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Inviting hallucinatory percepts during speech-listening to detect cognitive changes in early psychosis

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Abstract

Treatment outcomes for people with schizophrenia are more favourable if treatment starts early in the course of the disorder. Current detection methods lack specificity and do not make use of cognitive markers. We presented individuals experiencing a first episode of psychosis (FEP) and matched control participants with acoustically degraded meaningful and matched nonsense sentences to examine the degree to which people reported words that were not actually presented. Intrusion errors were counted when reported words were unrelated to words in the original sentence. Intelligibility (measured as words reported correctly) did not differ between groups but intrusion errors were more frequent at the lower SNR, for nonsense sentences, and in the FEP group when item variability was controlled. Our approach may hold promise for early identification of a psychotic prodrome.

Keywords

Psychosis, First-Episode Psychosis, Schizophrenia, Reality Monitoring, Linguistic Context, Intelligibility, Speech-in-noise, Speech Perception, Psycholinguistics, Hallucinations.

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Chapter 1

1 Introduction

Psychosis is when an individual experiences a loss of contact with external reality due to a combination of symptoms that alter thoughts, feelings, and behaviors. Early identification of individuals at high-risk of developing schizophrenia is helpful since early treatment has been shown to lead to favorable outcomes, compared to later identification (Hegelstad et al., 2012). However, current early detection methods lack specificity resulting in erroneous positive diagnoses, and do not make use of cognitive markers that are specific to psychosis. Individuals at high-risk of developing psychosis and schizophrenia experience cognitive dysfunctions (Broome et al., 2005; Fusar-Poli et al., 2012) and abnormal perceptual experiences. Cognitive patterns such as reality monitoring deficits (e.g. misinterpreting internal thought as external speech), and a drive to make sense of anomalous percepts, have been shown to be characteristics of individuals at high-risk. These cognitive patterns may be targeted by early detection tasks, where such individuals are prone to identifying imaginary events as real when tested using reality monitoring tasks (Bentall & Slade, 1985). The goal of the current study is to develop a behavioural test, using degraded speech, that can distinguish people at high-risk of developing chronic psychosis (schizophrenia) from those at low-risk, based on inviting overconfidence in perceptual judgements.

1.1 Psychosis and Schizophrenia

1.1.1 Symptoms

Psychosis is when an individual experiences a loss of contact with external reality due to a combination of symptoms that alter thoughts, feelings and behaviors. Psychotic symptoms can be substance-induced and also be secondary to another illness affecting brain function such as a brain injury or epilepsy (Bacon, Granholm, & Withers, 1998; David & Prince, 2005; Nadkarni, Arnedo, & Devinsky, 2007), but is also a symptom of major mental disorders such as Schizoaffective Disorder, Schizophreniform Disorder, Brief Psychotic Disorder, and Schizophrenia. Compared to schizophrenia, the other disorders have a briefer duration of psychotic symptoms. Other disorders such as Bipolar disorder can include psychotic symptoms, but a mood disorder is also present (Glahn et al., 2007).

Schizophrenia is a chronic psychiatric condition that is diagnosed if an individual experiences more than one psychotic episode, along with other symptoms of dysfunction, within a six-month period according to the Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM-5; American Psychiatric Association, 2013). A psychotic episode is characterized by three categories of symptoms: “positive”, “negative” and “disorganization”. Positive symptoms are thoughts and behaviors that are added on to a person’s experiences such as hallucinations (perceptual experiences with no external stimulus e.g. hearing voices) and delusions (strong beliefs that are resistant to contradictory evidence). Negative symptoms are thoughts and behaviors that are “taken away” or reduced such as a decrease in emotional expression, speech output, motivation, ability to experience pleasure, and interest in social interaction. Disorganization can affect speech, thought and behavior. Disorganized speech and thought, which is characterized as formal thought disorder (FTD), includes not being able to stay on topic or going off on a tangent while speaking, answering a question in a way that does not make sense, and talking about things that seem unrelated to the conversation. Disorganized behavior refers to inappropriate behaviors that do not fit the situation such as displaying inappropriate emotions in response to a situation, the inability to initiate goal-oriented tasks and not responding or reacting to the environment.

In addition to these three categories of symptoms, cognitive deficits are also present in schizophrenia, even before the onset of psychotic symptoms. Cognitive deficits are expressed in domains such as attention, working-memory, verbal learning, memory, language skills and executive functioning. These deficits are covered in more detail in section 1.1.4. Other cognitive changes include the tendency to impose meaning onto things that do not make sense, and otherwise irrelevant events in one’s experience (aberrant salience), as well as an inability to distinguish between an external stimulus and internal thoughts or imagined events (impairment in reality monitoring). These cognitive patterns are covered in more detail in section 1.2 and 1.3.

1.1.2 Burden of psychosis and schizophrenia

Psychotic disorders affect just over three percent of the population, whereas the average lifetime prevalence of schizophrenia is just under one percent of the population (McGrath, Saha, Chant, & Welham, 2008; Perälä et al., 2007). The life expectancy of those with schizophrenia is reduced by 20 years compared to the general population and this disparity has only been increasing over time (Hoang, Stewart, & Goldacre, 2011; Laursen, Nordentoft, & Mortensen, 2014). Individuals with schizophrenia experience impairments in multiple domains of daily living such as maintaining social relationships, sustaining employment and living independently (Harvey, 2014). Schizophrenia is generally reported to be slightly more frequent in men than in women, is more severe in men, and develops earlier on in life for men compared to women (Aleman, Kahn, & Selten, 2003; Castle & Murray, 1991; Eranti, MacCabe, Bundy, & Murray, 2013). Schizophrenia is also most common in disadvantaged areas of inner cities and among migrant groups (Cantor-Graae & Selten, 2005; Hollander et al., 2016)

1.1.3 Course of schizophrenia

The onset and course of schizophrenia is characterized by four sequential phases (Tandon, Nasrallah, & Keshavan, 2009):

1. The premorbid phase includes subtle cognitive, motor and social dysfunctions (Schenkel & Silverstein, 2004) and is the period of time preceding the first onset of psychosis. It reflects precursors or risk factors for developing schizophrenia (Tandon et al., 2009).
2. The prodromal phase is considered to be an early manifestation of schizophrenia characterized by subthreshold psychotic symptoms such as attenuated positive symptoms and negative symptoms, and an overall decline in cognitive function (Riecher-Rössler & Rössler, 1998; Schultze-Lutter, 2009). The prodromal phase may last from months to years with an average of five years (Klosterkötter, Schultze-Lutter, & Ruhrmann, 2008). This is the phase at which it would be ideal to be able to identify individuals with schizophrenia so treatment can begin as early as possible.

3. The first episode of psychosis (FEP) occurs the first time an individual has frank psychotic symptoms consistent with Criterion A in the DSM-5. To meet DSM-V criteria, an individual must experience two or more of the following symptoms for one month (or less if treated), and at least one must belong to one of the first three categories: (1) Delusions (2) Hallucinations (3) Disorganized speech (e.g. frequent derailment or incoherence), (4) Grossly disorganized or catatonic behaviour (4) Negative symptoms (American Psychiatric Association, 2013). Following the FEP, the course of schizophrenia varies substantially across individuals (Huber, Gross, & Schüttler, 1975; Modestin, Huber, Satirli, Malti, & Hell, 2003).
4. The stable phase or plateau starts when psychotic symptoms attenuate once again, and negative symptoms and cognitive deficits become more prominent (Tandon et al., 2009). The remaining course of schizophrenia is characterized by exacerbations of psychotic episodes and remissions (Andreasen et al., 2005; Haro, Novick, Suarez, Ochoa, & Roca, 2008). Over the long-term course of the disorder, positive symptoms become less severe and negative symptoms become more prominent. The progression and duration of the illness, and degree of recovery, vary markedly across individuals (Tandon et al., 2009).

1.1.4 Cognitive deficits in schizophrenia and psychosis

Cognitive impairments are pervasive features of schizophrenia and can be detected before the onset of psychotic symptoms and persist over the course of the illness despite remission of psychotic symptoms (Bowie & Harvey, 2005). Although studies have shown that deficits are stable throughout the course of the illness for most people, antipsychotic medication and its use long-term has been linked to a deterioration in cognitive performance (Bowie & Harvey, 2006; Husa et al., 2017). Cognitive impairments in people with schizophrenia are largely related to executive functioning, and are apparent using tasks tapping attention, working-memory, linguistic fluency and others. Executive function impairments in schizophrenia are strongly associated with poor treatment outcome and poor functioning such as lack of basic self-care, occupational, and social/interpersonal skills (Bowie & Harvey, 2006).

Attention includes “detecting relevant information, maintaining focus on those stimuli and ignoring irrelevant competing information” (Bowie & Harvey, 2005). Attention can be measured using a continuous performance test (sustained attention to a stimulus with and without a distractor), an attention span task (short-term recall capacity with or without a distraction) or digit span task (immediate recall of an increasingly long sequence of digits) (Cornblatt & Erlenmeyer-Kimling, 1985). The severity of attentional impairments is associated with higher severity of positive symptoms and poor treatment response (Goldman et al., 1993; Green & Walker, 1986).

Working-memory is a related domain, and is defined as the ability to store and mentally manipulate information over a short term. Deficits in verbal working-memory in particular are common in individuals with schizophrenia (Lee & Park, 2005). Verbal working-memory is commonly measured using a simple memory span task or testing the ability to manipulate and reorganize information. A consistent finding across studies on schizophrenia is the presence of moderate to severe deficits of verbal learning and memory where one has to learn new information and then recall the information after a delay with or without prompts or cues (Bowie & Harvey, 2005; J. Lee & Park, 2005).

Language impairments are very common in schizophrenia and are discussed in the next section (section 1.1.5) in more detail. Verbal fluency, another measure of executive function and language processing (Whiteside et al., 2016), is assessed by asking a participant to produce words that start with a specific letter (phonological fluency), or that belong to a superordinate category such as animals (semantic fluency). Individuals with schizophrenia tend to show mild to moderate deficits on these tests (Bowie & Harvey, 2005). Poor performance on tests of verbal fluency appear to be associated with greater negative symptoms but not positive symptoms (Kerns, Berenbaum, Barch, Banich, & Stolar, 1999).

1.1.5 Language processing in schizophrenia

Language abnormalities are displayed by many individuals diagnosed with schizophrenia, however these abnormalities are highly variable (Covington et al., 2005). Language impairments in schizophrenia have largely been associated with formal thought disorder (FTD) referring to "disorganized thinking as evidenced by disorganized speech" (Hales, 2003). Although it is not clear if there is a deficit in language itself, it has been proposed that language deficits arise due to related cognitive processes that influence both the production and processing of language (Kuperberg, 2010a). Language production has been widely studied in schizophrenia and specifically FTD and is manifested as poverty of speech content (not expressing sufficient information), word finding difficulties, other kinds of incoherence or unintelligibility and loosening of associations (Kuperberg, 2010). Loosening of associations or derailment refers to discourse that consists of a sequence of unrelated or remotely related ideas. Either individual words in a sentence do not belong together, or sentences do not belong together. A classic example of this phenomenon was documented by Andreasen (1979) from dialogue with a person with schizophrenia: "If we need soap when you can jump into a pool of water, and then when you go to buy your gasoline, my folks always thought they should get pop, but the best thing is to get motor oil...". Despite the breakdown of semantics and discourse organization, there is nothing ungrammatical about the speech: syntax is preserved (Covington et al., 2005).

Although language production in schizophrenia has been widely studied, research in language perception is less established, and has focused on how working-memory and the use of linguistic context affect language perception. Linguistic context refers to the meaning of individual words and the way in which these meanings are combined with syntactic structure and knowledge of the world to process sentences (Tanenhaus & Lucas, 1987).

Words and concepts are linked within a network according to how related they are and contribute to "semantic memory". Loosening of associations is said to stem from a faster and further spread of semantic memory activation in schizophrenia (J. R. Anderson, 1983; Manschreck et al., 1988; Spitzer, Braun, Hermle, & Maier, 1993). In addition, studies have also shown a lack of cognitive control in people with schizophrenia: such individuals appear to have difficulty suppressing irrelevant information, leading to an exaggerated semantic memory activation (Boudewyn, Carter, & Swaab, 2012). Semantic memory activation has largely been studied using words in isolation, however studies looking at high-level language processing (at the sentence or paragraph/discourse level) have argued that the ability to use, build, and maintain context, is at the root of language impairments in schizophrenia (Boudewyn et al., 2012). Literature on high-level language processing shows that individuals with schizophrenia are most impaired when cognitive control demands are highest, for example when needing to constrain a word's meaning based on context, when there is a strong semantic relation among individual words but they are in conflict with sentence-level meaning, or when a sentence violates the context of the paragraph or a group of related sentences (Kuperberg, Sitnikova, Goff, & Holcomb, 2006; Swaab et al., 2013). Individuals with schizophrenia also tend to rely on semantic memory at the expense of context due to an impairment in cognitive control mechanisms (Kuperberg, 2010).

Impairments of semantic activation are attributed to deficits in cognitive processes such as working-memory, and to abnormal enhancement and suppression of information such that there is an imbalance in the use of semantic memory-based processing and the build-up of context (Boudewyn et al., 2012; Swaab et al., 2013). Impairments in working-memory in individuals with schizophrenia are also thought to contribute to an inability to maintain context over time (Boudewyn et al., 2012; Ditman & Kuperberg, 2007; Gernsbacher, Tallent, & Bolliger, 1999; Swaab et al., 2013). The more complex the word or sentence or group of sentences are, the longer the build-up of context and the greater the processing demands such that use of context is impaired due to working-memory deficits (Condray, Steinhauer, van Kammen, & Kasparek, 1996). Studies have shown that impairments in the use of context and working-memory are greatest at the discourse level where integrating and maintaining multiple levels of meaning is needed (Boudewyn et al., 2012; Ditman & Kuperberg, 2007; Gernsbacher et al., 1999; Kuperberg, 2010a, 2010b; Swaab et al., 2013)

Linguistic context has been studied using anomalous sentences, which are sentences that include linguistic violations such as “The crowd was waiting eagerly; the young man drank the guitar” instead of “ The crowd was waiting eagerly; the young man grabbed the guitar” (Kuperberg, McGuire, & David, 1998). Healthy control participants and those with schizophrenia (with and without FTD) were presented with spoken sentences that either made sense or were anomalous (with pragmatic, semantic or syntactic violations) (Kuperberg, McGuire, & David, 1998). Participants were asked to monitor sentences for target nouns and press a button once they heard the target word. This reaction time (RT) is assumed to reflect the ease with which listeners process each target word given its linguistic context. The study found that healthy control participants and clinical participants without FTD had longer RTs to recognize the target words in anomalous sentences. In contrast, FTD participants had longer RTs overall and did not appear to benefit from context and linguistic information in processing sentences, since latencies did not differ between meaningful and anomalous sentences. A follow-up study found that, as severity of FTD increased, sensitivity to linguistic violations decreased (Kuperberg, McGuire, & David, 2000).

