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ORIGINAL ARTICLE

Fluctuations in Hallucination Spectrum Experiences Co-vary with Social Defeat but not with Social Deafferentation. A 3-Week Daily Assessment Study

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Abstract   The social deafferentation hypothesis proposes social isolation to be a risk factor for hallucinations, whereas the social defeat hypothesis postulates that only negatively appraised experiences of social exclusion constitute a risk factor. In a community sample, we tested whether social isolation and social defeat coincide with or precede hallucination spectrum experiences (HSE; i.e. auditory hallucinations and their subclinical precursors vivid imagination, perceptual sensitivity, and intrusive thoughts). Once daily for three weeks, 75 participants answered questionnaires on social contact, social exclusion, and HSE during the last 24 h. Multilevel-regressions were calculated. Social exclusion was associated with the subclinical precursors of auditory hallucinations on the same and following day but not with auditory hallucinations as such. Thus, social exclusion coincides with and potentially triggers HSE. Further research needs to expand on these findings in ESM studies with clinical samples to test whether these findings extend to brief time-intervals and clinical hallucinations.

Keywords   Schizophrenia · Psychosis like experiences · Social defeat · Social deafferentation · Hallucinatory experiences

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Introduction

Auditory hallucinations, mostly in the form of voices, are a core symptom of schizophrenia spectrum disorders and have been the subject of clinical research for decades. Much has been done to understand the neurobiological basis of auditory hallucinations, and increasing attention is paid to cognitive and emotional etiological factors (Beck et al. 2009). Nevertheless, our knowledge about the social causes and triggers of hallucinations is still limited. Given that social factors may be a fairly accessible therapeutic target at any point of the course of the disorder, a more detailed knowledge about which social factors contribute to the etiology of hallucinations can help us to develop effective psychosocial interventions.

In recent years, researchers have begun to investigate the social environment and specifically social contact as a potential cause for auditory hallucinations. Two distinct hypotheses were generated to explain how social contact (or the lack thereof) causes hallucinatory experiences: the social defeat hypothesis (Selten and Cantor-Graae 2005; Selten et al. 2013) and the social deafferentation hypothesis (Hoffman 2007, 2008). Both theories postulate that certain social factors make people vulnerable to psychosis and constitute stressors that trigger psychotic experiences such as hallucinations. Whereas evidence from epidemiological studies has been accumulated for both models' macro-level notion that a history of social adversity adds to the underlying vulnerability for psychosis, far less attention has been given to the role of social factors as stressors that directly trigger hallucinations at the micro-level in the context of daily life. Previous ambulatory assessment studies indicate that social interactions with unfamiliar individuals precede anomalous experiences in population samples with a preexisting vulnerability to psychosis (Verdoux et al. 2003), whereas social

engagement intensifies hallucinations in people with a psychotic disorder (Delespaul et al. 2002). Thus, the existing studies support the idea that social factors trigger hallucinatory experiences in daily life. However, to date, no study has investigated social factors as triggers of hallucinations within the framework of the social defeat or the social deafferentation hypothesis.

The Social Defeat Hypothesis

The social defeat hypothesis (Selten and Cantor-Graae 2005; Selten et al. 2013) is based on epidemiological findings that identified urbanicity, migration, childhood trauma, low IQ, and drug abuse as risk factors for schizophrenia (Selten et al. 2013). According to the social defeat hypothesis, the negative experience of exclusion from a majority group is the common denominator of these five risk factors. In essence, the hypothesis proposes that "any characteristic that defines a person as different from their environment may increase their risk for psychosis" by facilitating "one type of exposure, namely the negative experience of being excluded from the majority group" (Selten et al. 2013). According to the social defeat hypothesis, accumulated negative experiences of being excluded increase the risk for psychosis by sensitizing the mesolimbic dopamine system, leading to an enhanced dopamine response to subsequent social defeat. In line with this hypothesis, cross-sectional studies found an association of social defeat/social exclusion and psychotic symptoms (Jaya and Lincoln 2016; Stilo et al. 2013; Valmaggia et al. 2015; van Nierop et al. 2014). Specifically, people with psychosis who hear distressing voices report social and interpersonal cognitions characterized by an appraisal of their social rank as subordinate as well as a low sense of group identification and belonging, which indicates prior social defeat (Birchwood et al. 2000). Moreover, experimental studies that simulate social defeat have shown that experiencing social exclusion induces psychotic experiences (Kesting et al. 2013; Westermann et al. 2012). Finally, an fMRI-study showed that an anomalous activation of the medial prefrontal cortex in response to increasing levels of simulated exclusion in participants with schizophrenia was associated with the severity of delusions, grandiosity, and hallucinations (Gradin et al. 2012).

The Social Deafferentation Hypothesis

Whereas the social defeat hypothesis postulates that exposure to negative (or negatively appraised) social interactions constitutes the key social risk factor for schizophrenia, the social deafferentation hypothesis (Hoffman 2007, 2008) postulates that the lack of social interaction as such is the key risk factor: Much like certain brain regions respond to the loss of neural input due to a lost limb by internally

generating a phantom limb sensation from spurious neural activity, neural networks associated with social cognition begin to process spurious neural information in absence of external social stimuli (i.e. social withdrawal or isolation). This results in "complex, emotionally compelling hallucinations and delusions representing other social agents" (Hoffman 2007). This hypothesis is supported by epidemiological findings that identify social withdrawal (Kwapil 1998) and isolated living conditions (van Os et al. 2000) as risk factors for schizophrenia spectrum disorders. Moreover, it has long been known that hallucinations can be induced by extreme sensory deprivation (Schulman et al. 1967).

Suitability of Social Defeat and Social Deafferentation as Triggers for Hallucinations

The social deafferentation hypothesis primarily stems from observations regarding the emergence of distressing hallucinations (Hoffman 2007), which makes hallucinations the prototypical symptom to this hypothesis. The social defeat hypothesis, by contrast, postulates social defeat/social exclusion to be a risk factor for psychosis in general without further elaborating on single symptoms. Evidence from research on social rank threat in voice hearers, however, shows that social-cognitive beliefs indicative of recurring social defeat are associated with hearing distressing voices (Birchwood et al. 2004, 2000).

