

The Perception of Biological Sound: A Test of the Social Deafferentation Hypothesis

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CHAPTER I

Introduction

Being socially connected is not only important for psychological and emotional well-being, but it also has a significant and positive influence on physical well-being (Holt-Lunstad, Smith, Baker, Harris, & Stephenson, 2015). Social isolation is recognized as a major risk factor for morbidity and mortality (Cacioppo, Capitanio, & Cacioppo, 2014). According to Cacioppo et al., the most common explanation for this relationship may be captured by the social control hypothesis, which posits that interactions with friends, family, or other groups, lead to better health behavior and as a result decreases risks for morbidity and mortality. A meta-analysis found that the odds ratio for increased mortality for loneliness is 1.45, which is double the odds ratio for increased mortality for obesity and quadruple the odds ratio for air pollution (Cacioppo et al., 2014). These findings elucidate the importance of understanding the relative influence of social isolation and loneliness.

Recent formulations for the onset of psychosis cite loneliness and isolation as major factors. For example, a hypothesis proposed by Ralph Hoffman delineated the social nature of auditory verbal hallucinations and the direct effect of reduced social interactions on the development of schizophrenia. Hoffman's findings stress the importance of the social brain, defined as the amalgamation of neural resources dedicated to understanding conversational language, emotionality, intentions, actions, and state of mind of other persons based on on-going experiences (Hoffman, 2007). The inherent vulnerabilities of the social brain become evident when a person's opportunities for social interactions are drastically reduced. Therefore, the

weaknesses of the social brain are especially important in regards to mental illnesses. Hoffman proposed the social deafferentation (SDA) hypothesis for the induction of active schizophrenia, which states that high levels of social withdrawal or isolation in vulnerable individuals prompt the social brain to produce spurious social meaning in the form of complex, emotionally compelling hallucinations and delusions representing other persons or agents (Hoffman, 2007). Hoffman derived the SDA hypothesis from three observations: multiple studies suggest that social isolation often precedes and may be a risk factor for active schizophrenia, sensory deafferentation produces large-scale brain reorganization and complex hallucinations, hallucinations and delusions in schizophrenia generally contain emotionally compelling, aberrant social meaning (Hoffman, 2007).

Based on these three observations, Hoffman asserted that although people with schizophrenia do not directly suffer from sensory deafferentation, the social withdrawal that arises in a majority of cases prior to the onset of illness is likely to inhibit the flow of information to neural systems that aid in the processing of complex social meaning (Hoffman, 2007). This inhibition results in a deafferentation-like reorganization of the social brain. The theory suggests that people who developed schizophrenia may have experienced social isolation prior to the onset of symptoms, and the subsequent lack of information flow to the social brain resulted in auditory verbal hallucinations. Therefore, the social nature of positive symptoms may reflect some intrinsic desire to experience social interactions. Given that delusions and hallucinations tend to express highly personal and emotionally charged meaning, they could serve as functional replacements for actual social experiences.

Further highlighting the inherent risks of social isolation, several studies have demonstrated that immigration leads to a striking increase in risk of schizophrenia. For instance, a study

investigated the incidence of schizophrenia among people from non-white ethnic minorities in neighborhoods where they constituted a smaller portion of the total population. The incidence of schizophrenia increased significantly as the proportion of minorities in the local population fell (Boydell, Os, McKenzie, Allardyce, & et al., 2001). The incidence ratio ranged from 2.4 in areas where the minorities formed a large proportion of the local population to 4.4 in the areas where they formed a smaller proportion (Boydell et al., 2001). The authors suggest that a possible mechanism is increased exposure to and reduced protection against stress and adverse life events, as people from ethnic minorities may be more likely to be singled out or be more vulnerable when they are in a small minority. Social isolation and the lack of social support for people living in an alien environment may be factors contributing to schizophrenia. Under the assumptions of the SDA hypothesis, these individuals would be likely to experience socially compelling hallucinations and delusions. While this field of research highlights the role of social isolation in the induction of schizophrenia, it also cites events and emotions commonly experienced by the general population.