1.1.6 Importance of early detection of schizophrenia

Before the FEP (at which point symptoms are severe enough to meet clinical thresholds), those affected by schizophrenia experience subclinical attenuated psychotic symptoms in the prodromal stage. In order to detect psychosis early, the ultra-high-risk (UHR) of psychosis criteria (Fusar-Poli, Borgwardt, et al., 2013; Yung et al., 2003) are commonly used. An individual is designated as UHR if they have one or more of the following: attenuated psychotic symptoms (DSM-V subthreshold positive symptoms within the past 12 months), and/or a brief limited intermittent psychotic episode (an episode of frank psychotic symptoms that has not lasted more than one week and spontaneously subsides), and/or a genetically determined vulnerability (a first-degree relative with a psychotic disorder or schizotypal personality disorder), as well as a decline in social/occupational functioning within a year (measured by the Global Assessment of Functioning (GAF) score reflecting how much a person’s symptoms affect their day-to-day life) (Fusar-Poli, Borgwardt, et al., 2013; Fusar-Poli & Yung, 2012). It is unclear whether one particular

UHR criterion or a combination of criteria is associated with a higher risk of psychosis (Nelson, Yuen, & Yung, 2011).

UHR criteria do not include any cognitive markers/patterns that have been shown to be specific to psychosis in the scientific literature. Early intervention has been shown to reduce the likelihood of the onset of psychotic disorders in individuals meeting UHR criteria (Sommer et al., 2016). It is important to note that UHR status can only be given to those who have come into contact with clinical services, and does not predict psychosis well outside clinical samples (Fusar-Poli, 2017). Most UHR individuals are in their early to late teens, and many of the criteria for UHR status such as mood swings, anxiety, and social withdrawal are also confounded with typical adolescent behavior (Lieberman & Fenton, 2000).

Those classified with UHR status are significantly heterogeneous in their clinical outcomes, with follow-up studies showing only 30 - 40% of UHR subjects developing a psychotic disorder after clinical presentation (Gee & Cannon, 2011; Yung et al., 2003). One-third of those who do not develop a psychotic disorder, will have persistent attenuated symptoms, and/or another mental health disorder such as a mood disorder, personality disorder, PTSD, or substance use disorders. One-third will have recovered (Fusar-Poli, Bechdolf, et al., 2013; Gee & Cannon, 2011). This reflects the fact that the earliest stages of psychotic disorders are nonspecific and overlap phenotypically with the initial stages of other disorders (McGorry, Killackey, & Yung, 2008). Due to this heterogeneity in the UHR/FEP group, providing preventative treatment to all of those with UHR or FEP status is inefficient, as most will not develop schizophrenia. In addition, because of the stigma of schizophrenia and fear of poor prognosis, mislabeling a patient with schizophrenia early on can have negative effects on hope and the potential for recovery (Lee & Schepp, 2013).

However, untreated psychosis also has negative consequences (Hegelstad et al., 2012), and early identification enables early treatment, which has been shown to lead to more favorable outcomes (Marshall et al., 2005; Perkins, Gu, Boteva, & Lieberman, 2005) in addition to increasing treatment adherence, and healthcare utilization over time (Minsky et al., 2015; Mueser & Rosenberg, 2003).

There is a need for assessments that are able to predict psychosis more specifically (i.e., can correctly rule out those without the disorder). However, ideally there needs to be a balance between specificity and sensitivity (i.e., test can also correctly identify those who will develop schizophrenia). Additionally, stratifying UHR or FEP groups according to likely clinical outcome would allow for selective treatment interventions in the subgroup most at risk for developing psychosis. The aim of the current study is to begin to develop a test that is more specific, sensitive, and objective, using cognitive patterns that are characteristic of psychosis to identify individuals that are at high-risk of developing a psychotic disorder such as schizophrenia. Cognitive changes the current study targets are the tendency to add meaning to otherwise meaningless things (drive to make sense, explained below), and the tendency to believe imagined events as real (reality monitoring deficits, explained in section 1.3).

1.2 Drive to make sense

Apophenia is a universal human tendency to perceive patterns in random information. At times we all see patterns in stimuli (often an image or sound) where there is none, such that we may see a face in a cloud, or hear a word in random sounds. The brain seeks to add meaning to our surroundings based on an internal reference system made up of our prior experiences, feelings, values, motivations, contextual knowledge, expectations, and belief system. For example, studies have shown that strong beliefs in paranormal phenomena or religion are associated with a greater bias toward seeing a face in a jumbled non-face, and a word in a non-word, compared to skeptics (Krummenacher, Mohr, Haker, & Brugger, 2010; Riekki, Lindeman, Aleneff, Halme, & Nuortimo, 2013). The belief in extrasensory perception, paranormal phenomena, magic, and unusual behavior, can be contextualized in the personality dimension of schizotypy, which has been shown to be associated with an increased tendency to perceive complex meaning in ambiguous images made of random visual noise (Partos, Cropper, & Rawlings, 2016). Schizotypy is indicative of higher risk for psychosis-spectrum disorders and hallucination-proneness (Chapman, Chapman, Kwapil, Eckblad, & Zinser, 1994; Rössler, Hengartner, Ajdacic-Gross, Haker, & Angst, 2013).

In order to detect patterns and assign meaning to those patterns, the brain must determine what is important and meaningful in its environment, thus attributing "salience". This process determines which events or objects need attention and should drive action. In schizophrenia, the salience network is dysregulated so that salience is assigned to internal representations as well as external stimuli independent of context (Kapur, 2003). Aberrant salience attributed to internal representations drive the hallmark symptom of hallucinations. Hallucinations are also driven by the tendency of people with psychosis to mistake an internal thought as an external reality. Approximately 70% of people with schizophrenia report having auditory verbal hallucinations (AVH) (Waters et al., 2012), where they report hearing voices in the absence of an external source. It has been suggested that delusions are the result of cognitive effort to explain and give meaning to these experiences (Kapur, 2003).

1.3 Reality monitoring

Reality monitoring is the ability to distinguish between an external stimulus and internal thoughts or imagined events. There is mounting evidence for reality monitoring abnormalities in individuals affected by psychiatric disorders and with psychotic symptoms (Frith & Done, 1989; Garrison, Bond, Gibbard, Johnson, & Simons, 2017; Garrison, Fernandez-Egea, Zaman, Agius, & Simons, 2017; Moseley, Fernyhough, & Ellison, 2013; Radaelli, Benedetti, Cavallaro, Colombo, & Smeraldi, 2013). Findings from the reality monitoring literature show an externalization bias where participants have a greater likelihood of falsely attributing new items to an external source than an internal source. This externalization bias has been shown in healthy individuals (Anderson, 1984; Hicks, Marsh, & Ritschel, 2002) but to a greater extent in individuals with schizophrenia (Brébion et al., 2000; Radaelli et al., 2013; Woodward, Menon, & Whitman, 2007). One of the main symptoms of psychosis, AVHs (hearing voices in the absence of any speaker), is hypothesized to be a result of inner speech being misattributed to an external source (Moseley et al., 2013). This is supported by evidence showing that people experiencing AVHs tend to show a greater externalization bias during source-monitoring tasks (Allen et al., 2004; Bentall, 1990; Radaelli et al., 2013). Furthermore, electromyography (EMG) studies have shown subvocalizations (very small movements of the vocal musculature that occur during inner speech) during AVHs (Gould, 1948; Inouye & Shimizu, 1970; McGuigan, 1966). Neuroimaging studies suggest that similar cortical areas are active during inner speech as during AVHs (McGuire et al., 1995).

Theories explaining AVHs and delusions in schizophrenia range from reality monitoring deficits, overreliance on perceptual priors, and aberrant salience. It is suggested that because individuals experiencing delusions have strong reality monitoring impairments, delusional beliefs are first established through an initial hallucinatory false percept or unrecognized thought (Fletcher & Frith, 2009; Maher, 2005). Another framework explaining hallucinations and delusions is that individuals with schizophrenia as well as those on the psychosis spectrum, tend to favor prior knowledge over incoming sensory evidence (Davies, Teufel, & Fletcher, 2017; Teufel et al., 2015). Imposing prior expectations on sensory inputs can generate percepts (hallucinations) that have no direct sensory cause (Powers, Mathys, & Corlett, 2017).

Individuals with schizophrenia also tend to perceive coherent, meaningful patterns in nonsense stimuli. Alpert (1985) presented either white noise or some brief phrases masked by white noise at various Signal-to-noise ratio (SNRs) to individuals with schizophrenia. When listening to white noise, the participants tended to hear meaningful sounds, with non-hallucinators hearing things such as footsteps or voices and hallucinators reporting more meaningful and intelligible voices in the noise. When presented with brief phrases in white noise, hallucinators reported coherent phrases that tended to be quite different from the stimulus phrase, and they were inappropriately confident in their wrong responses. Non-hallucinators on the other hand, preserved fragments from the stimulus phrase, and were appropriately confident with their accuracy. Hoffman, Rapaport, Mazure, and Quinlan, (1999) also compared individuals on the schizophrenia spectrum, with or without hallucinations, and healthy controls in a speech perception task. Participants were presented with multi-talker babble and asked to report what they heard. Report did not differ between those with or without hallucinations, however multiword speech illusions were reported by individuals with early-phase schizophreniform psychosis, compared to both normal controls and individuals with chronic schizophrenia. In a follow-up study, Hoffman et al. (2007) presented a babble stimulus made up of six overlapping talkers reading neutral texts, to participants with prodromal psychosis symptoms, and asked them to report what they heard. Researchers measured the longest phrase generated (counted as the number of words) and gave a speech illusion (LSI) score based on the length of the reported phrase. They found that the larger the LSI score, the more likely the patient would convert to schizophrenia, and this factor was more reliable than DSM-identified symptoms for predicting conversion.

Individuals with psychosis or at high-risk tend to hear speech or other meaningful sounds in otherwise meaningless sounds. However, Alpert (1985) did not employ a control group and the materials used by Hoffman et al. in the 2007 study were short. In addition, Hoffman et al. in the 1999 study asked participants to repeat the speech as they heard a continuous narrative passage, introducing a dual-task component that is undesirable given the attentional deficits and other cognitive impairments of people at high-risk of schizophrenia. The current study seeks to address these limitations, and use not only noise or coherent phrases, but also anomalous phrases with little meaningful context and degraded by noise. This is done in the hope of amplifying the reported tendency in individuals that have experienced a FEP to incorrectly attribute a source to stimulus or imagined event, and to find meaning in a meaningless stimulus.

1.4 Influence of context and noise on intelligibility

In most listening situations, noise usually interferes with the understanding of speech. Noise has an effect of “masking” sounds so that the listener has less acoustic information from the acoustic signal, thereby making interpretations of the speech signal difficult. As the SNR becomes lower (strength of the noise is greater than the signal), understanding speech is more difficult than if the SNR is higher (strength of signal is greater than noise). However, comprehension of degraded speech does not only depend on perceptual clarity of the speech signal, but also on speech content (Miller, Heise, & Lichten, 1951; Miller & Isard, 1963). Comprehension of speech requires complex perceptual and cognitive processes to convert acoustic signal into a representation of meaning. As speech becomes degraded due to noise, missing words can often be inferred from the context. Words in a sentence are chosen based on grammatical, semantic and pragmatic rules of language. In order to give meaning to a sentence, a listener must adhere to the semantic rules of a language which limits the class of words from which to choose. To use Miller and Isard's (1963) example, the sentence “The boy spoke a triangle” is grammatically correct but is semantically anomalous. A listener’s expectations might be that the boy spoke a sentence, or the boy drew a triangle, but “spoke a triangle” violates semantic rules in the English language and provides the listener little context. Therefore, if one were to hear both anomalous and meaningful regular sentences with and without noise, one would expect there to be an interaction between the level of noise and context on intelligibility. This hypothesis has been tested in many studies, and proven to be correct. For example, Miller et al. (1951) found that intelligibility/word report under noisy conditions, was greater for content words (nouns, verbs, adjectives, adverbs) if they were heard in the context of a grammatical sentence compared to when scrambled or in isolation as items on a list. In another study by Miller & Isard (1963), participants were asked to shadow words from meaningful sentences and semantically anomalous sentences, both presented in noise. The anomalous sentences were syntactically correct and created by interchanging words that appeared in the same syntactic position in different sentences. Participants were able to report more words from the meaningful sentences than the anomalous/meaningless ones. There was also an interaction between context and noise, where at low SNRs, intelligibility was lower than at high SNRs.

More recently, Davis, Ford, Kherif, and Johnsrude (2011) also found that young adults reported more words correctly across a range of SNRs from coherent sentences (high context; e.g. “Her new skirt was made of denim” compared to the anomalous sentences (low context; e.g. “Her good slope was done in carrot”). Davis et al. found an interaction between SNR and context of the sentence. As the SNR dropped, both high and low context sentences became less intelligible. However, low context sentences were less intelligible than high context sentences. Also, as SNR became very low or very high, context did not have a meaningful effect. The study used sentences similar to those of Miller and Isard (1963) that were syntactically correct, but less stereotyped than the ones used by Miller and Isard. The sentences were psycholinguistically matched and ranged from 6 to 13 words in length. Unlike previous studies mentioned, Davis et al., used speech spectrum, speech correlated noise (SCN) to mask the acoustic signal. SCN is unintelligible and has the same envelope as the speech signal it masks, providing a constant masking over the speech stimulus and an easily measured SNR. Materials from the Davis et al. (2011) study were used in the current study.

