



Subnormal sensory attenuation to self-generated speech in schizotypy: Electrophysiological evidence for a ‘continuum of psychosis’



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ARTICLE INFO

Article history:

Received 3 January 2015

Received in revised form 8 May 2015

Accepted 25 May 2015

Available online 28 May 2015

Keywords:

Electroencephalography (EEG)

Sensory suppression

Schizophrenia

Schizotypy

Continuum of psychosis

Self-monitoring

Event-related potential (ERP)

ABSTRACT

Background: A ‘continuum of psychosis’ refers to the concept that psychotic-like experiences occur to certain extents in the healthy population and to more severe extents in individuals with psychotic disorders. If this concept is valid, neurophysiological abnormalities exhibited by patients with schizophrenia should also be present, to some degree, in non-clinical individuals who score highly on the personality dimension of schizotypy. Patients with schizophrenia have consistently been shown to exhibit electrophysiological suppression abnormalities to self-generated speech. The present study aimed to investigate whether these electrophysiological suppression abnormalities were also present in non-clinical individuals who scored highly on schizotypy.

Methods: Thirty-seven non-clinical individuals scoring High (above median) and 37 individuals scoring Low (below median) on the Schizotypal Personality Questionnaire (SPQ; a commonly used schizotypy scale) underwent electroencephalographic (EEG) recording. The amplitude of the N1 component of the auditory-evoked potential was measured while participants (a) vocalized simple syllables (Talk condition), (b) passively listened to a recording of these vocalizations (Listen condition) and (c) listened to a recording of the vocalizations while simultaneously watching a video depicting the sound-wave of the forthcoming vocalizations, allowing them to be temporally predicted (Cued Listen condition).

Results: The Low Schizotypy group exhibited significantly reduced N1-amplitude in the Talk condition relative to both the Listen and Cued Listen conditions; that is, they exhibited significant N1-suppression. The High Schizotypy group exhibited significantly lower levels of N1-suppression compared to the Low Schizotypy group. Furthermore, while the Cued Listen condition induced significantly lower N1-amplitudes compared to the Listen condition in the Low Schizotypy group, this was not the case for the High Schizotypy group.

Conclusions: The results suggest that non-clinical, highly schizotypal individuals exhibit subnormal levels of N1-suppression to self-generated speech, similar to the N1-suppression abnormalities which have previously been reported in patients with schizophrenia. This finding provides empirical support for the existence of a neurophysiological ‘continuum of psychosis’.

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1. Introduction

The concept of schizotypy describes various psychosis-like experiences that occur in non-clinical individuals of the general population (Rado, 1953). The quantity and severity of these experiences fall below the level that would qualify them as clinically significant, and these experiences generally do not impair daily functioning (Meehl, 1962). Yet there is evidence to indicate that individuals who score highly on scales of schizotypy have an underlying vulnerability to develop psychotic disorders such as schizophrenia (Lenzenweger, 2010).

Advantages of studying schizotypy are that the clinical and demographic confounds typically associated with studying schizophrenia, such as medication, comorbidities and downward social mobility can be avoided (Lenzenweger, 2010).

The concept of schizotypy is closely tied in with a proposed ‘continuum of psychosis’ (Van Os et al., 2009), whereby psychotic-like experiences exist on a continuum throughout the population. According to this model, non-clinical individuals are prone to experience low-to-intermediate levels of psychotic-like symptoms, while individuals diagnosed with schizotypal personality disorder (SPD) experience higher levels and individuals diagnosed with an established psychotic disorder, such as schizophrenia, experience very high levels of these symptoms (Krabbendam et al., 2004). While schizotypy describes a latent collocation of personality traits typically associated with schizophrenia and

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SPD, it should be emphasized that high levels of schizotypy are not diagnostic of schizophrenia, and that non-clinical, highly schizotypal individuals typically do not exhibit overt psychotic symptoms and behaviors (Claridge, 1997). Furthermore, the concept of schizotypy does not imply that healthy individuals who score highly on measures of schizotypy are necessarily more 'ill' than individuals who score lower. On the contrary, some aspects of schizotypy have been linked to creativity and academic achievement and may be regarded as beneficial (Nettle, 2005).

If the concept of a 'continuum of psychosis' is valid, it might be expected that non-clinical individuals who score highly on measures of schizotypy would exhibit neurophysiological characteristics that are comparable (but potentially less marked) than those exhibited by individuals with schizophrenia. Patients with schizophrenia fail to suppress the electrophysiological consequences of self-generated speech (Ford et al., 2001a; Ford and Mathalon, 2004; Ford et al., 2007a,b). These electrophysiological self-suppression abnormalities are theoretically important, as they provide a direct and plausible explanation for schizophrenia patients' bizarre yet characteristic tendency to misperceive sensations resulting from self-generated actions and thoughts as coming from external agents (Feinberg, 1978; Frith, 1995; Whitford et al., 2012).