Individuals predisposed to schizophrenia may inherit liability for psychosis, but experiences such as loneliness, social withdrawal, and sadness are not uncommon in the general population. Additionally, there are healthy individuals who experience hallucinations under no special circumstances, and surveys have shown that more people in the community experience hallucinations than come into contact with psychiatric services (Johns & van Os, 2001). For instance, Posey and Losch (1983) found that out of a sample of 375 college students, 71% of the subject reported some experience of at least brief, occasional hallucinated voices during periods of wakefulness. Additionally, 39% of the college students reported hearing their thoughts spoken aloud (Posey & Losch, 1983). Similarly, Barrett and Etheridge found that 30-40% of a sample of

586 college students reported hearing voices, and almost half of these indicated that the experience occurred at least once a month (Barrett & Etheridge, 1992). Further highlighting the finding that hallucinations occur in healthy individuals, Barrett and Etheridge found that reports of hallucinations were not related to measures of psychopathology.

Additionally, McKellar attempted to estimate the prevalence of hallucinatory experiences in the general adult population. McKellar interviewed a group of 500 healthy individuals and found that 125 (25%) subjects reported at least one hallucinatory experience (McKellar, 1968). It may be the case that schizophrenia is not a discrete disease entity and that psychotic symptoms exist as a continuum in the general population. For example, in the US National Comorbidity Survey, 28% of the sample endorsed psychosis-screening questions; however, when clinicians made diagnoses, the rate of clinically defined psychosis was 0.7% (Johns & van Os, 2001). Thus, it is possible that the clinical definition of psychosis may represent only a portion of the phenotypic continuum (Johns & van Os, 2001).

Furthermore, patients who receive a diagnosis of schizophrenia for the first time show, as a group, a characteristic pattern of demographic variables (Johns & van Os, 2001). They are more likely to be young, single, unemployed, and reside in an urban environment (Johns & van Os, 2001; Marcelis, Navarro-Mateu, Murray, Selten, & Van Os, 1998). This pattern is also observed in age-related groups of individuals with schizotypy, delusional ideation measured with the Peters Delusional Inventory (PDI; Peters, Joseph, Day, & Garety, 2004), and delusions and hallucinations in the absence of clinical diagnoses (Johns & van Os, 2001). Based on these findings, hallucinations and delusions, whether in a clinical or healthy sample of individuals, appear to be related to feelings of loneliness and social isolation.

Additional support for the continuum of psychotic experiences in the general population is captured by a construct called, “Openness to Absorbing and Self-Altering Experiences” or “Absorption” (Tellegen & Atkinson, 1974). “Absorption” suggests a state of total attention during which an individual seems to be entirely dedicated to experiencing and modeling the attentional object, be it a human being, a sound, a remembered incident, or an aspect of one’s self (Tellegen & Atkinson, 1974). Tellegen and Atkinson suggest that the attention described in absorption is a “total” attention, involving a full commitment of available perceptual, motoric, imaginative and ideational resources. Research suggests that absorbed attention amplifies the experience of one part of reality, while other parts fade from awareness. As a result, an ambiguous stimulus could become the object of absorbed attention, while more important stimuli fade from awareness.

Furthermore, according to Fitzgerald, individuals with high levels of Absorption or Openness to Absorbing possess a motivational-affective component that can best be characterized as Openness to Experience, one of the Big Five personality traits (Fitzgerald, 1966; Tellegen & Atkinson, 1974). Individuals high in Openness possess a distinct cognitive style that generates unconventional appraisals of their surrounding environment. Given that these individuals possess a desire to experience deep and personal connections with objects in the environment, they may be more likely to assign social significance to ambiguous stimuli.

While past experiences of social isolation play a crucial role in the induction of psychosis, it is equally important to examine how individuals process on-going social experiences. Our ability to process social information is crucial for effective social interactions; however, research suggests that patients with schizophrenia possess deficits in the recognition and interpretation of social cues. A study found that patients with schizophrenia exhibited

marked deficits in biological motion perception compared to healthy controls. Biological motion contains information about the living things (e.g. humans) such as intentions, and even emotions (Kim, Doop, Blake, & Park, 2005). The results also showed that subjects with impaired social functioning tended to have worse performance on the biological motion task (Kim et al., 2005; Kim, Park, & Blake, 2011). Overall, these results suggest that impaired social functioning, in both clinical and healthy populations, may severely impact the ability to extract and interpret social information from the environment.