1.5 Current study

The current study aims to make use of known cognitive patterns such as (abnormal) reality monitoring deficits and the (normal) drive to make sense of our experiences in order to identify individuals at high-risk of developing schizophrenia. This study investigates differences among non-medicated individuals with first episode psychosis and healthy matched controls in reporting of degraded (ambiguous) sentences that are semantically coherent (high semantic context condition; e.g. “Her new skirt was made of denim”) or anomalous (low semantic context condition; e.g. “Her good slope was done in carrot”). Previous studies using anomalous sentences only involved linguistic violations of one verb in the sentence: in the current study, all content words in anomalous sentences violate semantic constraints. Therefore, the use of context in anomalous sentences is much more limited in the current study than in previous studies and cannot aid participants (both healthy controls and FEP individuals) in word report. Furthermore, in the current study all sentences are degraded with noise, providing a challenge for all participants in processing the words of the sentence. In order to overcome acoustic degradation, healthy controls will use and benefit from available context (for semantically coherent, high semantic context sentences) more than FEP participants. In this study, prodromal or ultra-high-risk participants would be ideal to have as participants in order to test if their performance on the task would predict conversion to psychosis, however it is difficult to test this population as symptoms are subthreshold for psychosis and are not easily recognizable or regularly tested for, and individuals do not make contact with the medical system regarding symptoms until a first episode. However, having access to FEP individuals as participants allows us to validate this approach: if an effect were to be found in the FEP group, before extending this task to individuals in the prodromal state.

In this study, intelligibility will be measured as the number of words correctly reported. It is hypothesized that there will be no group difference between the FEP and control group on intelligibility due to a number of reasons. Participants will be young and have no hearing loss, and the task only produces a mild load on working-memory. As already demonstrated by Davis et al. (2011) for these stimuli, we predict an SNR and context effect, such that at the lower SNR both types of sentences are less intelligible than at the higher SNR, and the low context materials will be less intelligible than the high context materials at both SNRs. Given that individuals experiencing psychosis have reality monitoring deficits, this will lead to misattributing imagined words as having been perceived. This effect will be amplified for anomalous sentences that give little context to the listener and for sentences that are highly degraded, in which individuals have a greater potential to "fill in" with imagined words and construct their own meaning.

Such a pattern of behavior is supported by acoustic studies such as ones by Alpert (1985) and Hoffman et al. (1999; 2007), in which participants with hallucinations tended to hear meaningful sounds in otherwise meaningless sounds. When these participants were provided words or sentences masked by noise, they also tended to report material that was different from the original stimulus. We hypothesize that compared to control individuals, individuals with FEP will report more words that were not presented, (i.e., intrusion errors). This effect is expected to be greater for anomalous sentences and for highly degraded sentences (at the lowest SNR). We hypothesize an interaction effect between SNR and type of sentence such that the condition with the most intrusion errors for all participants will be in the condition with anomalous sentences presented at the lowest SNR and the least intrusion errors in the condition with meaningful sentences presented at the highest SNR.

Certain clinical subgroups such as participants with severe disorganization, FTD, delusion and hallucination symptoms will make a greater number of intrusion errors compared to other individuals in the FEP group. Alpert (1985) and Hoffman et al (1999; 2007) have demonstrated that those experiencing hallucinations tended to hear more meaningful sounds in meaningless stimulus, and report words that strayed from the original stimulus.

Chapter 2

2 Methods

2.1 Participants

All participants were part of a larger longitudinal research study, TOPSY (Tracking Outcomes of Psychosis), of which the current study was part of. We tested two groups of participants, see Table 1 for demographic data. The clinical group was composed of 48 individuals who were experiencing a first episode of psychosis (FEP). They were recruited from the Prevention and Early Intervention Program for Psychoses (PEPP) at Victoria Hospital in London, ON. Inclusion criteria for the study involved clinical participants experiencing a first episode of psychosis, having received antipsychotic medication for less than 14 days, able to provide informed consent and participate safely in the study protocol. Clinical participants were excluded if they met the DSM-5 criteria for a major substance use disorder in the past year; had a history of a major head injury that caused seizures or a significant period of unconsciousness; had a significant uncontrolled medical illness; or had a hearing impairment. A consensus diagnosis was established six months post FEP by psychiatrists using the Structural Clinical Interview for DSM-5 (First, Williams, Karg, & Spitzer, 2016). Thirty-two out of 48 clinical participants reached the six-month mark post FEP, and most were diagnosed with Schizophrenia. A list of diagnoses for these 32 individuals can be seen in Table 2.

The control group was composed of 29 healthy individuals recruited through advertisements in the community (London, ON) and the University of Western Ontario. Inclusion criteria for control participants involved having demographic characteristics such as age, years of education, sex, and socio-economic status (SES) that fell into the range defined by the same characteristics in the clinical group. There was no significant difference between the FEP group and control group on age, $U = 568.00$, $p = .18$, $r = 0.15$, SES, $U = 508.50$, $p = .26$, $r = 0.13$, and Sex, X^2 (2, $N = 77$) = 2.41, $p = .12$. However, controls had significantly more education than the FEP group, $U = 468.00$, $p = .019$, $r = 0.27$. Exclusion criteria for control participants included a history of mental illness; a major head injury that caused seizures or a significant period of unconsciousness; a significant uncontrolled medical illness; or a hearing impairment. Written informed consent was obtained from all participants prior to study participation and participants were compensated for their time. This study was approved by the Health Sciences Research Ethics Board at the University of Western Ontario, Canada (see Appendix A).

Table 1: Demographic data

	Clinical Group			Control Group		
	n	Median	Range	*n*	Median	Range
Sex (M;F)	39;9			19;10		
Age	48	22	16-39	29	22	16-29
Years of Education	47	12	11-18	29	14	11-16
National Statistics Socio-Economic Classification 5-class scale	43	4	1-5	28	3	1-5

Table 2: Diagnosis of 32 clinical participants 6 months post FEP

Diagnosis after 6 months (*n* = 32)	Number of diagnosed individuals
Schizophrenia	22
Schizoaffective Disorder	2
Psychosis Not Otherwise Specified	2
Clinical High-Risk for Psychosis	1
Bipolar Disorder	1
Manic Depressive Disorder	2
Brief Psychotic Disorder	1
Schizophreniform Disorder	1

2.2 Materials

2.2.1 Demographic and clinical measures

All participants were rated according to the National Statistics Socio-Economic Classification (NS-SEC). All participants were asked their mother and father’s highest held job and were assigned to one of five classes. Class 1 includes higher managerial administrative and professional occupations. Class 2 includes intermediate occupations and Class 3 small employers and “own account” workers, which the researchers understood as self-employed or managing own clients. Class 4 includes lower supervisory and technical occupations and Class 5 semi-routine and routine occupations. The NS-SEC has been shown to be valid tool for explanations of inequality in health (Chandola & Jenkinson, 2000) and has been used in a number of studies on psychosis (Kirkbride et al., 2008; Kirkbride et al., 2015; Kirkbride, Jones, Ullrich, & Coid, 2014).

The following clinical measures were administered to the FEP participants:

1) The Social and Occupational Functioning Assessment Scale (SOFAS) is used to assess a participant’s overall level of function (social, personal and occupational) on a scale from low function to high function with scores from 1 (extremely low functioning) to 100 (superior functioning) and has been used in multiple studies with healthy individuals as well as mental health patients (including those with schizophrenia) (Rybarczyk, 2011). Scores are based on the level of direct impairment caused by physical and mental disorders.
2) The Clinical Global Impression Scale (CGIS) is a commonly used clinical scale ranging from 1 (normal, not at all ill) to 7 (among the most extremely ill patients) (Busner & Targum, 2007).
3) The Positive and Negative Syndrome Scale 8 (PANSS8) (Kay, Fiszbein, & Opler, 1987) was used to evaluate the presence, absence and severity of positive and negative symptoms of schizophrenia. It is a benchmark assessment for measuring psychopathology of schizophrenia. Each item (symptom) is rated on a 7-point scale (1 = absent; 7 = extreme). In this study, 4 items were of interest: P1 (Delusions), P3

(Hallucinatory behavior), P2 (conceptual disorganization), G9 (unusual thought content).

4) The Brief Negative Symptom Scale (BNSS) (Kirkpatrick et al., 2011), was used to further evaluate negative symptoms of schizophrenia. The BNSS has a total of 13 items, each representing a negative symptom, scored on a 7-point scale of severity ranging from 0 (absent symptom) to 6 (severe). In this study the BNSS total was of interest in addition to the score on two specific items; item 12 (quantity of speech) and item 12 (spontaneous elaboration).

2.2.2 Cognitive measures

Two cognitive measures were used for all participants; Digit Symbol Substitution (DeLuca & Kalmar, 2008) and Category Fluency (Becker et al., 2010). Digit symbol substitution requires the participant to match a set of symbols to their corresponding digit within 90 seconds and is a measure of attention and cognitive processing speed. An oral and written symbol substitution test was used. In the category fluency task, participants were asked to name as many animals as they could in 60 seconds. Score is the number of different animals mentioned. It is a measure of verbal fluency, cognitive flexibility and executive function. In both the digit symbol substitution and category fluency tasks, the higher the score, the better the performance.

2.2.3 Experimental stimuli

The sentence materials were derived from a larger corpus originally described by Davis et al. (2005). Two sentence types were used; high context sentences were semantically coherent (e.g., “Her new skirt was made of denim”) and low context sentences were syntactically matched to the high context sentences, but were semantically anomalous (e.g., “Her good slope was done in carrot.”), see Appendix B for a list of sentences used in the current study. The sentences were between six and 13 words in length and were spoken by a female native English speaker with an accent typical for southern Ontario. They were recorded at a sampling rate of 44.1 kHz and root mean square normalized in amplitude. The sentence recordings were degraded by adding speech-spectrum noise with the same amplitude envelope as the masked sentence at two different SNRs: 0 dB and -4 dB. These SNRs have been shown to result in an intelligibility of the sentence materials intermediate between ceiling and floor and maximally differentiate intelligibility for high versus low context materials (Trang et al., in preparation).

The 68 sentences were chosen based on intrusion data from a previous pilot study using 180 sentences (90 high context and 90 matched low-context sentences) conducted at Queen's University, Canada. The pilot study included data from 40 individuals, including individuals with a first episode of psychosis (*n* = 20). Due to time constraints and other testing, the current experiment could only last a maximum of 30 minutes. The 68 sentences used here (34 low context and 34 matched high context sentences) were chosen from those used in the pilot study based on an item analysis on the low context sentences across SNR. The 34 low context sentences that yielded the greatest difference in intrusion errors between clinical and healthy participants in the pilot sample were included, as were the 34 matched high context sentences.

Intelligibility did not change in the current set of 68 sentences compared the 180 sentences used in the pilot study. In the current study, the sentence materials were counterbalanced across SNR levels between participants, producing two versions, each with 17 high context and 17 matched low context sentences at each SNR as seen in Appendix B. For example, a specific sentence in version 1 presented at an SNR of -4 dB will be presented at an SNR of 0 dB in version 2. Versions were assigned randomly to participants such that an equal number of participants in each group were tested with each version and the same version was not used more than two times in a row.

2.3 Procedure

Clinical participants were recruited into the study within two weeks of their initial assessment at the PEPP clinic. Most participants completed the study 10 days after their initial clinical assessment. Baseline clinical measures including the CGIS, SOFA, PANSS and BNSS were taken to measure symptoms and function over the last two weeks. Both clinical and control participants were tested at Robarts Research Institute, London ON in a quiet room. They were first asked for demographic information such as their sex, years of education, and parental work. Participants' baseline level of cognition was then assessed using the Trail Making B, Symbol Substitution, and Category Fluency measures. The cognitive battery took around 10 minutes to complete. Participants then completed the experimental task. The verbatim instructions to participants can be seen in Appendix C. Sentences were presented one at a time over headphones using E - Prime 2.0 stimulus presentation software running on a laptop at a comfortable listening level that was the same for all participants, and participants did not have access to changing the audio level. Even if the audio level could be changed, the SNR at each level would remain the same, as both the noise and signal would become louder or quieter at the same level. Participants were asked at the end of each sentence to report as much of the sentence as they could, by typing into a response box. Participants were told not to worry about punctuation, capitalization or spelling. They were also told to type “none” if they did not hear any words, but only to use this as a last resort and to try their best to report words. The participants were not informed in advance of the different sentence types; only that the sentences would be challenging to hear due to background noise. Participants reported what they heard in the sentences at their own pace. The first four sentences were sample trials for participants to get used to the task and after, all 68 sentences were presented one after another. Participants were given an option to take a break half-way. The experimental task took 20 - 30 minutes to complete. Once the testing was done, participants were debriefed about the study and compensated for their time.

2.4 Data analysis

Sentence reports were scored for several outcome variables, with a detailed list of scoring instructions in Appendix D. Researchers were blinded to the group (FEP or control) membership of participants while scoring. Intelligibility in each separate condition (2 Context x 2 SNR) was measured as the number of words correctly reported, expressed as a percentage of the total number of words in the original sentence and averaged across sentences. This was done in anticipation of a greater probability of intelligible words being reported for longer sentences. Intelligibility percentage data were transformed to rationalized arcsine units (RAU) to be suitable for parametric statistics. The RAU transform has been validated with the use of speech and language data and ensures homogenous variance over the range of proportional scores obtained (Studebaker, 1985).

Three types of errors were scored: morphological variants, phonological variants, and intrusion errors. Morphological variants were alterations of a single morphological affix but with the same root word meaning as the original, correct, word (e.g., “eased” reported as “ease”). Phonological variants were rhyme errors or alterations of a single phoneme (e.g., “ace” reported as “eight”). Intrusion errors were all words not present in the original sentence that were not either morphological or phonological variants – i.e., were not related to an original word in the sentence either morphologically or in phonological form. Spelling mistakes and placeholder words reported by participants for words they couldn’t hear (e.g. “something” or “none” or “…”) were ignored. Error type in each separate condition (2 Context x 2 SNR) was measured as the number of errors, expressed as a percentage of the total number of words in the original sentence and averaged across sentences. Similarly to intelligibility, this was done in anticipation of a greater probability of errors being made on longer sentences. Error percentage data were normalized using a log transformation to make the skewed proportional data suitable for parametric statistics.