A striking similarity of both hypotheses is their focus on a vulnerability-stress mechanism consisting of immediate and long-term exposure to certain social stimuli: According to the social defeat hypothesis, an increased risk of psychosis results from continued exposure to an adverse social situation (e.g., belonging to a minority in a majority-dominated neighborhood), which increases a person's vulnerability to future events of social stress (Selten et al. 2013). Similarly, the social deafferentation hypothesis postulates that prolonged social isolation, especially during critical developmental periods, induces cortical changes that increase the likelihood that future experiences of social isolation will trigger hallucinations (Hoffman 2007). As we mentioned before, the bulk of evidence for both theories comes from epidemiological and neurological studies of long-term risk-factors that support the vulnerability-part of both theories (Hoffman 2007, 2008; Selten and Cantor-Graae 2005; Selten et al. 2013). However, there is also correlational (Jaya and Lincoln 2016) and experimental (Kesting et al. 2013; Westermann et al. 2012) evidence supporting the idea that immediate social defeat or social deafferentation triggers psychosis symptoms.

Of importance, Selten et al. (2013) described a potential overlap between social defeat and social deafferentation. Social isolation could be a consequence of repeatedly experiencing social defeat. For example, after feeling

excluded, a person may decide to withdraw from a certain peer-group, leading to less social interaction. Furthermore, social isolation may be appraised as defeating (e.g., if a person attributes the absence of social contact as not 'fitting in'). In consequence, both theories have to be tested together. Otherwise, any association between social defeat and hallucinations could result from the confounding influence of social deafferentation or vice versa.

In sum, experimental evidence points towards a potential dose–response or trigger effect of social defeat and social deafferentation. Conclusive evidence for one hypothesis, however, requires a direct comparison of the influence of both social factors on hallucinations. Elucidating which of these two hypotheses holds true in daily life is not only of theoretical importance, but also yields crucial clinical implications. If social isolation is found to be the underlying social risk factor, interventions and prevention strategies could be improved by focusing on the client's social network and increasing social interactions. If, however, negative appraisal (i.e., social defeat) is found to be the most important social risk factor, interventions should focus on modifying negative social cognitions and teaching functional ways of relating to others.

Aims of This Study

In this study, we tested whether indicators of social deafferentation and social defeat reported once per day are associated with hallucination spectrum experiences (HSE; i.e., auditory hallucinations along with the subclinical precursors vivid imagination, perceptual sensitivity, and intrusive thoughts) in a community sample. We aimed to identify social factors that co-vary with HSE and may thus constitute potential triggers for first episodes of auditory hallucinations and their subclinical predecessors.

The rationale for using a community sample is that psychotic experiences such as hallucinations appear to exist along a continuum—with people who never had any psychosis-like experiences on the one end and people who fulfil all diagnostic criteria for a psychotic disorder on the other. Between these extreme ends, there is a large group of people with unusual experiences (e.g. vivid daydreams, perceptual sensitivity, and intrusive thoughts; Bell et al. 2010) and experiences below the diagnostic threshold (Johns and van Os 2001). These psychosis-spectrum experiences have been shown to predict transition to psychosis (Mark and Toulopoulou 2015). Furthermore, they share environmental and psychopathological causal factors with clinical symptoms (Van Os and Linscott 2012). Accordingly, it is possible to investigate the etiology of hallucinations based on HSE in community samples. In fact, community samples are advantageous for research on causal factors because compared to clinical groups, they allow to test for etiological factors that

contribute to an eventual onset of clinical symptoms without the risk of confounding etiological factors with factors that follow clinical symptoms (e.g. medication, stigma, decline in functioning).

Methods

Participants

Participants were recruited via online-advertisement on facebook.com ($n = 34$) as well as via posters and leaflets distributed on campus ($n = 41$). Psychology students were granted partial course credit for participating. Other participants could take part in a raffle and win one of four 25 Euro amazon.com gift cards. A participation in the raffle was only possible after completing the whole study.

A sample of 75 participants was recruited for this study (26 men and 49 women). The age ranged from 18 to 66 years ($M = 25.03$, SD $= 8.82$). The sample was a convenience sample consisting of adults from the general population. There were no particular eligibility criteria. All participants were German native speakers. Fifty-four participants (72%) provided data on their ethnic background. A majority of them (88.9%) reported to be German or white/Caucasian. Three participants (5.6%) reported to be German with Asian roots, one participant reported to have Arabic roots, and two participants reported to have a mixed ethnic background. The majority of participants (65.3%) reported their highest education level to be the university entrance diploma ("Abitur"), 16 participants (21.3%) held a university degree, and 8 participants (10.7%) had completed vocational training. Most participants (81.3%) were students (57.3% psychology students), and 13.3% were gainfully employed. The majority of participants (81.3%) reported to never have had a mental disorder. The other participants most frequently reported having been diagnosed with depression (14.7%), whereas others reported anxiety disorders (4%), PTSD (4%), panic disorders (2.7%), personality disorders (2.7%), eating disorders (2.7%), OCD (1.3%), and sleeping disorders (1.3%).

Design and Procedure

This longitudinal study consisted of an introductory questionnaire and a three-week daily diary assessment. All questionnaires were presented in QuestBack EFS-Survey (QuestBack GmbH 2014).

The introductory questionnaire comprised information on the study and informed consent, self-report assessments of psychosis-like experiences and HSE, and a demographic questionnaire. Completion of the introductory questionnaire took the participants 25 min on average. Participants could complete the introductory questionnaire either at home from

their own computer ($n = 34$) or in our laboratory ($n = 41$). The first daily questionnaire was sent to the participants via email 24 h after they had completed the introductory questionnaire. The daily questionnaires included self-report items about HSE (nine items), social isolation (three items), social defeat (five items), and general mood (six items). Over 21 consecutive days, the participants received daily emails containing the link to the online-questionnaire. Participants were instructed to complete the questionnaire on the day it was sent to them, preferably in the evening. If participants failed to complete a daily questionnaire by the end of the respective day, they were instructed to omit it. After completing the last daily questionnaire, all participants were debriefed and thanked for their participation.

