), and TH (females: 30%; males: 23%; $\chi^2 = 10.8$, $P = .001$). In addition, female participants indicated to feel lonelier (median = 3, IQR = 5) than males (median = 2, IQR = 3) ($U = 13.8$, $P < .001$) (table 1).

Increasing age was associated with a decrease in past month prevalence of hallucinations in general ($\beta = -0.02$, $SE = 0.004$, $P < .001$), with participants below the age of 21 having more often experienced hallucinations (67%) than participants of and above the age of 21 (58%) ($\chi^2 = 15.7$, $P < .001$). This pattern held for AH ($\beta = -0.02$, $SE = 0.004$, $P < .001$) and TH ($\beta = -0.02$, $SE = 0.003$, $P < .001$), but only at trend level for VH ($\beta = -0.01$, $SE = 0.003$, $P = .072$). Increasing age was also associated with a decrease in loneliness ($\beta = -0.07$, $SE = 0.023$, $P = .003$), with participants below the age of 21 feeling lonelier (median = 3, IQR = 5) than participants of and above the age of 21 (median = 2, IQR = 4) ($U = 11.3$, $P < .001$).

Table 1. Demographics and General Outcomes

	Total	Hallucinated past month	χ^2	<i>P</i>	Median loneliness score (IQR)	<i>U</i>	<i>P</i>
Total	2038	1271 (62%)			3 (5)		
Sex			14.1	< .001		13.8	< .001
Male	510	282 (55%)			2 (3)		
Female	1528	989 (65%)			3 (5)		
Age			15.7	< .001		11.3	< .001
14–20 years	929	623 (67%)			3 (5)		
21–25 years	1109	648 (58%)			2 (4)		

Note: χ^2 = chi-square statistic; IQR = inter-quartile range; *U* = Mann-Whitney *U* statistic. Bold values are $< .05$.

Loneliness and Social vs Nonsocial Hallucinations

Binary logistic regression analyses showed that loneliness increased the prevalence of experiencing hallucinations in general ($\beta = 0.16$, $SE = 0.02$, $P < .001$). Among these are also AH, VH, and TH included which are neither clearly social or nonsocial, such as hearing the doorbell ring (table 2).

Importantly, we further found that loneliness significantly affected the occurrence of social hallucinations in the past month. Specifically, more severe loneliness was associated with an increase in occurrence of hearing voices ($\beta = 0.08$, $SE = 0.02$, $P = .003$), hearing laughter ($\beta = 0.21$, $SE = 0.07$, $P = .011$), and the feeling of being touched ($\beta = 0.08$, $SE = 0.03$, $P = .011$) (figure 1).

In contrast, loneliness severity did not increase the occurrence of any nonsocial hallucinations, as evidenced by the absence of such a relation for hearing music ($\beta = 0.02$, $SE = 0.03$, $P = .698$), hearing environmental sounds ($\beta = 0.01$, $SE = 0.03$, $P = .945$), seeing animals ($\beta = -0.02$, $SE = 0.04$, $P = 0.755$), or feeling formication ($\beta = 0.02$, $SE = 0.03$, $P = .755$). Moreover, increased loneliness was associated with a decrease in the occurrence of hallucinating a tingling feeling ($\beta = -0.11$, $SE = 0.04$, $P = 0.011$).

We did not find the hypothesized effect of loneliness on the occurrence of seeing people ($\beta = 0.04$, $SE = 0.03$, $P = .290$) or feeling a presence ($\beta = 0.01$, $SE = 0.05$, $P = .945$).

Discussion

Following previous research, we show that increased loneliness is associated with a higher prevalence of hallucinations, in a dose response fashion and across perceptual modalities. We go further in showing that loneliness increases the likelihood of hearing voices or laughter, or hallucinating the feeling of being touched. Importantly,

these are all hallucinations that carry social meaning. Conversely, the nonsocial hallucination of a tingling feeling was less likely to be experienced with increased loneliness. Other hallucinations without a social connotation (ie, hearing music, hearing environmental sounds, seeing animals, feeling formication) were not more likely to be experienced with increased loneliness. These contrasting findings for social vs nonsocial hallucinations form a first direct confirmation of the SDA.