The primary analyses undertaken were multivariate ANOVAs, evaluating the influence of sentence type (two levels: high and low context), SNR (two levels: 0, -4 dB), and group membership (two levels: clinical and control) on outcome measures of interest. Although, there is one dependent variable that is being measured at a time for each level of SNR or context (either words correctly reported or intrusion errors), the analysis is a MANOVA instead of an ANOVA since the dependent variable in each condition (intelligibility, or errors) may be qualitatively different (i.e., relate to different cognitive processes) depending on the combination of the independent variables.

In addition, a correlation analysis was performed to relate performance on the experimental task to other cognitive and clinical measures.

Chapter 3

3 Results

3.1 Intelligibility

As seen in Figure 1, intelligibility (measured as the number of words correctly reported as a percentage of the total number of words in the original sentence) was highest for all participants in the 0 dB SNR / high context condition (*M* = 88.64, *SE* = 1.70), and lowest in the -4 dB SNR / low context condition (*M* = 21.13, *SE* = 1.21). For most participants, intelligibility was over 80% in the most intelligible condition at 0 dB with high context, but seven participants had very low intelligibility in this condition. One control participant had 53.91% intelligibility, and six participants in the FEP group also had low intelligibility (at 22%, 25.89%, 41%, 56.58%, 67.9% and 67.63%). These participants also had lower intelligibility in all other conditions. These individuals were not excluded from analysis.

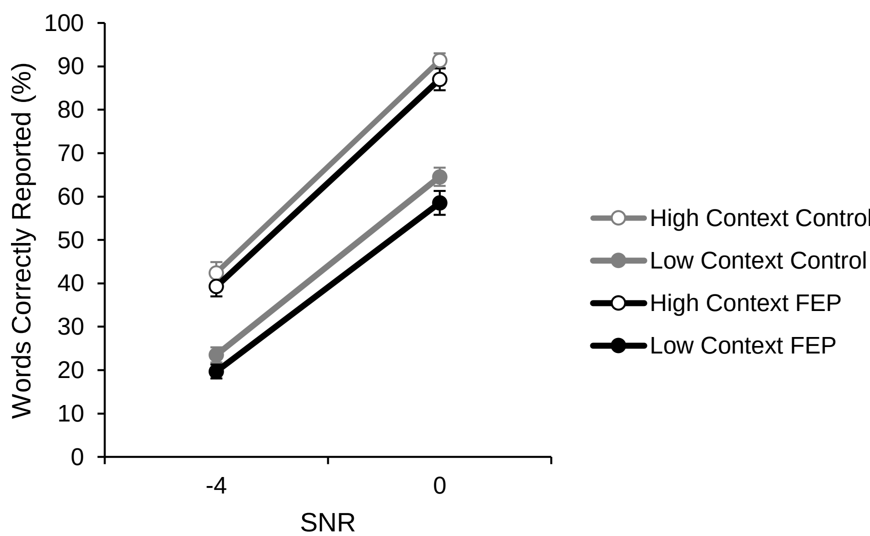

Figure 1: Words correctly reported as a percent of the original sentence by SNR, Context and group. Errors bars represent standard errors of the mean.

A 2 (SNR: -4 vs. 0) X 2 (Context: Low vs High) X 2 (Group: Control vs FEP) multivariate analysis of variance (MANOVA) was conducted to test the effect of SNR, Context and group on intelligibility. Test version was added as a covariate along with number of years of education. As expected, a main effect of SNR emerged such that intelligibility was higher in the 0 dB SNR (M = 75.25, SE = 1.78) condition compared to the -4 dB SNR condition (M = 31.15, SE = 1.43), F (1, 72) = 6.27, p = .02. Also, intelligibility was higher in the high context condition (M = 64.00, SE = 1.65) than in the low context condition (M = 41.51, SE = 1.52), F (1, 72) = 6.92, p =.01. Groups did not differ in intelligibility performance. No interactions involving Group, or between Context and SNR, were observed.

Test version was found to interact with SNR, F (1, 72) = 13.54, p < .001 and a SNR * Context * Version three-way interaction also emerged, F (1, 72) = 9.20, p = .003. However, MANOVAs conducted at each version separately (again with years of education as a covariate) revealed identical results for the two versions, with main effects of SNR and Context as expected, and no effects of Group nor interactions involving Group. Intelligibility in Version 1 can be seen in Figure 2 and intelligibility in Version 2 can be seen in Figure 3.

A subsequent 2 (SNR: -4 vs. 0) X 2 (Context: Low vs High) X 2 (Group: Control vs FEP) x 2 (Version: 1 vs 2) MANOVA was conducted with test version as a factor instead of a covariate in order to characterize the differences in intelligibility between versions. In this analysis SNR, F (1, 73) = 2058.20, p < .001 and Context, F (1, 73) = 881.62, p < .001 were still significant with higher intelligibility in the 0 SNR conditions, and high context conditions. There was a significant SNR * Context interaction, F (1, 73) = 3499.16, p < .001 where intelligibility was highest overall in the 0 dB SNR condition compared to the -4 dB SNR condition, but within each SNR high context sentences were more intelligible than low context sentences. Again, there was no effect of Group or Group interaction effects. The main effect of Version was not significant but the interaction between SNR and Version was; F (1, 73) = 11.51, p = .001 as was the interaction between SNR, Context and Version, F (1, 73) = 10.49, p = .002. The SNR * Version interaction is explained by one set of sentences being more intelligible than the other: the materials used at 0 dB in Version 1 and -4 dB in Version 2 had higher intelligibility than the other set of materials.

For the three-way interaction of SNR * Context * Version, this SNR * Version two-way interaction is different at the two levels of context, with a larger difference between the two low context sets of sentences compared to the two matched high context sets of sentences.

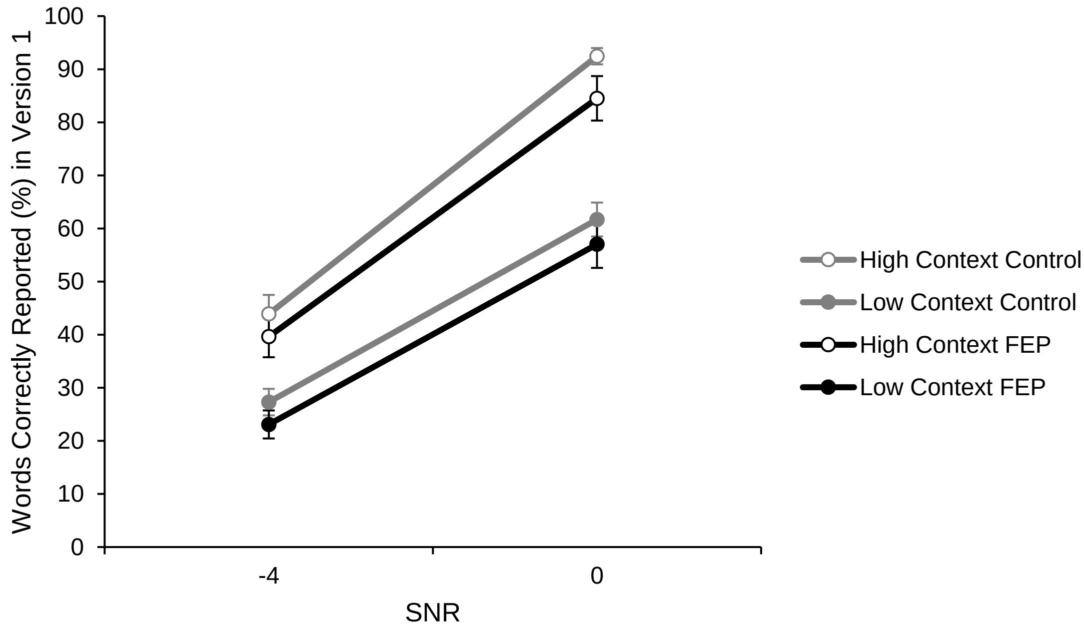

Figure 2: Words correctly reported as a percent of the original sentence by SNR, Context and group in Version 1. Error bars represent standard errors of the mean.

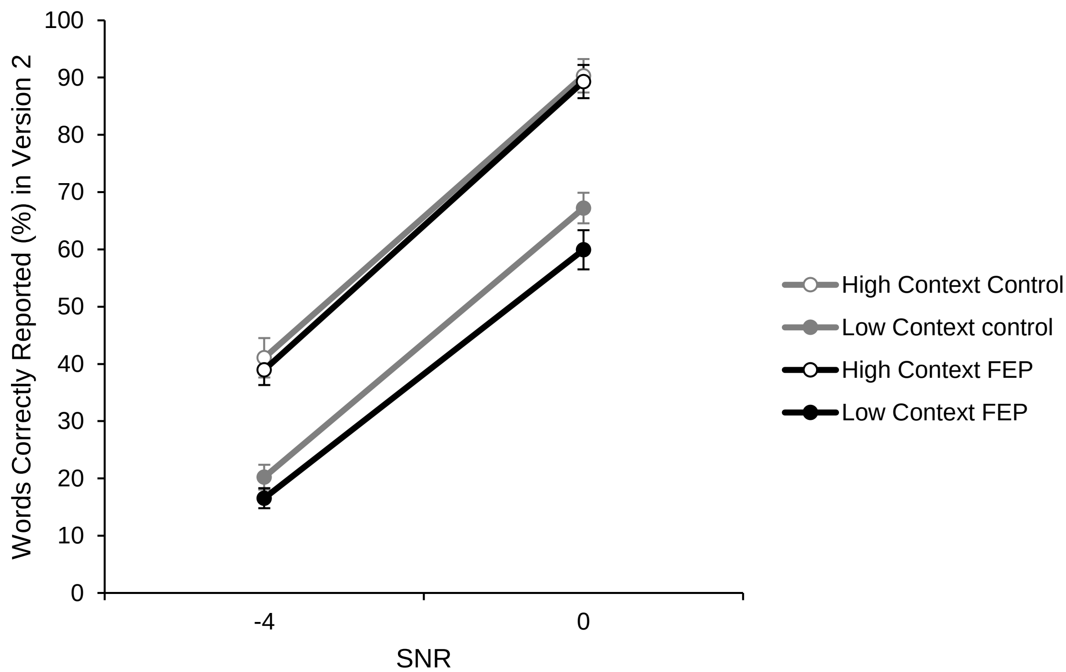

Figure 3: Words correctly reported as a percent of the original sentence by SNR, Context and group in Version 2. Error bars represent standard errors of the mean.

3.2 Intrusion errors

As expected, and seen in Figure 4, the most intrusion errors (measured as the number of intrusion errors reported as a percentage of the total number of words in the original sentence) were reported in the -4 dB SNR / low context condition (M = 12.53, SE = 1.17), and the fewest intrusion errors in the 0 dB SNR / high context condition (M = 3.10, SE = 0.48). There were a number of outliers (more intrusion errors than 1.5 times the interquartile range (IQR)) and extreme outliers (more intrusion errors than three times the interquartile range) across conditions, listed in Table 3. In the low context -4 dB SNR condition there were three control and one FEP outliers. When comparing the outliers from the intelligibility analysis to intrusion errors outliers (those who achieved < 70% intelligibility in the most intelligible condition of 0 dB SNR high context), only one of seven (in the FEP group) was an outlier in both. Figure 5 shows the distribution of overall intrusion errors for each group, and outliers that are 1.5 times the IQR.

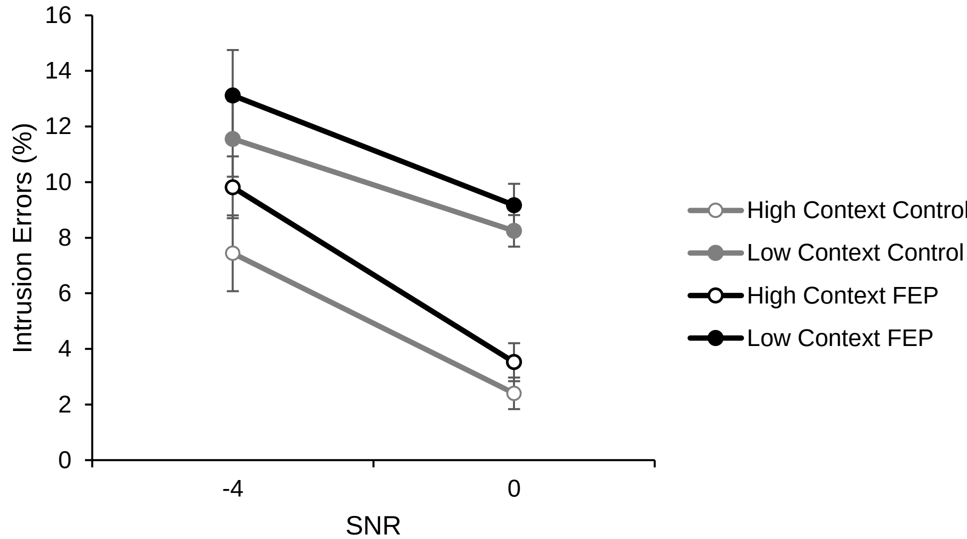

Figure 4: Intrusion errors reported as a percent of the original sentence by SNR, Context and group. Error bars represent standard errors of the mean.