Materials

Introductory Assessment

The introductory questionnaire included the Community Assessment of Psychic Experiences (CAPE; Schlier et al. 2015; Stefanis et al. 2002) and the Launay-Slade Hallucination Scale (LSHS-Bentall and Slade 1985), which were presented in the aforementioned order.

The CAPE measures the lifetime prevalence of psychosis-like experiences. It consists of 42 items that tap into positive symptoms (20 items, e.g., "Do you ever hear voices when you are alone?"), negative symptoms (14 items, e.g., "Do you ever feel that you have no interest to be with other people?"), and symptoms of depression (eight items, e.g., "Do you ever feel pessimistic about everything?"). Participants rated how often they had experienced each symptom over the course of their life. The items are answered on a four-point Likert scale (0 = "never", 1 = "sometimes", 2 = "often", 3 = "nearly always"). The CAPE and its German translation have been shown to be sufficiently valid and reliable (Schlier et al. 2015; Stefanis et al. 2002).

The LSHS-R (Bentall and Slade 1985) assesses hallucination proneness in community samples. The scale includes twelve items. Participants answer on five-point Likert scales ranging from 0 = "certainly does not apply to me" to 4 = "certainly applies to me". The LSHS taps into different aspects of hallucinatory experiences (Waters et al. 2003), including auditory and visual hallucinations (e.g. "I have been troubled by hearing voices in my head."), vivid daydreams (e.g. "The sounds I hear in my daydreams are usually clear and distinct.") and religious hallucinations (e.g. "In the past I have heard the voice of God speaking to me."). In the present study, a validated German version of the LSHS-R was used, for which good reliability (*Cronbach's α* = 0.83–0.87) and an acceptable criterion and construct validity has been shown (Lincoln et al. 2009).
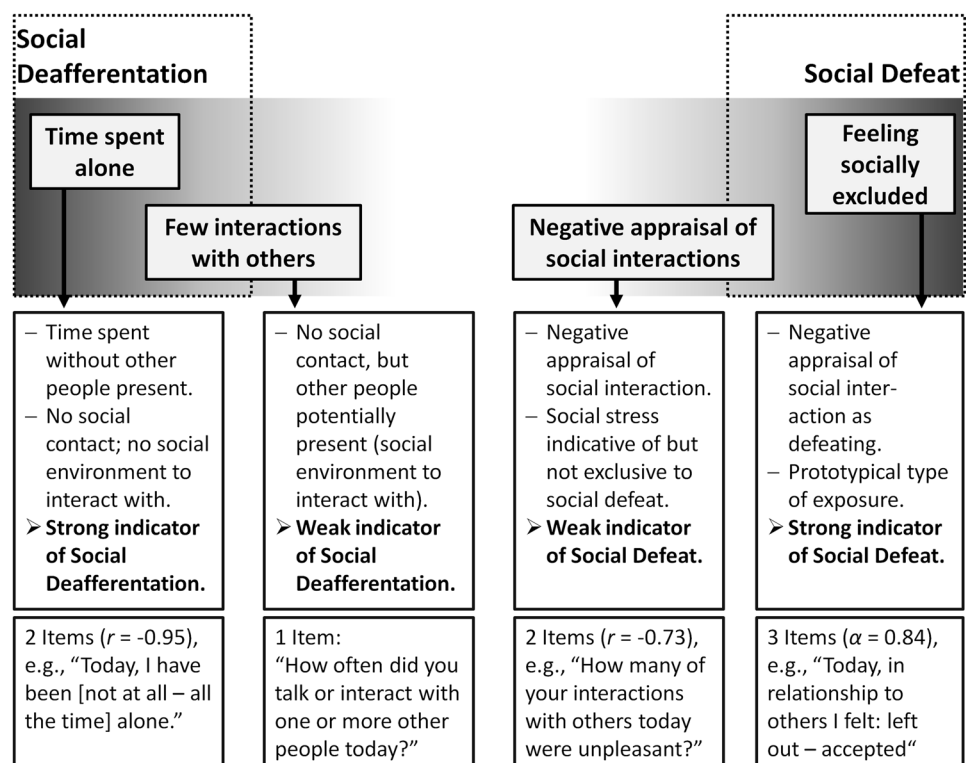
Daily Assessment

The daily questionnaires included the nine-item Continuum of Auditory Hallucinations—State Assessment (CAHSA), the six-item Multidimensional Mood Questionnaire (MDMQ), as well as four indicators of social interactions, ranging from a strong indicator of social isolation to a strong indicator of social defeat (see Fig. 1).

The CAHSA (Schlier et al. 2017) assesses HSE and was specifically developed for repeated measurement. It includes three subclinical precursors of auditory hallucinations, namely vivid imagination (two items, e.g., "I daydreamed a lot"), perceptual sensitivity (two items, e.g., "Even distant noises distracted me"), intrusive thoughts (two items, e.g., "My thoughts were so powerful and vivid that I could almost hear them"), and auditory hallucinations (three items, e.g., "I heard something other people could not hear"). Participants answered the question of how much each item applied to them for the last 24 h on seven-point Likert-scales ranging from 1 = "not at all" to 7 = "very much". The questionnaire shows good criterion validity and is sensitive to change. Previous research showed a good fit of a four-factor model with a second-order general factor (Schlier et al. 2017). In the present study, model fit was acceptable according to two out of three fit-indices (*CFI* = 0.854; *RMSEA* = 0038; *SRMR-within* = 0.050, *SRMR-between* = 0.081). The CAHSA sum score was used as primary outcome measure.

The MDMQ (Wilhelm and Schoebi 2007) is a six-item questionnaire that has been shown to reliably and validly measure mood in everyday life. Using six-point bipolar scales to answer the question "over the past day, I felt…", it assesses calmness ("agitated–calm", "relaxed–tense"), valence ("unwell–well", "content–discontent"), and energetic arousal ("full of energy–without energy", "tired–awake").