Hearing voices or laughter, and feeling touch (other than one's own) can be interpreted as social hallucinations as they would have to derive from another person had the experience been externally generated. With regard to voices, Alderson-Day and Fernyhough²¹ argue that there are more grounds on which to base their social interpretation. Specifically, the authors note that auditory verbal hallucinations are often associated with distinct identities and are perceived as having agent-like properties. This is not restricted to patients with a schizophrenia-spectrum disorder, as Daalman et al.²² showed personification of voices to also take place among nonclinical voice hearers. Furthermore, Alderson-Day and Fernyhough highlight the role of general language processes (eg, speech perception cuing social interaction) in perceiving voices as social representations.²¹ The fact that we show similar results for the hallucination of laughter indicates that this mechanism transcends language and is possibly applicable to all human voice sounds. This tallies with theories about laughter being a precursor to language, and having the function of social bonding in early hominin species.²³

Unexpectedly, we found that increased loneliness is associated with a decrease in the hallucination of a tingling feeling. In interpreting this result, it is important to note that we, conversely, found increased loneliness to be associated with an increase in the hallucination of feeling touch. It can be hypothesized that the sensory qualities of hallucinating tingling and touch are quite similar.

Table 2. Past Month Prevalence of Social and Nonsocial Hallucinations

Past month hallucinations	Total	β loneliness (SE)	<i>p</i>
All hallucinations	1271 (62%)	0.16 (0.02)	< .001
Social			
Voices (AH)	281 (14%)	0.08 (0.02)	.003
Laughter (AH)	19 (1%)	0.21 (0.07)	.011
People (VH)	210 (10%)	0.04 (0.03)	.290
Touch (TH)	264 (13%)	0.08 (0.03)	.011
Presence (TH)	37 (2%)	0.01 (0.05)	.945
nonsocial			
Music (AH)	140 (7%)	0.02 (0.03)	.698
Environment (AH)	174 (9%)	0.01 (0.03)	.945
Animals (VH)	85 (4%)	-0.02 (0.04)	.755
Tingling (TH)	88 (4%)	-0.11 (0.04)	.011
Formication (TH)	172 (8%)	0.02 (0.03)	.755

Note: AH = auditory hallucination; VH = visual hallucination; TH = tactile hallucination; SE = standard error. Percentages reflect the prevalence of hallucination types in the total sample ($N = 2038$). Bold values are $< .05$.