Table 3: Frequency of intrusion errors outliers by group and condition

Condition		Number of FEP outliers		Number of Control outliers	
SNR	Context	1.5 x IQR	3 x IQR	1.5 x IQR	3 x IQR
0	High	2	2	3	0
-4	High	1	0	1	3
0	Low	1	0	0	0
-4	Low	1	0	3	0

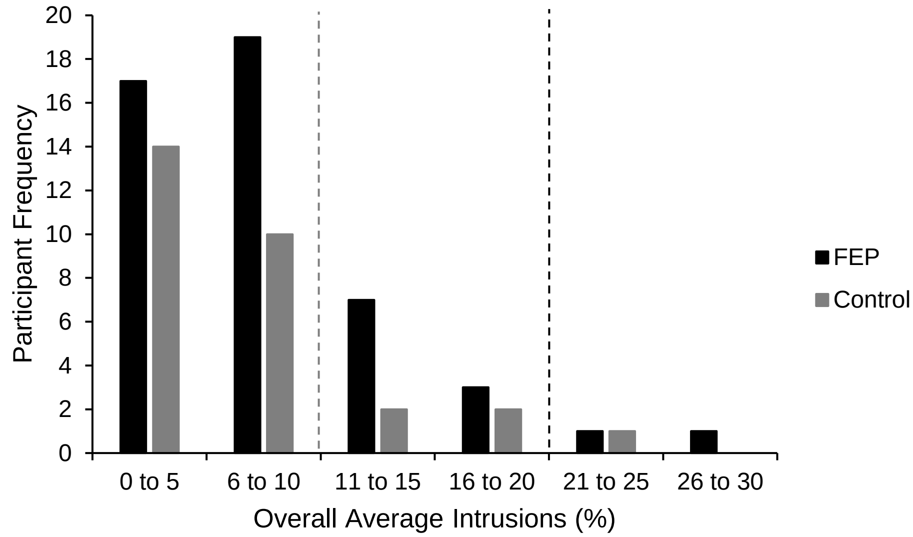

Figure 5: Overall average intrusions as a percent of the original sentence reported by participants. Dotted lines represent 1.5 times the interquartile range for participant groups.

For data analysis, the high context 0 dB SNR condition was excluded. The high context 0 dB SNR condition is a control condition in which very few intrusion errors were expected. In fact, seven control and three FEP participants made no intrusion errors in this condition, and 13 controls and 10 FEP made very low rates of intrusion errors (less than 1% of the words) in this condition.

To examine the effect of SNR on intrusions we looked at low context sentences only, and compared the -4 dB SNR condition to the 0 dB SNR condition, using a MANOVA (with Group as a between subjects variable). To examine the effect of context on intrusions, we compared performance on the high- and low context sentences at -4 dB SNR, again using a MANOVA (with Group as a between subjects variable). Test version was added as a covariate along with number of years of education. The SNR MANOVA revealed no significant effects. The Context MANOVA revealed more intrusion errors in low compared to high context sentences at -4 dB SNR, F (1, 70) = 4.89, p = .03 (High context: M = 12.53, SE = 1.17; Low context: M = 8.92, SE = 0.89). Group was not significant, and no interactions were observed.

To examine the effect of group on intrusions, controlling for item variability, we conducted an analysis by item, in which Group was a "within-items" factor and Context was a "between items" factor. The analysis was a 2 (SNR: -4 vs. 0) X 2 (Context: Low vs High) X 2 (Group: Control vs FEP) ANOVA.

Four sentences (one low context and three high context sentences) were removed for the statistical analysis because no intrusion errors were made, and zeros were not able to be log transformed. The zeros were only in the 0 dB SNR condition for the control group. A main effect of SNR emerged, F (1, 62) = 102.75, p <.001, with more intrusion errors made in the -4 dB SNR condition (M = 10.43, SE = 0.42) compared to the 0 dB SNR condition (M = 6.17, SE = 0.44). A main effect of Context was also significant, F (1, 62) = 52.82, p < .001 with more intrusion errors reported in the low context condition (M = 10.44, SE = 0.47) than in the high context condition (M = 6.03, SE = 0.38). There was also a main effect of Group, F (1, 62) = 9.82, p = .003 with more intrusions reported by the FEP group (M = 8.94, SE = 0.49) compared to the control group (M = 7.65, SE = 0.45). There was also an SNR * Context interaction, F (1, 62) = 20.49, p <.001 with a greater difference in intrusion errors between high and low context sentences at the 0 dB SNR compared to the -4 dB SNR.

3.3 Morphological and phonological errors

As seen in Figure 6, very few morphological and phonological errors (measured as the number of phonological and morphological errors reported as a percentage of the total number of words in the original sentence) were committed. The condition with the most errors of these types (combined) was the 0 dB SNR / low context condition (M = 5.73, SE = 0.25), and the fewest errors were committed in the 0 dB SNR / high context condition (M = 2.12, SE = 0.20). There were a number of outliers (than 1.5 times the inter quartile range) and extreme outliers (three times the inter quartile range), mostly in the 0 dB SNR / high context condition (two outliers and one extreme outlier in each group). Another outlier was in the control group in the -4 dB SNR / low context condition.

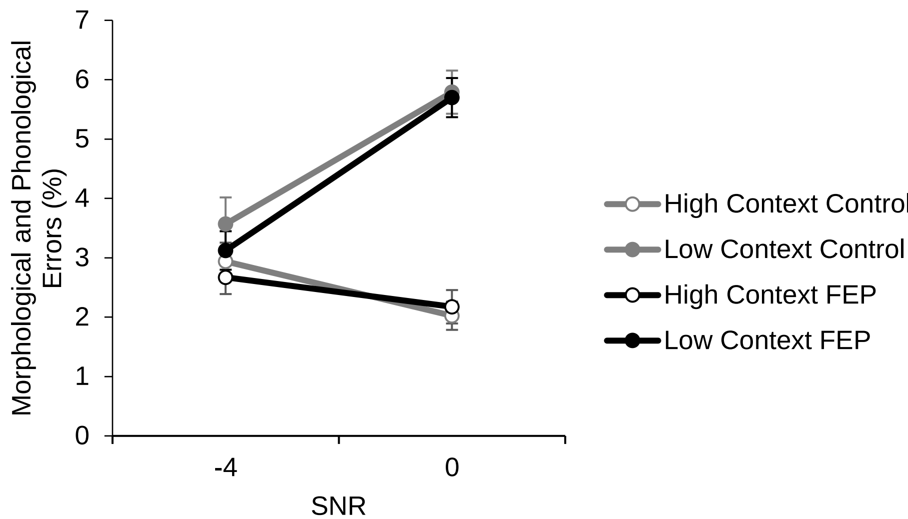

Figure 6: Morphological and phonological errors reported as a percent of the original sentence presented by SNR, Context and group. Error bars represent standard errors of the mean.

For data analysis, the high context 0 dB SNR condition was excluded, as one control and seven FEP participants made no errors and 25% participants from each group made very low rates (less than one percent of total stimulus words) of morphological and phonological errors in this condition. Two control and eight FEP participants were removed as they made no errors in at least one of the other conditions, and their data would not be able to be log transformed.

To examine the effect of SNR on morphological and phonological errors, we compared the -4 dB SNR condition to the 0 dB SNR condition, using a MANOVA (with Group as a between subjects variable) on the low context sentences only. To examine the effect of Context on morphological and phonological errors, we compared performance on the high- and low context sentences at -4 dB SNR, again using a MANOVA (with Group as a between subjects variable). Test version was added as a covariate along with number of years of education.

In the SNR MANOVA, there was no effect of SNR or group. In the Context MANOVA, there was no effect of Context or Group. However, test version did interact with the within-subjects factors in these MANOVAs (SNR * Version, F (1, 62) = 6.30, p = 0.15; Context * Version, F (1, 62) = 7.79, p =.007.

Due to the interaction with version, the MANOVA on morphological and phonological errors was performed within each version. As seen in Figure 7, in Version 1, there was no effect of SNR, but there was a Context effect, F (1, 29) = 6.48, p = .02 and Context * Group interaction trending towards significance, F (1, 29) = 3.68, p = .06, due to the control group exhibiting an elevated number of errors in the low context condition. There was also a Context * Year of education interaction, F (1, 29) = 4.43, p = .04, which was explained by a larger difference in errors between years of education in the low context sentences compared to the high context sentences. In Version 2 there were no significant effects.

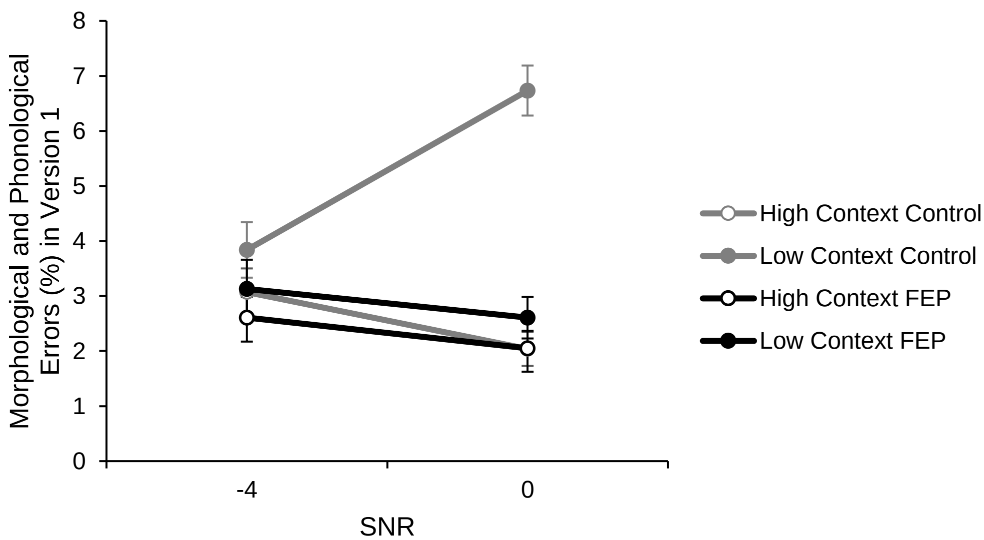

Figure 7: Morphological and phonological errors in Version 1 reported as a percent of the original sentence presented by SNR, Context and group. Error bars represent standard errors of the mean.

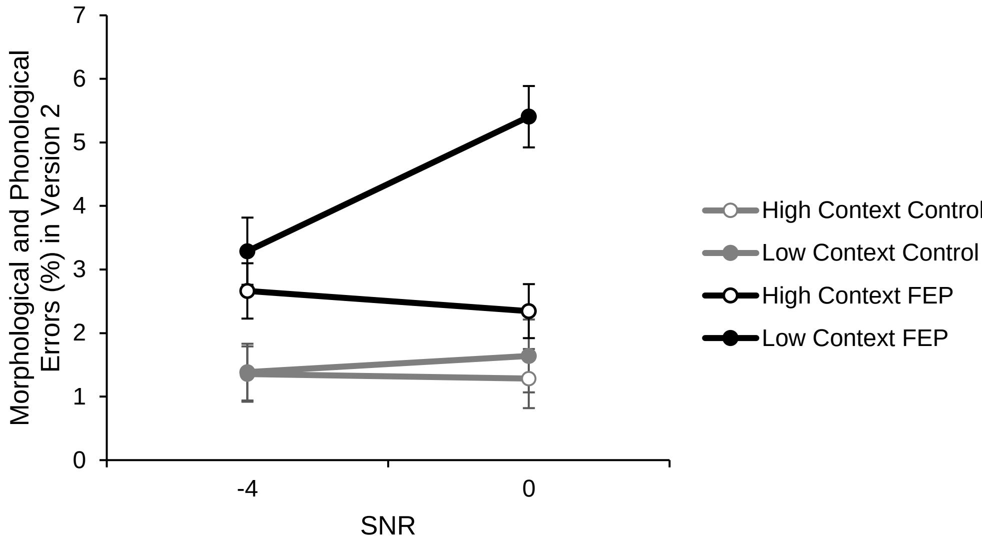

Figure 8: Morphological and phonological errors in Version 2 reported as a percent of the original sentence presented by SNR, Context and group. Error bars represent standard errors of the mean.

3.4 Cognitive measures

The scores on cognitive measures in the two groups are shown in Table 4. Cognitive data from all cognitive measures are missing for 19 individuals in the FEP group and four in the control group. Mann-Whitney *U* tests indicated that the rest of the FEP group performed significantly worse compared to the control group on all measures such as category fluency ($U = 195.5$, $p = .002$), oral symbol substitution ($U = 202.0$, $p < .001$), written symbol substitution ($U = 268.5$, $p < .001$), and trail making time ($U = 151.5$, $p < .001$).

The relationship between these cognitive measures and the experimental measure of intrusion error rate was studied using Spearman correlation. We used two experimental measures: 1) rate of intrusions in the -4 dB SNR / low context condition (i.e. the condition with the most intrusion); and 2) the overall rate of intrusion errors.

Table 4: Scores on cognitive measures

Cognitive Measure	FEP		Control	
	Median	Range	Median	Range
Category Fluency	19	11-33	23	13-41
Oral Symbol Substitution	51	38-81	66	35-89
Written Symbol Substitution	53	29-91	66	36-92
Trail Making B Time (seconds)	67.9	45-201	52.9	31-80

Note. FEP group n = 29 and control group n = 25.

Table 5 displays the correlations between cognitive measures and intrusion errors in each group. Figures 9 – 16 show scatterplots for cognitive measures. In the -4 dB SNR / low context condition, there were no significant correlations between intrusion errors and performance on oral or written symbol substitution or on Trail Making B after FDR correction. However, performance on category fluency and intrusion errors was significantly correlated in the FEP group; the more words reported in category fluency, the more intrusion errors in the -4 dB SNR / low context condition. When looking at overall intrusion errors made by participants, there were no significant correlations with cognitive measures in the FEP or control group.

To compare correlation coefficients for cognitive measures between FEP and controls, the 95% confidence intervals (CIs) were computed for the difference between the correlations (Zou, 2007). If the CI range includes 0, then the two correlation coefficients do not differ significantly from each other. Using this approach, the (weakly positive but nonsignificant) correlation in the FEP group was significantly different from the (weakly negative but nonsignificant) correlation in the control group for oral symbol substitution and intrusion errors in the -4 SNR / low context condition (95% CI = [0.14, 1.11) and the average overall intrusions made (95% CI = [0.01, 1.01). There was no significant difference between groups on any of the other measures.