The four indicators of social interactions included two variables indicative of social isolation and two variables indicative of social defeat (see Fig. 1). The first indicator was "time spent alone" (two items: "Today, I have been alone" and "Today, I have been in company of others", rated on seven-point Likert scales ranging from 1 = "not at all" to 7 = "all the time"). As a second "weak" indicator of social deafferentation (see Fig. 1) the amount of social interactions (one item: "How often did you talk or interact with one or more other people today?", rated on seven-point Likert scales ranging from 1 = "not at all" to 7 = "all the time") was assessed. The items for these two indicators were developed for the purpose of this study: Initially, prototype items were constructed based on the environment and functioning items from the computerized Ecological Momentary Assessment Questionnaire (EMAc; Granholm et al. 2007). The items and answer options were adapted

Fig. 1 Conceptual proximity of the independent variables to the constructs social deafferentation and social defeat

Social Deafferentation		Negative appraisal of social interactions	Social Defeat
Time spent alone	**Few interactions with others**		**Feeling socially excluded**
− Time spent without other people present. − No social contact; no social environment to interact with. ➢ **Strong indicator of Social Deafferentation.**	− No social contact, but other people potentially present (social environment to interact with). ➢ **Weak indicator of Social Deafferentation.**	− Negative appraisal of social interaction. − Social stress indicative of but not exclusive to social defeat. ➢ **Weak indicator of Social Defeat.**	− Negative appraisal of social interaction as defeating. − Prototypical type of exposure. ➢ **Strong indicator of Social Defeat.**
2 Items (r = -0.95), e.g., "Today, I have been [not at all – all the time] alone."	1 Item: "How often did you talk or interact with one or more other people today?"	2 Items (r = -0.73), e.g., "How many of your interactions with others today were unpleasant?"	3 Items (α = 0.84), e.g., "Today, in relationship to others I felt: left out – accepted"

to a one-day sampling interval, presented to a group of experts and finalized based on their feedback.

As a first indicator for social defeat, we included the three-item group fit subscale of the Social Comparison Scale (Allan and Gilbert 1995) which measures social exclusion (i.e. the defining type of experience of the social defeat hypothesis; Selten et al. 2013). In this scale, participants rated their subjective experience of feeling accepted vs. excluded by their peer group on ten-point semantic differentials (e.g., "In relationship to others I feel: left out—accepted"). For this study, we translated the three items into German and adapted the scale to daily assessment by changing the instruction "In relationship to others I feel" to "Today, in relationship to others I felt". Good internal consistency was shown in previous studies (Allan and Gilbert 1995). As a second "weak" indicator for social defeat we asked for the amount of unpleasant social interactions (two items: "How many of your interactions with others today were enjoyable?" and "How many of your interactions with others today were unpleasant?"). Participants answered on seven-point Likert scales ranging from 1 = "none" to 7 = "all of them". Internal consistencies for the indicators are shown in Fig. 1. Mean scores were calculated for all indicators except the one-item measure "few interactions with others". If necessary, items were reversed so that higher values indicate higher levels of social deafferentation/defeat.

Data Analysis

Based on EFS-Survey time logs, daily questionnaires were checked for consecutively made entries outside the daily assessment schedule. Any questionnaires completed immediately after the previous one were treated as a missing value. All analyses were carried out using R 3.1.3 (R Core Team 2014). Multilevel models were estimated using the R packages lme4 (Bates et al. 2015) and lmerTest (Kuznetsova et al. 2016). For all analyses, we originally aimed to calculate linear multilevel regression models. However, the hallucination-spectrum experiences in our community sample showed a skewed, non-normal distribution that could have biased findings in linear regression (see Table 1 and online supplements to this article). Thus, we switched to binomial logistic regression analyses. For this purpose the respective dependent HSE variable was dichotomized, with the low end of the scale "1" (i.e. having not at all experienced the HSE in question) set to 0 and all other values (i.e. having experienced the HSE to some degree) set to 1.

For our main analyses, we calculated random-intercept, random-slope multilevel regression analyses of daily assessments nested in participants. HSE (i.e., CAHSA scores) were the dependent variable and the independent variable was one out of the four social deafferentation/social defeat indicators: Four separate regression models were calculated for (1) time spent alone, (2) few social interactions, (3) social exclusion,

Table 1 Descriptive values of baseline and daily assessment instruments

	M	SD	Skew	Range (min–max)	Possible range (min–max)
Baseline assessment					
CAPE					
Positive symptoms	7.77	4.67		1–23	0–60
Negative symptoms	13.03	5.61		3–31	0–42
Symptoms of depression	7.75	3.92		1–19	0–24
LSHS total score	7.64	6.65		0–29	0–48
Daily assessments					
Time spent alone	2.78	1.62	0.79	1–7	1–7
Few social interactions	3.14	1.37	0.36	1–7	1–7
Social exclusion	3.23	1.77	0.73	1–10	1–10
Unpleasant interactions	2.30	1.16	0.80	1–7	1–7
HSE global score	1.47	0.64	1.78	1–4.67	1–7
HSE vivid imagination	1.95	1.33	1.75	1–7	1–7
HSE perceptual sensitivity	1.48	0.97	2.54	1–7	1–7
HSE intrusive thoughts	1.36	0.78	2.74	1–5.5	1–7
HSE auditory hallucination	1.10	0.39	5.06	1–4.67	1–7

CAPE Community Assessment of Psychic Experiences, *LSHS* Launay-Slade Hallucination Scale, *HSE* hallucination spectrum experiences

and (4) unpleasant interactions. In the first set of analyses, predictors from the same day (cross-sectional analyses) were entered. In a second set, four time-lagged regression analyses were carried out to test whether changes in social factors preceded the occurrence of HSE. The respective social isolation/social defeat predictor from the previous day was the independent variable in these models and the CAHSA score from the previous day served as a covariate. Additionally, the reverse patterns of HSE predicting social isolation or social defeat on the following day were tested.