In summary, the Social Deafferentation (SDA) hypothesis proposes that high levels of social isolation in vulnerable individuals induce the brain to generate social outlets in the form of emotionally driven hallucinations and delusions (Hoffman, 2007). Similarly to other deafferentation syndromes, such as phantom limb syndrome, social isolation may lead to cortical reorganizations that elicit hyperactivity in the social brain, causing it to interpret social meaning in the absence of socially relevant information. Similar to clinical populations, healthy individuals also experience hallucinations and delusions with social content. A construct called Openness to Absorption, which is related to Openness to Experience, describes individuals who possess a tendency to fall into states of absorbed attention. During periods of absorbed attention, individuals become intensely focused on a single stimulus and often assign great importance to it. It is possible that individuals high on Openness will assign social significance to ambiguous stimuli during periods of elevated loneliness and social distress. Similarly to biological motion, biological sound provides information that is crucial to effective social functioning. Thus, high levels of social isolation in vulnerable individuals, who are also high on Openness, may exhibit marked deficits in the ability to interpret biological sound. It is likely that they will seek out social meaning in the absence of socially relevant information.

In the present study, we sought to test the social deafferentation hypothesis by examining the roles of loneliness and social isolation in the false perception of social meaning in auditory stimuli in relation to psychosis-risk.

CHAPTER II

Methods

Participants:

A total of 22 healthy participants were recruited using an online university research system for class credit. All participants were screened for history of DSM-V Axis I disorders. Exclusion criteria were as follows: a prior history of traumatic head injury or neurological disorders or history of drug use. All participants had normal hearing. All participants gave written informed consent as approved by the Vanderbilt Institutional Review Board and were given course credit. Table 1 presents the demographic information.

Table 1. Demographic Information.

	Participants (n=22)
Age, mean (SD)	18.9 (1.15)
Gender, n	
Male	9
Female	13
Handedness, n	
Left	3
Right	19

Design and Procedure

After the informed consent procedure, participants completed self-report questionnaires and participated in the auditory perception task described below.

Clinical and Psychological Information

Loneliness: The UCLA Loneliness Scale was used to measure subjective feelings of loneliness as well as feelings of social isolation (Russell, Peplau, & Ferguson, 1978). The

respondents were instructed to rate each item as “I often feel this way,” “I sometimes feel this way,” “I rarely feel this way,” or “I never feel this way.” Prior studies indicate that the measure is highly reliable, both in terms of internal consistency (coefficient alpha ranging from 0.89 to 0.94) and test-retest reliability over a 1-year period ($r=0.73$) (Russell, 1996).

Social support: The Multi-Dimensional Support Scale measures the availability and adequacy of social support sources (Winefield, Winefield, & Tiggemann, 1992). The measure yields 6 subscale scores, each measuring the availability and adequacy from three different sources of social support. The three sources include the confidants (family and closest friends), peers, and experts (those who have an official role to provide specialist help for a given challenge) (Winefield et al., 1992). Alpha coefficients of internal reliability for the six subscales are high (0.75 and above) (Winefield et al., 1992). Adequacy and availability are relatively independent of each other. In the present study, respondents indicated the availability of their social support sources. Availability of support is defined as the total frequency of supportive behavior (Winefield et al., 1992).

Openness: The Big Five Inventory was used to assess Openness to Experience, which Fitzgerald identified as the motivational-affective component of Openness to Absorbing and Self-Altering Experiences or Absorption (Fitzgerald, 1966; Tellegen & Atkinson, 1974). The instrument consists of 44 items, 10 of which pertain specifically to Openness to Experience. The items were answered on a 5-point scale ranging from strongly disagree to strongly agree.

Prodromal signs for schizophrenia-spectrum: The Brief Prodromal Questionnaire (PQ-B) was used to assess prodromal signs (Ising et al., 2012). The Prodromal Questionnaire is a self-report screening questionnaire that assesses the presence of attenuated psychotic symptoms on a two-point scale (true/false) (Ising et al., 2012). If a psychotic symptom is present, the

participant indicates the level of distress on a scale of 0 to 3. The measure provides two scores: a total measure of prodromal symptoms and a measure of distress.