Table 5: Spearman correlations between performance on cognitive measures and intrusion errors

Cognitive Measure	-4 dB SNR / Low Context Condition		Overall Intrusions	
	FEP	Control	FEP	Control
Category Fluency	.40*	.17	.31	.00
Oral Symbol Substitution	.32	-.37	.22	-.34
Written Symbol Substitution	.34	-.14	.21	-.23
Trail Making B Time	-.08	.27	.05	.42

*significant at the 0.05 level (2-tailed) after FDR correction

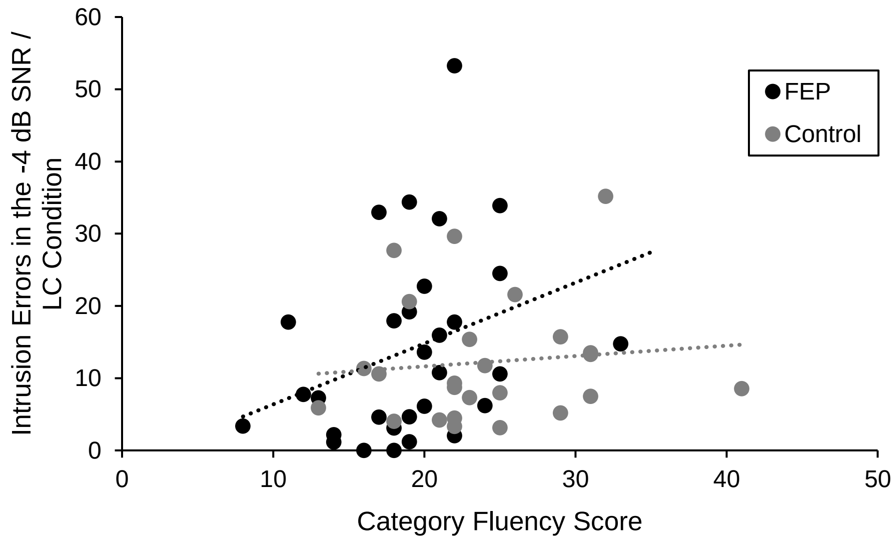

Figure 9: Relationship between the category fluency score and percent intrusion errors in the -4 dB SNR / low context (LC) condition. Spearman's correlation for FEP is .40* and for controls is .17. These do not differ.

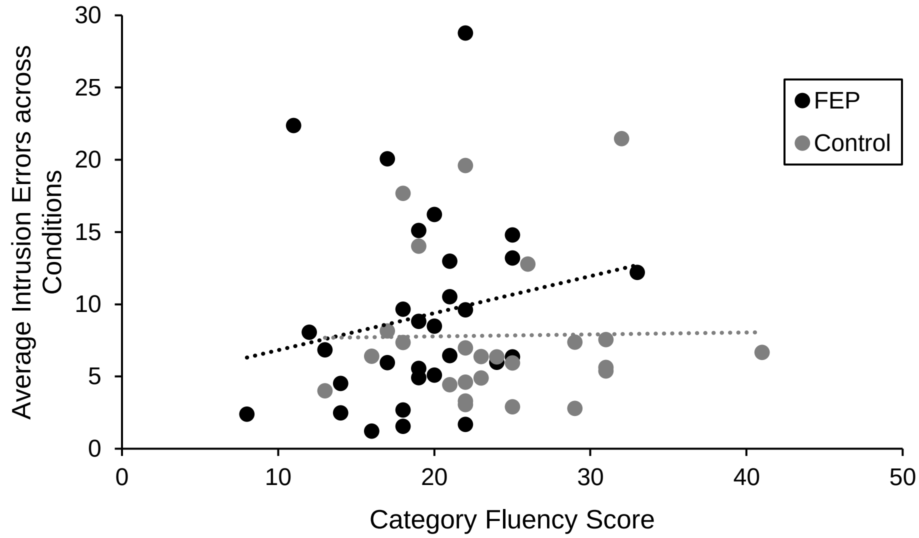

Figure 10: Relationship between the category fluency score and average percent intrusion errors across conditions. Spearman's correlation for FEP is .31 and for controls is .00. These do not differ.

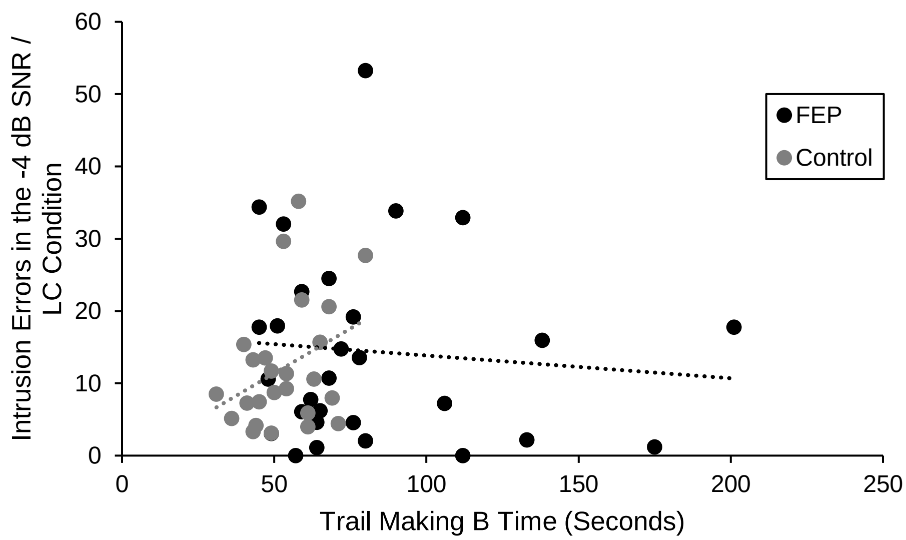

Figure 11: Relationship between the Trail Making B time in seconds and percent intrusion errors in the -4 dB SNR / low context (LC) condition. Spearman's correlation for FEP is -.08 and for controls is .27. These do not differ.

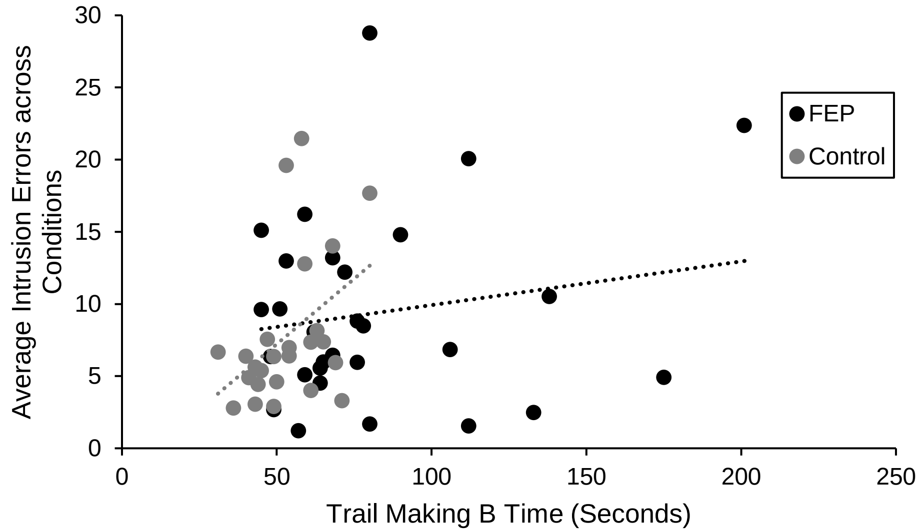

Figure 12: Relationship between Trail Making B time in seconds and average percent intrusion errors across conditions. Spearman's correlation for FEP is .05 and for controls is .42. These do not differ.

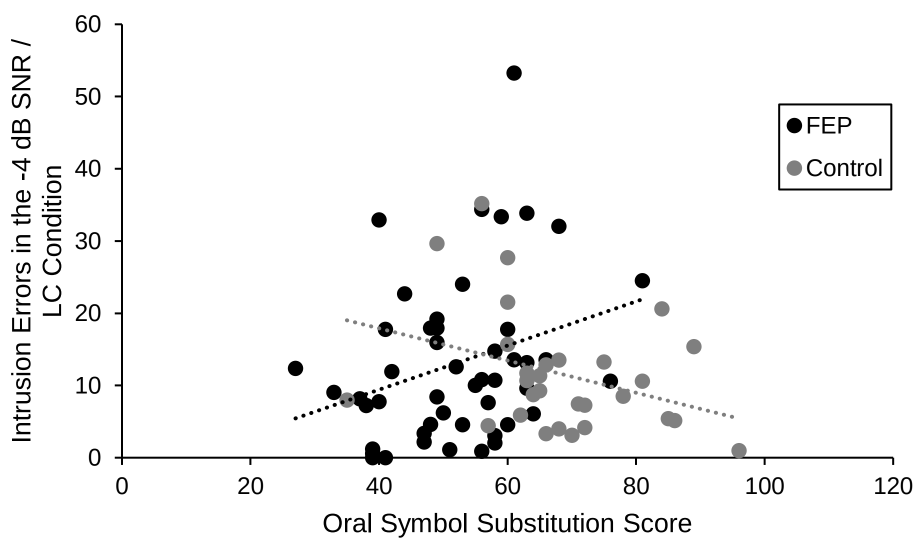

Figure 13: Relationship between the Oral Symbol Substitution score and percent intrusion errors in the -4 dB SNR / low context (LC) condition. Spearman's correlation for FEP is .32 and for controls is -.37. These differ significantly.

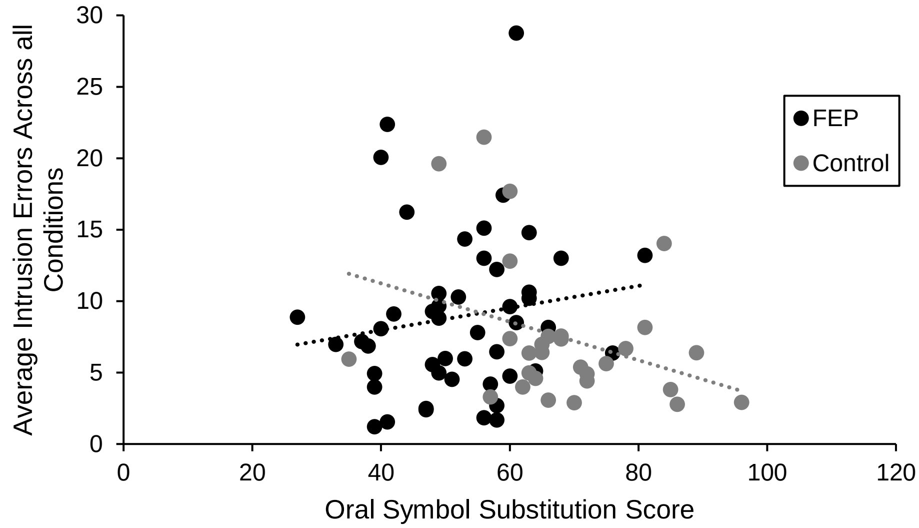

Figure 14: Relationship between Oral Symbol Substitution score and average percent intrusion errors across conditions. Spearman's correlation for FEP is .22 and for controls is -.34. These differ significantly.

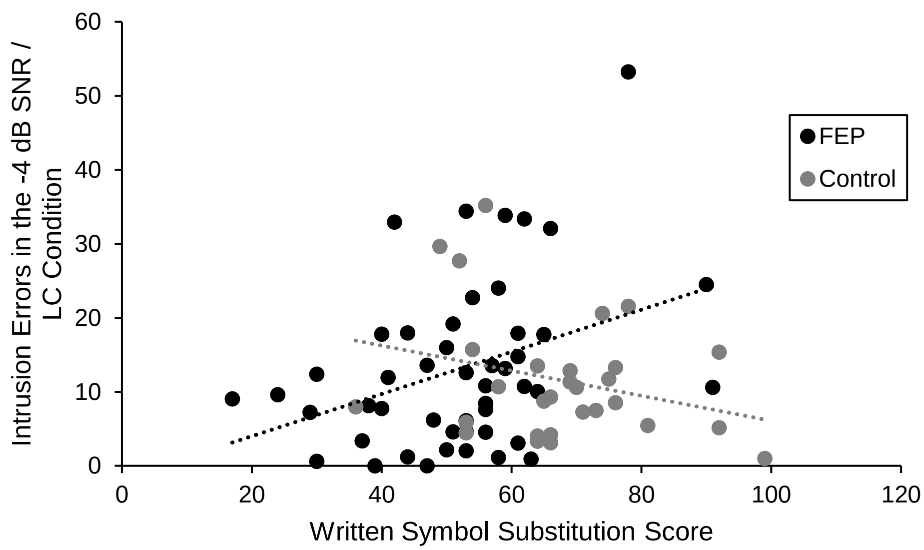

Figure 15: Relationship between the Written Symbol Substitution score and percent intrusion errors in the -4 dB SNR / low context (LC) condition. Spearman's correlation for FEP is .34 and for controls is -.14. These do not differ.

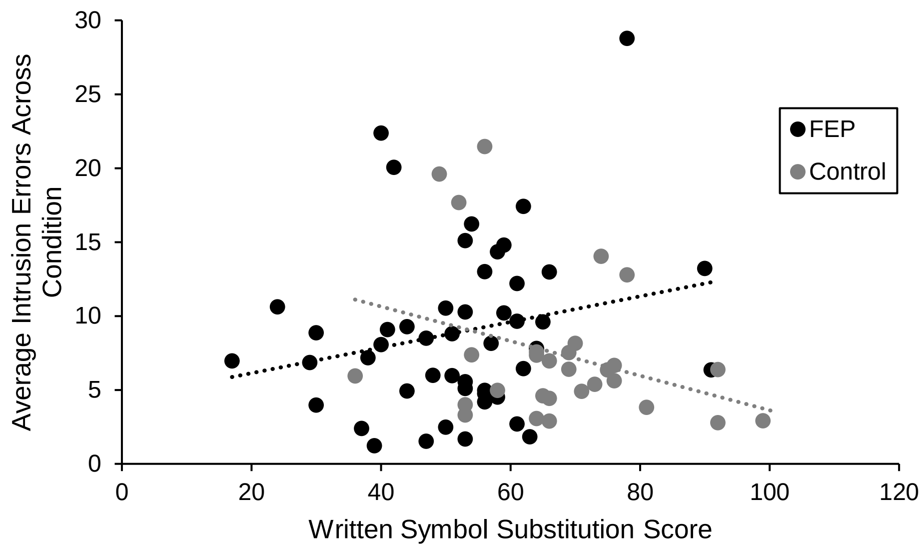

Figure 16: Relationship between Written Symbol Substitution score and average percent intrusion errors across conditions. Spearman's correlation for FEP is .21 and for controls is -.23. These do not differ.