Furthermore, any significant association between social defeat indicators and HSE was tested again while controlling for general mood (MDMQ-subscales), in order to rule out that the influence of social defeat is just a by-product of overall negative mood. Finally, the association between social isolation/social defeat and HSE was further explored by repeating the cross-sectional analyses with the four CAHSA-subscales vivid imagination, perceptual sensitivity, intrusive thoughts, and auditory hallucinations as dependent variable.

Results

Baseline Assessment and Compliance

Baseline and mean daily assessment scores are summarized in Table 1. All participants indicated to experience at least one CAPE-symptom of each subscale at least "sometimes". Forty-seven participants (62.67%) indicated to experience at least one positive symptom "often" or "nearly always", 56 participants (74.67%) indicated the same for at least one negative symptom and 48 participants (64%) for at least one symptom of depression. The mean total score of the LSHS was 7.64 (SD = 6.65), with 34 participants (45.33%) indicating that at least one item "possibly" or "certainly" applies to them. Valid data was available for 1291 of 1575 days. Thus, the compliance rate was 81.97%. Participants omitted daily assessments on an average of 3.79 days (SD = 5.16; range 0–17).

Regarding the daily assessments, all HSE variables were positively skewed, with the auditory hallucination subscale showing the most deviation from normal distribution (5.06). Based on the dichotomized HSE variables, the majority of participants experienced some degree of vivid imagination on at least one day (90.7%), about three quarters reported perceptual sensitivity (78.7%) and intrusive thoughts (74.7%) on one or more days, whereas 37.3% reported some degree of auditory hallucinations on at least one day. Further details regarding the distribution of all independent and dependent variables can be found in the online-supplements to this article.

Cross-Sectional Prediction of HSE by Social Deafferentation versus Defeat

Logistic multilevel regression models yielded neither significant results for the two social deafferentation variables (time spent alone; *OR* 1.06, $z = 0.52$, $p = 0.601$; few interactions: *OR* 1.16, $z = 1.09$, $p = 0.275$) nor for the amount

of unpleasant interactions (*OR* 1.04, $z = 0.32$, $p = 0.748$). However, social exclusion was associated with more HSE on the same day (*OR* 1.27, $z = 2.10$, $p = 0.036$, see Table 2).

Time-Lagged and Reversed Time-Lagged Prediction Models

In time-lagged logistic regression, again neither the indicators of social deafferentation nor the social defeat indicator unpleasant interactions predicted HSE on the following day. However, social exclusion was significantly associated with the presence of HSE on the next day (*OR* 1.46, $z = 2.37$, $p = 0.018$). In comparison, reversed time-lagged models showed that HSE did not predict any of the social deafferentation or social defeat indicators on the next day (see Table 2).

The Influence of Social Deafferentation and Social Defeat after Controlling for Potential Covariates

The cross-sectional and time-lagged effects of social exclusion on HSE remained significant when the MDMQ scales were entered as control-variables (cross-sectional: *OR* 1.24 $z = 2.75$, $p = 0.006$; time-lagged: *OR* 1.20, $z = 2.14$, $p = 0.032$). Furthermore, all other indicators in cross-sectional, time-lagged and reversed time-lagged analyses remained non-significant when mood was controlled for. Similarly, the pattern of results remained the same when gender and age of the participants were controlled for.

Exploratory Analyses of Continuum of Auditory Hallucinations Subscales

Separate analyses for the CAHSA-subscales vivid imagination, intrusive thoughts, perceptual sensitivity, and auditory hallucinations are summarized in Table 3. There were no significant associations between the indicators of social deafferentation and any of the CAHSA subscales.

Regarding the indicators of social defeat, social exclusion was associated with increased vivid imagination (*OR* 1.18, $z = 2.28$, $p = 0.023$), perceptual sensitivity (*OR* 1.27, $z = 2.44$, $p = 0.015$) and intrusive thoughts (*OR* 1.24, $z = 2.70$, $p = 0.007$) in the cross-sectional analyses. Time-lagged analyses further showed that social exclusion was associated with vivid imagination (*OR* 1.12, $z = 2.46$, $p = 0.014$) and intrusive thoughts (*OR* 1.27, $z = 2.44$, $p = 0.015$) on the following day. Finally, one reversed time-lagged analysis was significant: vivid imagination was associated with increased reports of social exclusion ($b = 0.31$, $t = 3.09$, $p = 0.002$).

Discussion

In this study, we investigated whether social defeat and social deafferentation co-vary with HSE in healthy participants. We found that social defeat, but not social deafferentation was associated with self-reported HSE on the same day. This association was not accounted for by general mood. Moreover, feeling socially excluded was consistently associated with HSE, whereas having unpleasant social interactions per se was not. This is in line with the social defeat hypothesis (Selten and Cantor-Graae 2005; Selten et al. 2013), which posits that experiencing social exclusion is more strongly related to HSE than social stress in general. Possibly, this result provides a framework to explain why social engagement (rather than social withdrawal) predicted hallucinatory experiences in previous ambulatory assessment studies (Delespaul et al. 2002; Verdoux et al. 2003).

Moreover, the same pattern was found regarding a temporal order of social risk factors preceding an increase of HSE on the following day: Social exclusion was the sole significant predictor of later HSE in the logistic regression models. This further highlights that social exclusion is the most promising candidate as a potential trigger of HSE. Given the covariation of HSE and social exclusion for this comparatively long time-interval of 24 h, one may speculate that the

Table 2 Cross-sectional and time-lagged multilevel regression of hallucination spectrum experiences, social defeat indicators, and social deafferentation indicators

	OR/B (95% confidence interval)		
	Cross-sectional	Time-lagged	
	Social factors predicting HSE (OR)	Social factors predicting HSE (OR)	HSE predicting social factors (B)
Social deafferentation			
Time spent alone	1.06 (0.87; 1.29)	1.22 (0.99; 1.49)	0.11 (−0.11, 0.33)
Few social interactions	1.16 (0.89; 1.50)	1.15 (0.93; 1.42)	0.03 (−0.16; 0.22)
Social defeat			
Social exclusion	1.27* (1.02; 1.59)	1.46* (1.06; 1.88)	0.03 (−0.16; 0.23)
Unpleasant interactions	1.04 (0.82; 1.31)	1.03 (0.79; 1.35)	−0.05 (−0.24; 0.14)