Depression: The Beck Depression Inventory assessed levels of depression in participants. A previous meta-analysis indicated that the internal consistency of the measure for non-psychiatric samples ranges from 0.73 to 0.92 with a mean alpha of 0.81 (Beck, Steer, & Garbin, 1988).

Biological Sound Detection Task: Stimuli and procedure

The auditory perception sequences were presented via speakers from a MacBook laptop. The sound sequences were controlled by Matlab © version 2010a and the Psychophysics Toolbox. Sound editing was conducted with Audacity1.2.5. For both the hearing test and the auditory task, the MacBook laptop speakers were set to the maximum output level.

Biological Sound Detection Task: The auditory stimuli were selected from the Montreal Neurological Institute (Belin, Zatorre, & Ahad, 2002). Sound stimuli were 1 second long in duration. There were two types of sounds: human vocal sound (single words, foreign language, laughs) and energy-matched non-human sound (animals, environmental sounds). There were two levels of background noise: pure sound or pure sound plus added white noise. Thus there were 4 types of stimuli: human vocal sound, human vocal sound with modified white noise, energy-matched non-human sound, and energy-matched non-human sound with modified white noise.

We utilized a dual-alternative, forced-choice task. Participants were instructed to listen to the sound intervals and decide as quickly and accurately as possible whether the sound was human or non-human. They were instructed to respond by pressing the b-key if they perceived

human vocal sound. Alternatively, they were instructed to press the n-key if they perceived non-human vocal sound. Participants used their dominant hand for key presses. There were 167 trials.

CHAPTER III

Hypotheses

It was hypothesized that individuals with elevated levels of loneliness, as indicated by the UCLA loneliness scale, would exhibit decreased sensitivity (d') to the biological sound task due to increased reports of false alarms. Individuals with low scores on the MDSS were also expected to report more false alarms and receive lower sensitivity scores. Furthermore, it was hypothesized that healthy controls endorsing more items on the Prodromal Questionnaire and reporting higher levels of distress would be more likely to show a decreased sensitivity to the biological sound task as a function of false alarms. Lastly, it was expected that participants with higher levels of Openness would be more likely to report false alarms.

CHAPTER IV

Data Analysis

To determine sensitivity indices for discriminating biological sound from non-biological sound or noise, d' was calculated according to signal detection theory (SDT; Green & Swets, 1966). d' indicates the sensitivity of an individual in discriminating two different categories by subtracting the proportion of false alarms from the proportion of hits (see Peterman, Christensen, Giese, & Park, 2014). In the present study, a human vocal response to a human vocal sound with and without modified white noise was defined as a hit. A human vocal response to a non-human sound with and without white noise was defined as a false alarm.

Pearson correlations were computed to examine relationships between performance on the biological sound detection task and psychological and clinical measures. P-values were computed for each correlation. 95% confidence intervals were also calculated for significant correlations. A stepwise regression was performed in order to determine which psychological and clinical measures best predict performance on the biological sound detection task.

CHAPTER V

Results

Mean rating scale scores are shown in Table 2. Sensitivity, d' , was not significantly associated with Openness ($r = -0.2344$, $p = 0.2937$), availability of social support ($r = -0.0414$, $p = 0.8550$), total score for PQ-B (prodromal signs for schizophrenia-spectrum) ($r = 0.0525$, $p = 0.8166$), subscale score of distress for PQ-B ($r = 0.0360$, $p = 0.8736$), or loneliness ($r = -0.3756$, $p = 0.0849$).

False alarms were significantly and positively associated with Openness ($r = 0.4686$, $p = 0.0278$) and loneliness ($r = 0.5135$, $p = 0.0145$), but not with total PQ-B scores ($r = 0.1354$, $p = 0.5480$) or the Distress subscale ($r = 0.0516$, $p = 0.8195$). While availability of social support and proportion of false alarms were not significantly correlated ($r = 0.0521$, $p = 0.8178$), it is important to note that availability of social support and loneliness were significantly negatively correlated ($r = -0.5621$, $p = 0.0065$).

The stepwise regression analysis revealed that loneliness, availability of social support, and Openness to Experience best predict the number of false alarms produced in the biological sound task (Table 3). The model accounts for 57.73% of the variance in the proportion of false alarms. Even though availability of social support was not directly correlated with the proportion of false alarms, the measures accounted for an additional 16.98% of the variance in the proportion of the false alarms. Thus, the availability of social support functioned as a moderator variable to loneliness as measured by the UCLA Loneliness scale.