3.5 Clinical measures

Scores on clinical measures by the FEP group are listed in Table 6. Most individuals in the FEP group scored a 5 on item P1 of the PANSS, which indicates "tenacious well-formed and interfering delusions", a 5 on item P3, which indicates frequent hallucinations in multiple modalities that were disruptive with a delusional response, a 3 on item G9, which indicates "thoughts that are somewhat peculiar or idiosyncratic in context", and a 4 on item P2, which indicates "conceptual disorganization characterized by irrelevant or loose thoughts with complex communications". The majority of individuals were also characterized as "markedly ill" (scored as a 5) on the CGIS. Scores on the SOFA indicated most individuals as being in between having the inability to function in almost all areas (scored as a 30) and having major impairments in several areas (scored as a 40). Individuals in the FEP group also tended to score on the lower end of the BNSS which indicates that many did not have strong negative symptoms.

Table 6: Scores on clinical measures in the FEP group

Clinical Measure	Median/Mode	Range
PANSS Items		
Delusions (P1)	Mode: 5	4-7
Hallucinatory Behavior (P3)	Mode: 5	1-7
Unusual Thought Content (G9)	Mode: 3	1-6
Conceptual Disorganization (P2)	Mode: 4	1-6
BNSS Total	Median: 20.6	0-66
CGIS	Mode: 5	2-7
SOFA	Median: 35	15-70

I examined the correlation between these items of clinical interest and the raw proportion scores of intrusions in the -4 dB SNR / low context condition and with the overall intrusion errors. Correlation values are presented in Table 7 with corresponding scatterplots below (Figure 17 - 23). There were no significant correlations for clinical measures and intrusion errors after FDR correction. Scatterplots for average overall intrusions are not shown as the pattern is very similar to the -4 dB SNR low context condition.

Table 7: Spearman's correlations between scores on clinical measures and intrusion errors in the FEP group

Clinical Measure	SNR -4 dB / Low Context	Average Overall Intrusions
PANSS Items		
Delusions (P1)	.02	.01
Hallucinatory Behavior (P3)	.02	.03
Unusual Thought Content (G9)	.02	.06
Conceptual Disorganization (P2)	.07	.15
BNSS Total	-.36	-.27
CGIS	.10	.15
SOFA	-.06	-.15

*correlations were FDR corrected

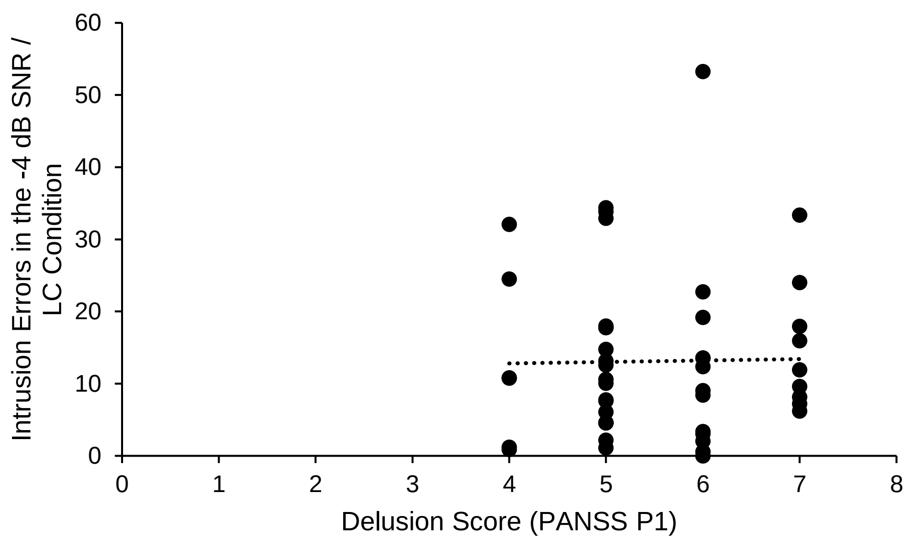

Figure 17: Relationship between PANSS P1 score and percent intrusion errors in the -4 dB SNR / low context (LC) condition (FEP group only). Spearman's correlation is .02.

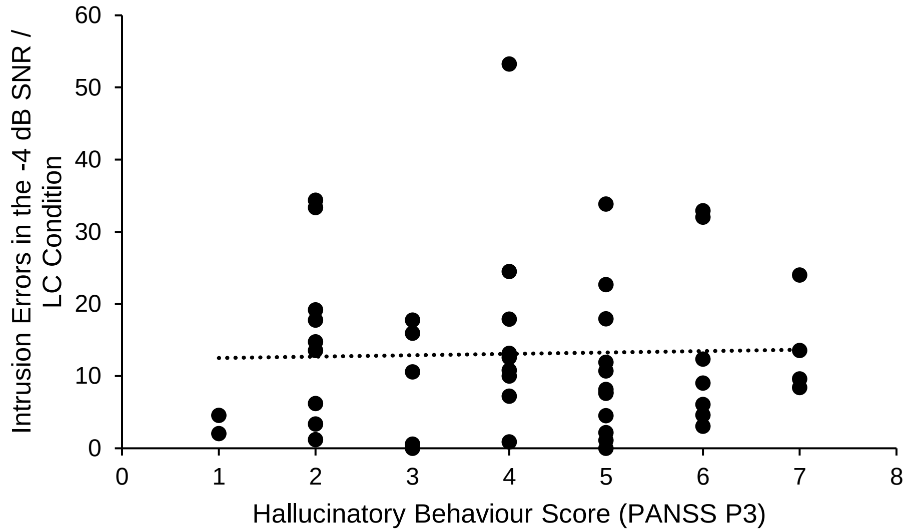

Figure 18: Relationship between PANSS P3 score and percent intrusion errors in the -4 dB SNR / low context (LC) condition (FEP group only). Spearman's correlation is .02.

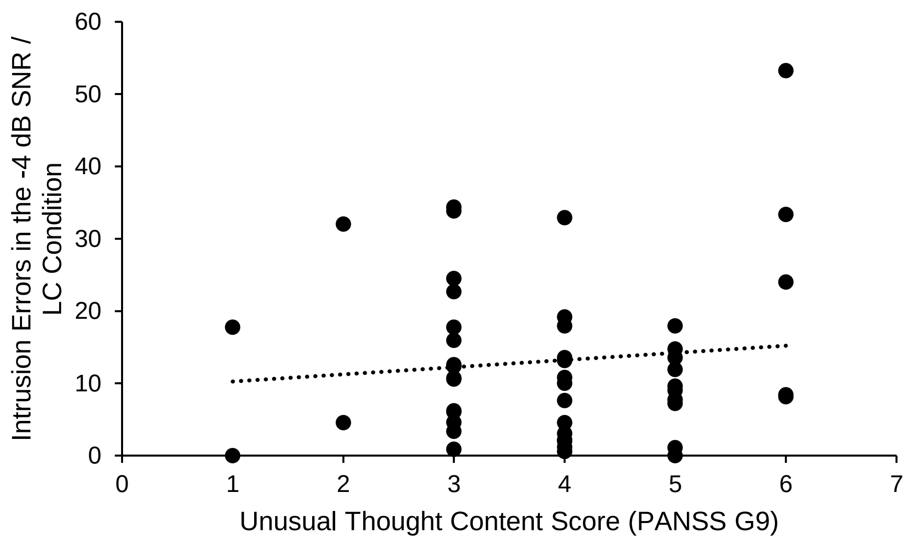

Figure 19: Relationship between PANSS G9 score and percent intrusion errors in the -4 dB SNR / low context (LC) condition (FEP group only). Spearman's correlation is .02.

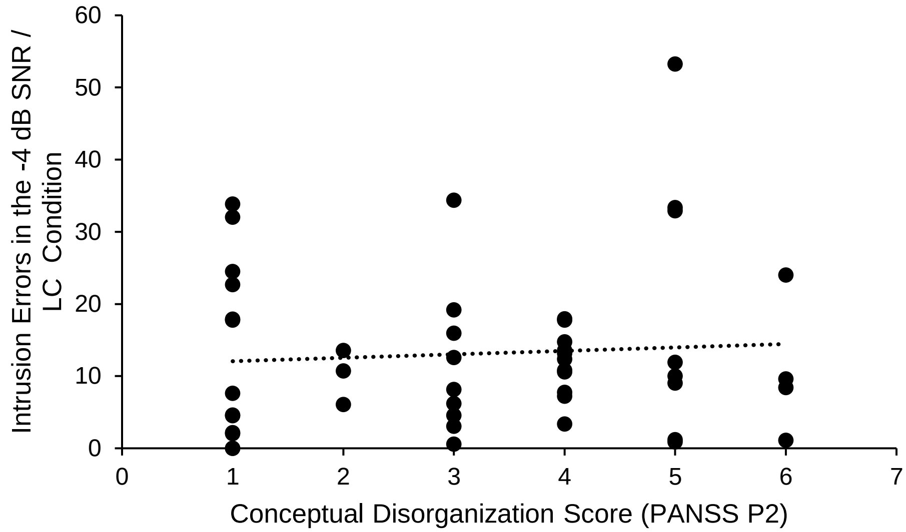

Figure 20: Relationship between PANSS P2 score and percent intrusion errors in the -4 dB SNR / low context (LC) condition. FEP group only. Spearman's correlation is .07.

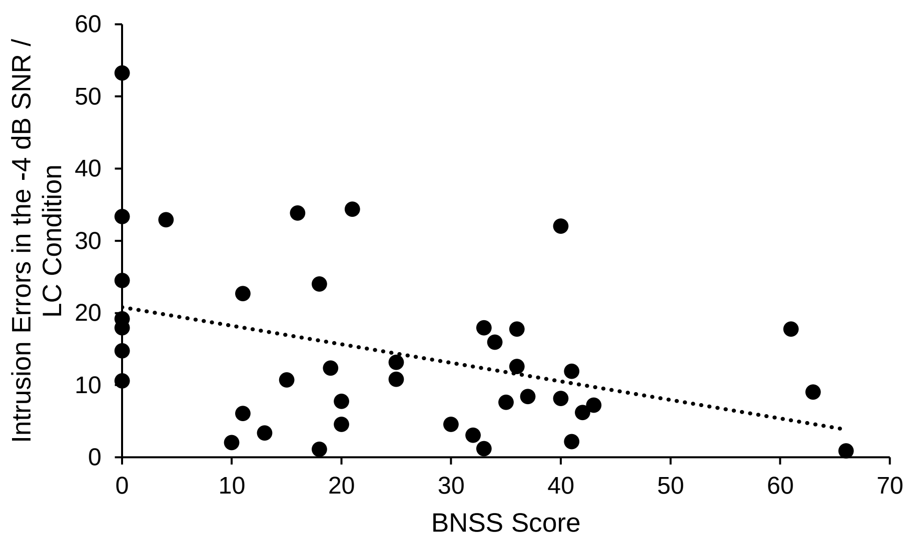

Figure 21: Relationship between the BNSS score and percent intrusion errors in the -4 dB SNR / low context (LC) condition. FEP group only. Spearman's correlation is -.36.

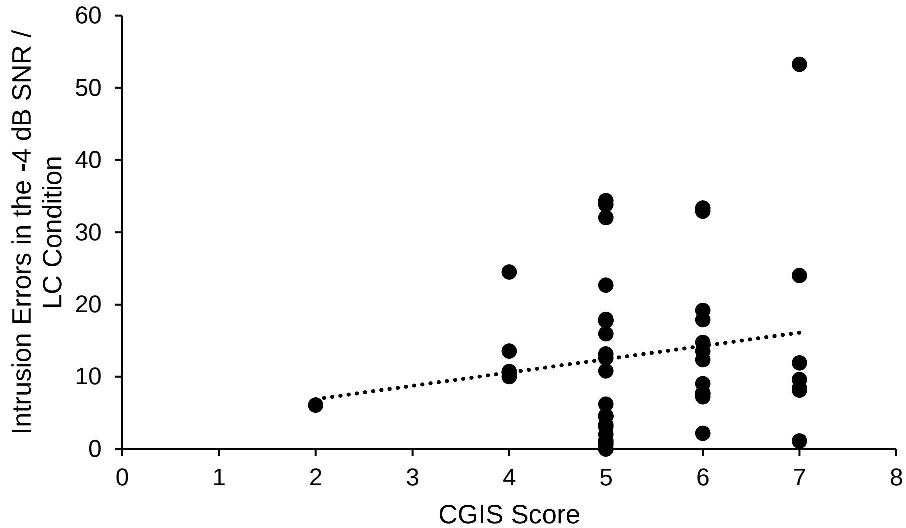

Figure 22: Relationship between CGIS score and percent intrusion errors in the -4 dB SNR / low context (LC) condition. FEP group only. Spearman's correlation is .10

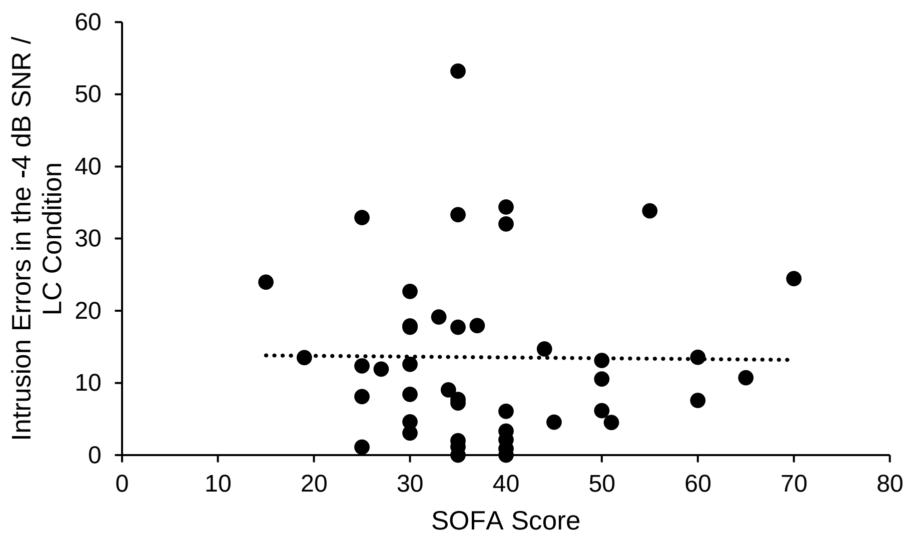

Figure 23: Relationship between SOFA score and percent intrusion errors in the -4 dB SNR / low context (LC) condition. FEP group only Spearman's correlation is -.06.