HSE hallucination spectrum experiences, *OR* odds ratio, *B* linear regression estimate

*$p < 0.05$

Table 3 Associations between hallucination spectrum experiences subscales and indicators of social deafferentation and social defeat

Social contact variable	Analysis type	Hallucination spectrum experiences subscale			
		Vivid imagination	Perceptual sensitivity	Intrusive thoughts	Auditory hallucinations
Social deafferentation					
Time spent alone	Cross-sectional (OR)	1.07	1.00	0.90	0.69
	Time-lagged (OR)	1.04	1.09	0.85	1.20
	Rev. time-lagged (B)	0.19	−0.03	−0.04	−0.04
Few social interactions	Cross-sectional (OR)	1.08	1.05	0.87	0.70
	Time-lagged (OR)	1.04	1.08	0.95	0.75
	Rev. time-lagged (B)	0.04	0.04	0.18	0.18
Social defeat					
Social exclusion	Cross-sectional (OR)	1.18*	1.27*	1.24**	0.99
	Time-lagged (OR)	1.21*	0.95	1.27*	1.07
	Rev. time-lagged (B)	0.31**	0.02	0.05	0.05
Unpleasant interactions	Cross-sectional (OR)	0.97	1.15	0.96	1.01
	Time-lagged (OR)	1.05	0.86	1.17	1.28
	Rev. time-lagged (B)	0.01	−0.01	0.01	0.20

OR odds ratio based on logistic multilevel regression, *B* estimate based on linear multilevel regression

*$p < 0.05$, **$p < 0.01$

cause-and-effect relationship between social exclusion and subsequent HSE may be even more pronounced over a narrow time-interval. Time-lagged associations between days may already be subject to further moderating variables.

Regarding social deafferentation, time-lagged analyses indicated no significant associations with HSE at all. We need to take into account, however, that we approximated isolation with the relative time spent alone and few social interactions. The social deafferentation hypothesis proposes that extreme forms of social isolation trigger hallucinatory experiences. Possibly, social isolation needs to reach a critical threshold before it contributes to HSE, with only severe forms of social isolation that include sensory deprivation triggering HSE. Another possibility is that the critical threshold for social isolation depends on a person's negative appraisal of the situation in the sense that only unwanted social isolation triggers HSE.

Finally, analyses of the CAHSA subscales revealed that the social defeat indicators were primarily associated with subclinical hallucination-like experiences such as intrusive thoughts and perceptual sensitivity. Hallucinations constituted a comparatively scarce phenomenon in our community sample. From a methodological point of view, one could thus argue that the variation in auditory hallucination scores was too small to detect any associations. However, one could also interpret that these findings are in line with the social defeat hypothesis: Present exposure to social exclusion has a base effect (i.e. triggering subclinical, unusual experiences), which is short-lived in healthy people. Possibly, the very same experience leads to more severe HSE or clinical auditory hallucinations in a person with a history of recurring social defeat that lead to a sensitization of the mesolimbic system (Selten et al. 2013). Moreover, although vivid imagination, perceptual sensitivity, and intrusive thoughts have been frequently associated with hallucinations as subclinical variations (Bell et al. 2010; Larøi et al. 2004; Waters et al. 2003), distractibility and intrusive thoughts have also been referred to as facets of a cognitive-attentional factor that is predictive of psychosis symptoms in general (e.g., Brett et al. 2007). Thus, the results pertaining to the subclinical factors are relevant to psychosis. However, further research is needed to explore the specificity with respect to hallucinations.

In sum, we found initial evidence for an association between daily variation in subclinical HSE and concurring as well as preceding experiences of social exclusion. However, no direct evidence extending to full-blown auditory hallucinations was found. While these findings do not confirm the hypothesis that an experience of social defeat triggers hallucinations in people with psychotic disorders or people at risk, they warrant further tests in more suitable samples.

Implications for Research and Clinical Practice

In order to directly test the hypothesis that episodes of social defeat trigger hallucinations, future studies could investigate a social-defeat vulnerability-stress model by comparing

the response to momentary experiences of social defeat in people with low risk vs. high risk of experiencing repeated social defeat (e.g., non-migrants vs. first and second generation migrants; Egerton et al. 2017) or for developing psychosis (e.g., first-degree relatives of people with psychosis). Furthermore, to further corroborate the assumption that social defeat triggers HSE, ambulatory assessment studies with multiple assessments per day would be helpful. Specifically, we need to assess the fleeting experience of a hallucination when it occurs and test for correlations with immediately preceding social experiences.

Irrespective of whether feelings of social defeat ultimately trigger HSE or coincide with them, their association has practical implications: People with more frequent HSE experience distressing social exclusion more frequently, which is known to lead to reduced well-being and a lower level of functioning (Björkqvist 2001). Possibly, interventions that focus on functional ways of relating to others meet a specific need of people with frequent HSE. For example, psychosis-specific cognitive-behavioral therapy based on social rank theory (Birchwood et al. 2002; Trower et al. 2004) or focused on relating assertively to others (Hayward et al. 2009) could be adapted to reduce the impact of social defeat in people with HSE. If future studies continue to find a consistent link between social defeat and HSE, such prevention strategies may prove to reduce the burden of HSE and prevent the transition to psychosis.