Confidence intervals were also calculated. The 95% confidence interval for the correlation between false alarms and Openness ($r=0.4686$) spanned from 0.0585 to 0.7433. The 95% confidence interval for the correlation between false alarms and loneliness ($r=0.5135$) was determined to be 0.1173 to 0.7687.

Table 2. Summary of Results

	Mean (n=22)	SD
Biological Sound Task		
Hits	0.57	0.12
False Alarms	0.05	0.04
Sensitivity (d')	1.97	0.31
Openness to Experience	34.55	7.27
MDSS (Availability of social support)	52.59	7.04
UCLA Loneliness Scale	16.77	9.09
PQB (Prodromal Signs)		
Distress	8.32	8.93
Total score	3.05	2.82
Beck Depression Inventory	3.09	3.18

Table 3. Summary of Stepwise Regression.

Step	Variable Entered	Variable Removed	Number Variables In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	UCLA		1	0.2637	0.2637	10.3170	7.16	0.0145
2	MDSS		2	0.1698	0.4335	5.7862	5.70	0.0276
3	Openness		3	0.1438	0.5773	2.2560	6.12	0.0235

CHAPTER VI

Discussion

In this study we examined the roles of loneliness and social isolation in the false perception of social meaning in auditory stimuli in relation to psychosis-risk. Sensitivity measured the sensitivity of an individual in discriminating human sound from non-human sound (Peterman, Christensen, Giese, & Park, 2014). Sensitivity was obtained by subtracting the proportion of false alarms from the proportion of hits. A human vocal response to a human vocal sound with and without modified white noise was defined as a hit. A human vocal response to a non-human sound with and without white noise was defined as a false alarm. We hypothesized that sensitivity would be related to loneliness, availability of social support, openness to experience, and prodromal signs as a function of false alarms.

In contrast to our predictions, we found that sensitivity was not significantly correlated with loneliness, availability of social support, prodromal symptoms, or Openness to Experience. However, we predict that patients with schizophrenia would exhibit greater difficulties in the biological sound task and their performance as a group would be correlated with loneliness, availability of social support, and severity of positive symptoms. Previous studies have found that patients with schizophrenia are less sensitive to social cues (Kim et al., 2005; Kim et al., 2011; Peterman et al., 2014). Furthermore, Kim et al. found that deficits in the extraction of social information were correlated with impaired social functioning as measured by the Zigler social competence scale (Kim et al., 2005).

In agreement with our hypotheses, the proportion of false alarms was significantly correlated with loneliness and Openness to Experience. Additionally, the stepwise regression analysis identified loneliness, Openness to Experience, and availability of social support as the best predictors of false alarms. Thus, the findings suggest that the endorsement of non-human sound as human is related to participants' feelings of social isolation, loneliness, and proneness to states of absorbed attention. Participants experiencing stress due to elevated levels of loneliness and low levels of social support may be inclined to seek out social information in ambiguous stimuli, while ignoring more pertinent information.

The proportion of false alarms was not significantly correlated with prodromal signs, which is in agreement with the results from Barrett and Etheridge's finding that hallucinations in a healthy sample of college students were not related to reports of psychopathology (Barrett & Etheridge, 1992). Johns and Van Os's finding that the prevalence of psychotic experiences in healthy samples is highly dependent on the instrument used could also explain this.

There are important limitations. The sample size was small. The wide ranges of the 95% intervals are indicative of this limitation and suggest that increased sample size will prove highly beneficial to the accuracy of this experiment. To address this limitation, we are continuing to collect additional data, as similar studies investigating hallucinatory experiences in healthy populations utilized significantly larger samples.

In conclusion, the results of this study suggest that the perception of social information in healthy people may be hindered by feelings of loneliness and social isolation. Lonely individuals who possess a greater propensity for psychotic-like experiences, as indicated by the relationship between Openness to Experience and Openness to Absorbing, may be more likely to assign

social significance to ambiguous stimuli, while ignoring more relevant information. Thus, these results provide partial support for the Social Deafferentation Hypothesis.

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