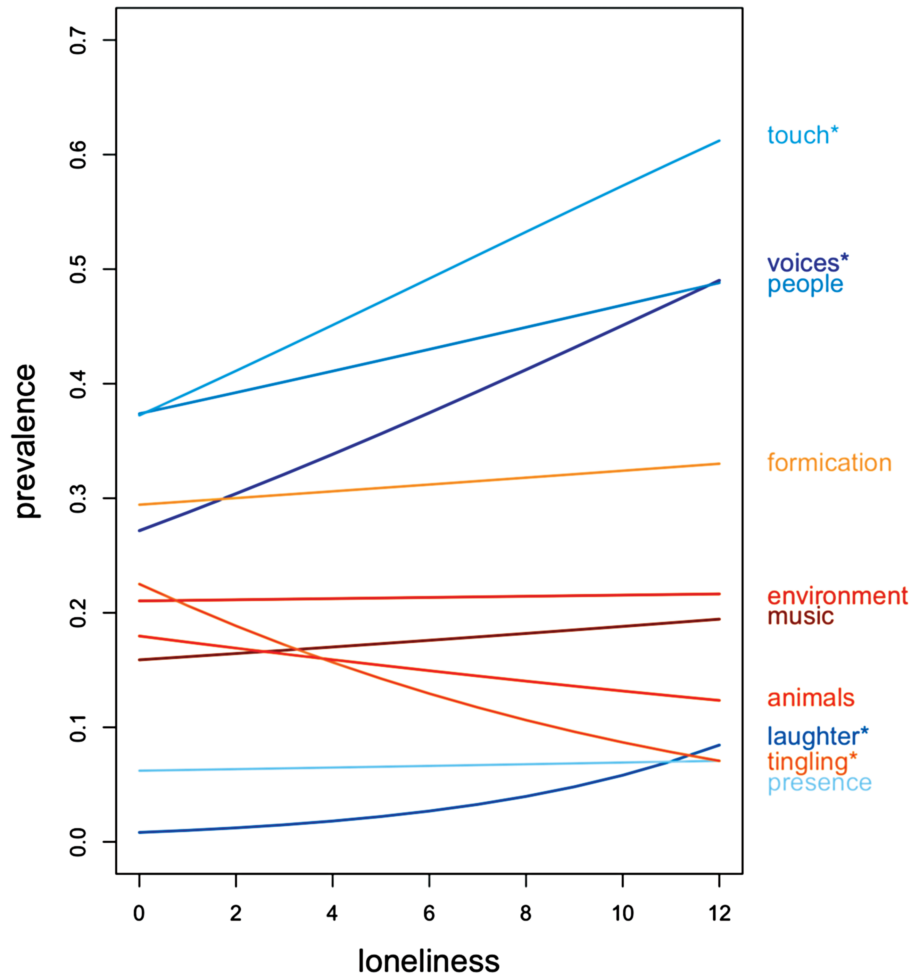


Fig. 1. Past month prevalence of hallucinations as relating to loneliness. Plotted regression curves for past month prevalence of social and nonsocial hallucination types by loneliness score. Asterisks indicate a significant effect of loneliness on hallucination prevalence.

Loneliness then can be seen as increasing the likelihood that this experience is interpreted to the backdrop of a social schema (ie, being touched by someone), while people who feel less lonely will denote this experience as a tingling feeling. Tactile hallucinations are relatively understudied, but some indication exists that loneliness is related to aberrations in the relation between tactile perception and the sense of one's body's boundaries. Specifically, Michael and Park²⁴ showed that increased loneliness is associated with the proneness to experience a proprioceptive hallucination in the Pinocchio Illusion paradigm. They interpret these findings in light of the SDA, stating that impaired tactile awareness and anomalous proprioception can be the result of social isolation.²⁴

We failed to find the hypothesized relation between loneliness and the hallucinations of seeing people and felt presence, which we deemed social hallucinations. While the relation between loneliness and seeing people was in the expected direction, it was not significant, which arguably may be an issue of power. However, any relation between loneliness and felt presence seemed to be absent

in our data. A possible explanation for its absence is that the underlying mechanism for felt presence is different from that of other hallucinations, with controversy existing about whether it should be regarded a perceptual hallucination at all.²⁵⁻²⁷ Several mechanisms by which felt presence may occur have been identified. First, in the general population, felt presence often occurs in the context of sleep paralysis and Parkinson's disease, and has been related to REM-sleep related brain activity.^{27,28} This sets it apart from AH and VH which were shown not to be more prevalent during waking or falling asleep than at other times during the day or night.²⁹ In the current study, we did not assess whether the experience of felt presence mostly occurred around sleep onset or waking, but given previous literature this does not seem unlikely. Second, the occurrence of felt presence has been associated with endurance, extreme conditions, and survival. Examples are reports of felt presence during polar expeditions and extreme sports.³⁰ However, these instances of felt presence are not necessarily related to social isolation or loneliness, as this phenomenon has also been

described to occur in groups of people on expedition (with Sir Ernest Shackleton's description of a fourth "presence" accompanying their expedition group of three being an exemplary account).³¹ A third context, arguably most tightly related to loneliness, in which felt presence has often been reported is that of bereavement, where the bereaved indicate to sense the presence of their lost loved one.³² These examples go to show that there are several routes to the experience of felt presence, each of them not similarly likely candidates of "spurious activity of social schema". In case felt presence is indeed particularly related to REM-sleep mechanisms or endurance and survival, it is understandable that its prevalence is unaffected by social factors such as loneliness. It may, therefore, be the case that in our sample felt presences occurred relatively little in the context of bereavement and more often in the context of REM-sleep disturbances or endurance, possibly explaining why we failed to find a relation with loneliness severity.