Limitations

It has to be noted that the sample is an ad-hoc community sample and no prescreening criteria were used. Although our study seems to adequately capture early stages in which social defeat co-varies and potentially triggers subclinical precursors of hallucinations, a community sample may not suffice to reliably estimate the relationship of social factors and auditory hallucinations. Moreover, the analyses comprise a large number of significance tests. This is no limitation for the effect of social exclusion on HSE, which is found consistently in all variations of the analyses. However, isolated effects (e.g., vivid imagination being the only HSE-factor preceding social exclusion) with a comparatively large exact p value need to be treated carefully. We cannot rule out that these latter effects are false positives due to multiple comparisons. Finally, this study focused on one type of psychotic experiences, whereas the social defeat and social deafferentation hypotheses are used to explain psychotic experiences in general (Hoffman 2007; Selten et al. 2013). We limited our research to HSE to keep the daily assessments brief and to minimize the content overlap between independent and dependent variables (e.g. paranoid thoughts and feeling socially excluded, negative symptoms and social isolation). Needless to say, further research focusing on the

social defeat and the social deafferentation hypotheses has to extend the focus to other symptom categories in order to comprehensively test their validity.

Conclusion

In sum, this study shows that short-term variation in HSE is associated with experiences of social defeat. Whereas previous epidemiological studies provided evidence for the long-term effect of repeatedly experiencing social defeat, we were able to show covariation of experiencing social defeat and subclinical hallucination spectrum experiences over the course of days. This opens the door for future ambulatory assessment and ambulatory intervention studies targeting negative social interactions and social exclusion.

References

Allan, S., & Gilbert, P. (1995). A social comparison scale: Psychometric properties and relationship to psychopathology. *Personality and Individual Differences, 19*(3), 293–299. doi:10.1016/0191-8869(95)00086-L.

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48. doi:10.18637/jss.v067.i01.

Beck, A. T., Rector, N. A., Stolar, N., & Grant, P. (2009). *Schizophrenia. Cognitive theory, research and therapy*. New York: Guilford Press.

Bell, V., Raballo, A., & Larøi, F. (2010). Assessment of hallucinations. In F. Larøi & A. Aleman (Eds.), *Hallucinations: A guide to treatment and management* (pp. 377–397). Oxford: Oxford University Press.

Bentall, R. P., & Slade, P. D. (1985). Reality testing and auditory hallucinations: A signal detection analysis. *British Journal of Clinical Psychology, 24*(3), 159–169. doi:10.1111/j.2044-8260.1985.tb01331.x.

Birchwood, M., Gilbert, P., Gilbert, J., Trower, P., Meaden, A., Hay, J., … Miles, J. N. (2004). Interpersonal and role-related schema influence the relationship with the dominant "voice" in schizophrenia:

A comparison of three models. *Psychological Medicine, 34*(8), 1571. doi:10.1017/S0033291704002636.

Birchwood, M., Meaden, A., Trower, P., & Gilbert, P. (2002). A social rank theory approach to cognitive intervention with voices and delusions. In A. P. Morrison (Ed.), *A Casebook of Cognitive Therapy for Psychosis*. New York: Routledge.

Birchwood, M., Meaden, A., Trower, P., Gilbert, P., & Plaistow, J. (2000). The power and omnipotence of voices: subordination and entrapment by voices and significant others. *Psychological Medicine, 30*(2), S0033291799001828. doi:10.1017/S0033291799001828.

Björkqvist, K. (2001). Social defeat as a stressor in humans. *Physiology & Behavior, 73*(3), 435–442. doi:10.1016/S0031-9384(01)00490-5.

Brett, C. M. C., Peters, E. P., Johns, L. C., Tabraham, P., Valmaggia, L. R., & McGuire, P. K. (2007). Appraisals of Anomalous Experiences Interview (AANEX): a multidimensional measure of psychological responses to anomalies associated with psychosis. *The British Journal of Psychiatry, 191*(51), s23–s30. doi:10.1192/bjp.191.51.s23.

Delespaul, P., deVries, M. W., & van Os, J. (2002). Determinants of occurrence and recovery from hallucinations in daily life. *Social Psychiatry and Psychiatric Epidemiology, 37*(3), 97–104. doi:10.1007/s001270200000.

Egerton, A., Howes, O. D., Houle, S., McKenzie, K., Valmaggia, L. R., Bagby, M. R., … Mizrahi, R. (2017). Elevated striatal dopamine function in immigrants and their children: A risk mechanism for psychosis. *Schizophrenia Bulletin, 43*, 293–301. doi:10.1093/schbul/sbw181.

Gradin, V. B., Waiter, G., Kumar, P., Stickle, C., Milders, M., Matthews, K., … Steele, J. D. (2012). Abnormal neural responses to social exclusion in schizophrenia. *PLoS ONE, 7*(8), e42608. doi:10.1371/journal.pone.0042608.

Granholm, E., Loh, C., & Swendsen, J. (2007). Feasibility and validity of computerized ecological momentary assessment in schizophrenia. *Schizophrenia Bulletin, 34*(3), 507–514. doi:10.1093/schbul/sbm113.

Hayward, M., Overton, J., Dorey, T., & Denney, J. (2009). Relating therapy for people who hear voices: A case series. *Clinical Psychology & Psychotherapy, 16*(3), 216–227. doi:10.1002/cpp.615.

Hoffman, R. E. (2007). A social deafferentation hypothesis for induction of active schizophrenia. *Schizophrenia Bulletin, 33*(5), 1066–1070. doi:10.1093/schbul/sbm079.

Hoffman, R. E. (2008). Auditory/Verbal hallucinations, speech perception neurocircuitry, and the social deafferentation hypothesis. *Clinical EEG and Neuroscience, 39*(2), 87–90. doi:10.1177/155005940803900213.

Jaya, E. S., & Lincoln, T. M. (2016). Social adversities and psychotic symptoms: A test of predictions derived from the social defeat hypothesis. *Psychiatry Research*. doi:10.1016/j.psychres.2016.09.002.

Johns, L. C., & van Os, J. (2001). The continuity os psychotic experiences in the general population. *Clinical Psychology Review, 21*(8), 1125–1141. doi:10.1016/S0272-7358(01)00103-9.

Kesting, M.-L., Bredenpohl, M., Klenke, J., Westermann, S., & Lincoln, T. M. (2013). The impact of social stress on self-esteem and paranoid ideation. *Journal of Behavior Therapy and Experimental Psychiatry, 44*(1), 122–128. doi:10.1016/j.jbtep.2012.07.010.