The N1 component is the largest negative component of the auditory event-related potential (ERP), which typically occurs 80 to 120 ms after the presentation of an auditory stimulus. Evidence from fMRI studies suggests that N1 is generated in the primary auditory cortex (Zouridakis et al., 1998). The amplitude of the N1 component is dependent on stimulus intensity; that is, all else held equal, high intensity sounds evoke larger N1 components than do low intensity sounds (Picton et al., 2000). Numerous previous studies with healthy control participants have shown that the amplitude of the N1 component is significantly reduced (i.e., suppressed) when participants self-initiate auditory sensations compared to when passively listening to a recording of the same sounds. N1-suppression has been reported both to tones self-initiated via a button-press (McCarthy and Donchin, 1976; Schafer and Marcus, 1973; Ford et al., 2014; Martikainen et al., 2005) and to speech initiated by willed vocalizations (Ford et al., 2001a; Ford and Mathalon, 2004; Ford et al., 2007a,b; Curio et al., 2000; Houde et al., 2002). N1-suppression – particularly to willed vocalizations – has been interpreted as being caused by an efference copy / corollary discharge mechanism that predicts and suppresses the sensory consequences of self-generated actions. Recordings of neuronal activity in the temporal cortex during neurosurgery found that neuronal firing was suppressed during overt speech compared to passive listening (Creutzfeldt et al., 1989), and this suppression appeared to be highly localized to circumscribed areas within the auditory cortex (Chen et al., 2011; Greenlee et al., 2011).

A substantial body of evidence has accumulated indicating that patients with schizophrenia exhibit reduced levels of N1-suppression to self-generated vocalizations, relative to healthy controls (Ford et al., 2001a; Ford and Mathalon, 2004; Ford et al., 2007a,b). This suggests that at a basic neurophysiological level, schizophrenia patients fail to distinguish between self-generated and externally-generated vocalizations, possibly as a result of abnormalities in underlying corollary discharge mechanisms.

The current paper has two primary aims. First, if the concept of a 'continuum of psychosis' is valid and deficient N1-suppression represents a neurophysiological marker of psychotic-like experiences, then highly schizotypal but non-clinical individuals would be expected to exhibit subnormal levels of N1-suppression relative to low schizotypy individuals. However, to date, N1-suppression during willed vocalization has not been investigated in the context of schizotypy. The present study tested this hypothesis by comparing a sample of healthy, highly schizotypal individuals (defined on the basis of their score on the Schizotypal Personality Questionnaire (SPQ; Raine, 1991)) to a sample of low schizotypy individuals on a modified version of the talk/listen paradigm used by Ford et al. (2001b).

Second, the majority of previous studies on N1-suppression have compared the amplitude of the N1 component evoked by self-generated vocalizations in an active 'talking' condition with the amplitude of N1 evoked by passively 'listening' to a recording of the vocalizations generated in the 'talking' condition. However, as previously noted, while the auditory stimulus is physically identical in both conditions, there is nonetheless a substantial difference between the conditions in that vocalizations are temporally predictable in the 'talking' condition, as speakers vocalize whenever they choose, a confound noted by Hughes et al. (2013). This raises the possibility that N1-suppression is due, at least in part, to differences in temporal predictability between the conditions, rather than true sensory suppression resulting from corollary discharge mechanisms per se. The present study explored this issue by adding a third experimental condition, dubbed the 'Cued Listen' condition, to the 'Talk' and 'Listen' conditions that are typically used in experiments of this nature. In the 'Cued Listen' condition, participants passively listened to a recording of their willed vocalizations (as per the 'Listen' condition) but were cued as to the imminent onset of each vocalization by watching a video of their vocalization waveform. The 'Cued Listen' condition represents a superior comparison condition than the typical 'Listen' condition, given that the cued vocalizations are externally-generated (as per the 'Listen' condition) yet temporally predictable (as per the 'Talk' condition).

Based on the aforementioned findings in patients with schizophrenia, it was hypothesized that participants scoring high on schizotypy would show less N1-suppression in the Talk condition compared to both the Listen and the Cued Listen conditions, compared to low schizotypy participants. In contrast, low schizotypy participants were expected to show significant N1-suppression in the Talk condition relative to both Listen and Cued Listen, reflecting the operation of a corollary discharge mechanism to self-generated speech. Furthermore, we also predicted that the low schizotypy participants would show significantly reduced N1-amplitudes in the Cued Listen condition relative to the Listen condition, reflecting the effects of temporal predictability.

2. Material and methods

2.1. Participants

Seventy-five participants were recruited through online recruitment systems (SONA-1 and SONA-P) at UNSW Australia. Participants from the SONA-1 recruitment system were first-year psychology students who were reimbursed for their time with course credit. SONA-P is an online recruitment system, which is open for everyone to enroll and offers participants financial reimbursement for their time. Participants' demographic data, alcohol, nicotine and caffeine consumption, recreational drug use, exclusion criteria and scores on the Schizotypal Personality Questionnaire (SPQ; Raine, 1991) are displayed in Table 1. Estimates of drug use and history of Axis I disorders were also based on participants' self-report. One participant was excluded due to a self-reported diagnosis of an Axis I disorder, based on DSM-IV-TR criteria (American Psychiatric Association, 2000). Participants were assigned to Low ($n = 37$) and High ($n = 37$) Schizotypy groups based on a median split of their score on the SPQ. (In a supplementary analysis, described in the Supplementary Materials section, participants were divided into more extreme schizotypy groups, where participants scoring in the upper quartile were assigned to the High Schizotypy group ($n = 21$) and participants scoring in the lower quartile to the Low Schizotypy group ($n = 21$)). The schizotypy groups did not differ in self-reported consumption of caffeine, alcohol, nicotine or recreational drugs. Fifty-nine percent of participants reported that English was not their native language. However, there was no significant difference between the groups on this measure, and all individuals were able to converse fluently in English, which is an admission requirement by UNSW Australia. After explaining the procedure of the study and providing an opportunity to participants to ask questions for clarification, all

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