Although it was not a primary goal of our study, we found sex and age to affect the prevalence of hallucinations and loneliness severity. The fact that we found younger participants to report a higher prevalence of hallucinations is in line with studies reporting similar findings for adolescents (13–17 years of age) compared to adults (>17 years of age) and young adults (18–30 years of age) compared with older adults (>30 years of age).^{33,34} In addition, the higher hallucination prevalence among females compared to males replicates a previously reported outcome in a large nonclinical sample of adolescents from Japan.³⁵

Furthermore, although there is controversy regarding sex differences with regards to loneliness severity, it has been shown that females are more likely to admit that they feel lonely, which may explain the increased loneliness score among women in the current study.^{36,37} With regard to the effect of age, loneliness has previously been shown to decrease as people get older, a finding we replicate in the current study.^{37,38}

Limitations

Due to the survey design, the presented data are cross sectional, thus preventing any conclusions to be drawn with regards to causality. A subsequent test of the SDA could be performed by investigating the effect of loneliness on different hallucination types over time, the hypothesis being that increased loneliness precedes the occurrence of social—but not nonsocial, hallucinations.

Furthermore, the study being an online survey prevented us from asking participants for clarification in case of ambiguity in social interpretation of a hallucination. For example, for some people the hallucination of hearing the doorbell ring may have a strong social connotation, while for others it may not. For this reason, a number of hallucination types that were

reported in the current study (for a full report of hallucination types see Linszen et al.¹⁶) had to be excluded from the analyses.

Finally, as being familiar with the experience of hallucinations may have driven participants to take part in the survey, the current study is likely affected by sampling bias. Indeed, previous studies and reviews that may have been less affected by sampling bias show prevalences of hallucinations of 12% (lifetime prevalence of AH in people aged 13–17 years), and 7% (past-year prevalence of AH or VH in people aged 16–19 years).^{33,39} An additional explanation for the increased reported prevalence may be the fact that in the current study we profiled hallucinatory experiences as common phenomena, possibly reducing stigma and lowering the threshold to report their occurrence.¹⁶ Of importance to the generalizability of our results, however, is the fact that sampling bias is unlikely to have affected any existing relation between loneliness and social or nonsocial hallucinations, since both are independently related to the bias.⁴⁰ More specifically, while it could be argued that loneliness increases the likelihood that a person sits behind their computer and takes the time to submit a response, we expect them to do so regardless of whether their hallucinations are social or nonsocial. Likewise, we do not expect participants who experience social hallucinations to fill out the survey because they are lonely, and participants who experience nonsocial hallucinations to do so because they are not lonely.

Conclusion

The current study provides support for the SDA, in showing that loneliness increases the prevalence of social but not nonsocial hallucinations in a nonclinical sample of adolescents and young adults. These findings stress the importance of social wellbeing for healthy development of socially-related brain networks. Resonating with a recent appeal to clinical settings to monitor loneliness among patients, we recommend that more attention is given to the prevention of social isolation of adolescents and young adults.⁴¹ The COVID-19 pandemic has made this an unfortunately urgent matter, having caused a recent surge in loneliness among young people.⁴²

Supplementary Material

Supplementary material is available at <https://academic.oup.com/schizophreniabulletin/>.

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Author Contributions

J.B., M.L., M.B., and I.S. designed the study and coordinated the project. S.B., J.B., and M.L. helped with data preparation and designing of the data set. S.B. analyzed the data. S.B. wrote the initial draft, and all authors contributed to, read, and approved the final manuscript.

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