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2016). *lmerTest: Tests in Linear Mixed Effects Models*.

Kwapil, T. R. (1998). Social anhedonia as a predictor of the development of schizophrenia-spectrum disorders. *Journal of Abnormal Psychology, 107*(4), 558–565. doi:10.1037/0021-843X.107.4.558.

Larøi, F., Marczewski, P., & Van der Linden, M. (2004). Further evidence of the multi-dimensionality of hallucinatory predisposition: factor structure of a modified version of the Launay-Slade

Hallucinations Scale in a normal sample. *European Psychiatry, 19*(1), 15–20. doi:10.1016/S0924-9338(03)00028-2.

Lincoln, T. M., Keller, E., & Rief, W. (2009). Die Erfassung von Wahn und Halluzinationen in der Normalbevölkerung: Deutsche Adaptationen des Peters et al. Delusions Inventory (PDI) und der Launay Slade Hallucination Scale (LSHS-R). *Diagnostica, 55*(1), 29–40. doi:10.1026/0012-1924.55.1.29.

Mark, W., & Touloupoulou, T. (2015). Psychometric properties of "Community Assessment of Psychic Experiences": Review and meta-analyses. *Schizophrenia Bulletin*. doi:10.1093/schbul/sbv088.

QuestBack GmbH. (2014). QuestBack EFS Survey 10.3.

R Core Team. (2014). *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing. Retrieved from http://www.r-project.org/.

Schlier, B., Hennig, T., & Lincoln, T. M. (2017). Measuring fluctuations across the Continuum of Auditory Hallucinations. Development and validation of a state inventory. *Psychiatry Research, 253*, 325–332. doi:10.1016/j.psychres.2017.03.051.

Schlier, B., Jaya, E. S., Moritz, S., & Lincoln, T. M. (2015). The Community Assessment of Psychic Experiences measures nine clusters of psychosis-like experiences: A validation of the German version of the CAPE. *Schizophrenia Research, 169*(1–3), 274–279. doi:10.1016/j.schres.2015.10.034.

Schulman, C. A., Richlin, M., & Weinstein, S. (1967). Hallucinations and disturbances of affect, cognition, and physical state as a function of sensory deprivation. *Perceptual and Motor Skills, 25*(3), 1001–1024. doi:10.2466/pms.1967.25.3.1001.

Selten, J.-P., & Cantor-Graae, E. (2005). Social defeat: Risk factor for schizophrenia? *British Journal of Psychiatry, 187*, 101–102.

Selten, J.-P., Van Der Ven, E., Rutten, B. P. F., & Cantor-Graae, E. (2013). The social defeat hypothesis of schizophrenia: An update. *Schizophrenia Bulletin, 39*(6), 1180–1186. doi:10.1093/schbul/sbt134.

Stefanis, N. C., Hanssen, M., Smirnis, N. K., Avramopoulos, D. A., Evdokimidis, I. K., Stefanis, C. N., … van Os, J. (2002). Evidence that three dimensions of psychosis have a distribution in the general population. *Psychological Medicine, 32*(2), 347–358. doi:10.1017/S0033291701005141.

Stilo, S. A., Di Forti, M., Mondelli, V., Falcone, A. M., Russo, M., O'Connor, J., … Morgan, C. (2013). Social disadvantage: Cause or consequence of impending psychosis?. *Schizophrenia Bulletin, 39*(6), 1288–1295. doi:10.1093/schbul/sbs112.

Trower, P., Birchwood, M., Meaden, A., Byrne, S., Nelson, A., & Ross, K. (2004). Cognitive therapy for command hallucinations: Randomised controlled trial. *The British Journal of Psychiatry, 184*(4), 312–320. doi:10.1192/bjp.184.4.312.

Valmaggia, L. R., Day, F., Garety, P., Freeman, D., Antley, A., Slater, M., … McGuire, P. (2015). Social defeat predicts paranoid appraisals in people at high risk for psychosis. *Schizophrenia Research, 168*(1–2), 16–22. doi:10.1016/j.schres.2015.07.050.

van Nierop, M., van Os, J., Gunther, N., van Zelst, C., de Graaf, R., ten Have, M., … van Winkel, R. (2014). Does social defeat mediate the association between childhood trauma and psychosis? Evidence from the NEMESIS-2 Study. *Acta Psychiatrica Scandinavica, 129*(6), 467–476. doi:10.1111/acps.12212.

van Os, J., Driessen, G., Gunther, N., & Delespaul, P. (2000). Neighbourhood variation in incidence of schizophrenia. Evidence for person-environment interaction. *The British Journal of Psychiatry, 176*(3), 243–248. doi:10.1192/bjp.176.3.243.

Van Os, J., & Linscott, R. J. (2012). Introduction: The extended psychosis phenotype - Relationship with schizophrenia and with ultrahigh risk status for psychosis. *Schizophrenia Bulletin, 38*(2), 227–230. doi:10.1093/schbul/sbr188.

Verdoux, H., Husky, M., Tournier, M., Sorbara, F., & Swendsen, J. D. (2003). Social environments and daily life occurrence of psychotic

symptoms: An experience sampling test in a non-clinical population. *Social Psychiatry and Psychiatric Epidemiology, 38*(11), 654–661. doi:10.1007/s00127-003-0702-8.

Waters, F. A. V., Badcock, J. C., & Maybery, M. T. (2003). Revision of the factor structure of the Launay-Slade Hallucination Scale (LSHS-R). *Personality and Individual Differences, 35*(6), 1351–1357. doi:10.1016/S0191-8869(02)00354-9.

Westermann, S., Kesting, M. L., & Lincoln, T. M. (2012). Being deluded after being excluded? How emotion regulation deficits in paranoia-prone individuals affect state paranoia during experimentally induced social stress. *Behavior Therapy, 43*(2), 329–340. doi:10.1016/j.beth.2011.07.005.

Wilhelm, P., & Schoebi, D. (2007). Assessing mood in daily life. *European Journal of Psychological Assessment, 23*(4), 258–267. doi:10.1027/1015-5759.23.4.258.