Chapter 4

4 Discussion

4.1 Intelligibility

As hypothesized, there was an effect of SNR and context on intelligibility. These results replicate the findings of previous studies (Davis, Ford, Kherif, & Johnsrude, 2011a; Miller et al., 1951; Miller & Isard, 1963) where high context and low context materials presented at the lower SNR were less intelligible than at the higher SNR, and the low context materials were less intelligible than the high context materials at both SNRs. As expected, there was no difference between the FEP and control group in intelligibility. This finding demonstrates that any group difference in intrusion errors is not driven by group differences that also yield differences in intelligibility such as hearing loss, or working-memory impairment. This statement is also supported by the findings from the analysis on morphological and phonological errors, where again there was no significant group effect. In addition, the non-significant group difference in intelligibility shows that even if the FEP group had negative symptoms that could affect word report such that people with more negative symptoms would report less words in general, they did not influence intelligibility in such a way that caused group differences. These findings strengthen the argument that the difference between groups on errors made in word report is likely to be driven by reality monitoring deficits in the FEP group characterized by intrusion errors.

However, the intelligibility analysis revealed marked differences between test versions suggesting large item differences. There were only 17 items per condition, and so even a few items that were markedly more (or less) intelligible in one of the two sentence sets could produce the version differences we observed. This item variability complicates our analysis, and may obscure real effects when the data are analyzed by subjects (this item variability is controlled in analyses by items).

4.2 Intrusion errors

Due to item variability evident from the intelligibility analysis, an analysis that accounts for both item and subject variability was needed to analyze the effects of SNR, context and group on intrusion errors. When holding subjects constant and analyzing intrusion errors based on subject performance across items in a condition, no effects of SNR, context, group or interaction effects are seen, possibly due to marked item variability. Indeed, when holding items constant, we see these hypothesized effects. The items analysis revealed that the FEP group produced significantly more intrusion errors than the control group. This suggests that individuals experiencing psychosis have reality monitoring deficits that lead them to misattribute imagined words as having been perceived, especially on anomalous and ambiguous material that maximize the potential for such individuals to construct their own meaning. Also, all participants significantly produced more intrusion errors in the low SNR compared to the high SNR conditions, and on high context sentences compared to low context sentences. However, these effects were only observed when item variability was taken into account, pointing to a number of limitations of my task which are discussed later in this chapter.

4.3 Clinical and cognitive measures

Exploratory analyses were conducted on cognitive measures to see if cognitive patterns were different between the groups, and if level of cognition in a specific domain influenced performance on the experimental task. There were no significant correlations within groups after FDR correction other than in the FEP group for category fluency (a measure of verbal fluency, executive function and cognitive flexibility) and intrusion errors in the -4 dB SNR / low context condition. The positive correlation showed that the higher the category fluency score was for the FEP group, the more intrusion errors were made in the least intelligible condition. Analyses revealed no evidence to suggest qualitative differences in structure of cognition between groups other than for oral symbol substitution, a measure of attention and cognitive processing. There was a significant group difference between groups for correlations between oral symbol substitution and intrusion errors in the -4 dB SNR / low context condition. For the FEP group, there was a nonsignificant positive correlation such that if the oral symbol substitution score was higher, the more intrusion errors reported. Conversely, there was a nonsignificant negative correlation for the control group with a higher score on oral symbol substitution associated with fewer intrusion errors.

It was expected that individuals in the FEP group who had any or stronger hallucinations, delusion or disorganization symptoms would also make more intrusion errors. This is supported by studies (Alpert, 1985; Hoffman et al., 2007, 1999) demonstrating that those experiencing hallucinations tend to hear more meaningful sounds in a meaningless stimulus, as well as studies showing that those with FTD had a reduced sensitivity to context and linguistic violations (G. R Kuperberg et al., 2000; G R Kuperberg et al., 1998). In this study, correlations between intrusion errors and the clinical measures were not significant. This finding may be due to three reasons. Firstly, most clinical individuals in the study were experiencing mild to severe delusions or hallucinations, so variability of symptoms within the group was quite low. Secondly, the items on the PANSS have a restricted scale ranging from 1-7 with very low variability, and thirdly, items and their scales are built to optimize the psychometric properties of the PANSS as a whole, thus not ideal for running correlations using single items.

4.4 Limitations and future directions

The group difference in intrusion errors was only seen when holding items constant in analyses. With the subject analyses, there were significant interactions with test version. These results demonstrate that there was greater variability across items than across participants. The task does show that there is a significant difference in intrusion errors between groups, however a task with items that give more consistent responses from participants is needed for it to be a reliable tool in predicting psychosis or schizophrenia. One possibility is to have more stereotyped sentences similar to the Speech Perception in Noise (SPIN) test developed by Kalikow, Stevens, & Elliott (1977) where sentences have controlled word predictability. For example in the sentence “The witness took a solemn oath”, oath is highly predictable based on the previous words in the sentence. We could alter the high-predictability sentences of the SPIN test to create anomalous sentences such as “The witness took a solemn wreath”. This might push individuals to make sense of the sentence, and those experiencing psychosis may be inclined to use imaginary words to replace the word that violates. For sentences presented in a clear SNR condition, sensory input is unambiguous and participants may be likely to report the sentence with the word violation correctly. However if the sentence is degraded, participants at risk of psychosis may rely too much on their internal prediction. The high context SPIN sentences are used clinically, and different versions have been psychometrically tested for similarity; altering the final word to be anomalous (for half the sentences) should still result in versions that yield similar performance.

Researchers in the past have used sentences with highly controlled linguistic violations to study schizophrenia, and, in particular, FTD (Kuperberg et al., 1998; 2000)These researchers only measured reaction time in detecting target words between anomalous and meaningful sentences. Based on reaction time being longer for FTD individuals overall, but with no difference in reaction time between the two types of sentences, researchers concluded that individuals with FTD had a decreased sensitivity to linguistic violations compared to healthy controls and individuals with schizophrenia without FTD. The lack of sensitivity to linguistic violation could have been due to individuals with FTD filling in the linguistic violation in anomalous sentences with a related word or one that made sense to the individual. There is no way to know what participants actually perceived unless word report data is collected. Although the Kuperberg et al. (1998; 2000) studies did not degrade the sentences at various SNRs, individuals with FTD could have still perceived a different word, as in our study the FEP group made more intrusion errors than controls in every condition regardless of how clear the sentences sounded.

The sensitivity of my task may be improved by categorizing intrusion errors as either function or content words. Function words are words that are necessary for grammar such as “for”, “to”, “so”; and content words are nouns, verbs, adjectives and adverbs that convey meaning and information. In the current study, any word that was not a morphological or phonological error and was not in the original sentence was considered an intrusion error. If individuals make intrusion errors because they are mistaking imaginary words for having being heard, and are adding meaning to a meaningless sentence, then the intrusions that we should be measuring are specifically content-word intrusions. Function words can be interchanged for other function words in a way that preserves the meaning of the rest of the sentence, such as “I” interchanged for “she” in the sentence “She wrote the book”. Thus, the group effect may be more pronounced if we examine content words specifically, or examine the group by intrusion type interaction (same proportion of function-word intrusions in both groups but more content-word intrusions in the FEP group).

The way in which the error data were analyzed using a log transformation required zeros be either replaced or removed from the analysis. A more appropriate analysis should be used to normalize the proportional count data, taking into account instances where participants made zero intrusion errors. In addition, an analysis that can take into account both subject and item variability is needed. Perhaps a Poisson regression or mixed effects modelling would be more suitable for analyses. A Poisson regression is used for count data, and would evaluate how the units of change in predictors lead to a percentage change in the count of intrusion errors. A mixed effects model could take into account fixed effects such as the effects of SNR, context and group, and random effects such as the effects of items and subjects.

Instead of the individual PANSS items that were used as proxies for clinical symptoms in this study, it would be helpful to have a scale or score that allows for more variability in clinical symptoms. The low variability in PANSS scores may have made correlations with our experimental measures of intrusion errors hard to observe. This experiment might not only be a test for reality monitoring in general, but specifically for auditory hallucinations, therefore using appropriate clinical scales measuring hallucinations is important. During this study, aside from the PANSS, we were able to administer the Thought and Language Index (TLI) to all participants, which is a sensitive measure of thought disorder (Liddle et al., 2002). The TLI is complex to score and the TOPSY research team did not have time to score it in time for my analyses. We hope to analyze this data in the future, to see if scores on the TLI in both healthy and FEP participants is related to the number of intrusion errors reported in this task.

4.5 Conclusion

Many studies in the psychosis literature have shown reality monitoring deficits in individuals with early psychosis or schizophrenia. Such individuals tend to experience internal thoughts or events as real stimuli in the external world. Hallucinations, a hallmark symptom of psychosis, are thought to be a direct result of this phenomenon as an individual misattributes inner speech as to an external source: individuals with psychosis may hear voices in the absence of any speaker. Along with reality monitoring deficits, such individuals also have a tendency to ascribe meaning to otherwise meaningless, anomalous percepts. These cognitive patterns of schizophrenia can be targeted with early detection tasks to distinguish individuals at high-risk for developing schizophrenia from those at low-risk. Our study compared healthy control individuals and individuals in a first episode of psychosis on their ability to report degraded (ambiguous) sentences that were either semantically coherent (high context) or anomalous (low context). Degraded sentences provided a challenge to participants in processing the sensory information, requiring individuals to 'fill in' based on fragmentary percepts, and anomalous sentences provided little context to listeners to rely on. Given that individuals experiencing psychosis have reality monitoring deficits and a tendency to add meaning to otherwise meaningless percepts, this may have led individuals who are more liable to construct meaning and to mistake imagined words for heard ones to commit intrusion errors. To our knowledge, this is the first time researchers have used a listening task that used both degraded and anomalous sentences to target reality-monitoring deficits in people with early psychosis. People in the FEP group indeed made more intrusion errors than did healthy controls, but this effect was only significant when item variability was controlled with analyzing by item instead of by subject. This group effect was seen despite normal intelligibility and normal rates of other types of error in the FEP group. Our study also replicated findings from a number of previous studies showing the effects of SNR and linguistic context on intelligibility. These factors also significantly affected the rate of intrusion errors (when item variability was controlled). Individuals with a FEP were tested as an initial validation step: a longer-term aim is to use a similar procedure with individuals in the prodromal state in order to predict conversion to psychosis at the earliest stage in the illness. The aim of our study was to make a more sensitive tool for identifying early psychosis compared to current clinical assessments, however our tool needs to be modified further, with items that produce a more consistent response from participants, in order to increase sensitivity. The use of degraded anomalous sentences to illicit hallucinatory percepts is a promising approach for detecting individuals at risk of developing schizophrenia.

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Appendices

Appendix A: Documentation of ethics approval

Western Research

Research Ethics

Western University Health Science Research Ethics Board
HSREB Amendment Approval Notice

Principal Investigator: Dr. Lena Palaniyappan
Department & Institution: Schulich School of Medicine and Dentistry\Psychiatry,Western University

Review Type: Delegated
HSREB File Number: 108268
Study Title: The Pathophysiology of Thought Disorder in Psychosis (TOPSY)
Sponsor:

HSREB Amendment Approval Date: March 20, 2017
HSREB Expiry Date: October 24, 2017

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Revised Western University Protocol	Received February 27 2017	
Recruitment Items	Healthy Control Poster-Received February 27 2017	
Recruitment Items	Recruitment poster-Received February 27 2017	

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the amendment to the above named study, as of the HSREB Initial Approval Date noted above.

HSREB approval for this study remains valid until the HSREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice Practices (ICH E6 R1), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

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~~Ethics Officer~~, on behalf of Dr. Joseph Gilbert, HSREB Chair

EO: Erika Basile ___ Nicole Kaniki ___ Grace Kelly ___ Katelyn Harris___ Nicola Morphet ___ Karen Gopaul __✓_

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Appendix B: Items used in experimental task

High Context Sentence	SNR in Version 1	SNR in Version 2	Low Context Sentence	SNR in Version 1	SNR in Version 2
the game ended as a draw	-4	0	the town pointed as a coin	-4	0
he searched the pack for the ace of hearts	-4	0	he charged the lap for the niece of wheels	-4	0
the recipe for the cake was easy to follow	-4	0	the agenda for the soap was easy to listen	-4	0
the dessert was put in the oven at the start of the meal	-4	0	the expanse was said in the sofa at the taste of the luck	-4	0
the fog in the valley was quite thick	-4	0	the lime in the engine was quite glad	-4	0
the burglar came up over the wall of the palace	-4	0	the frailty made up over the oil of the notion	-4	0
there were mice in the cave	-4	0	there were dimes in the bomb	-4	0
the game of chess lasted four hours	-4	0	the hair of toast painted five pounds	-4	0
the new computer was sent back after the first month	-4	0	the great election was bought down between the first form	-4	0

the old tree was in danger	-4	0	the great neck was in quiet	-4	0
the view from the top of the ridge was amazing	-4	0	the road from the glass of the truth was appalling	-4	0
the goal was scored by a defender	-4	0	the ice was eased by a believer	-4	0
the salary of the lawyer was quite large	-4	0	the studio of the county was quite high	-4	0
the man read the newspaper at lunchtime	-4	0	the day stood the secretary at grandchild	-4	0
the wife of the priest helped out the elderly	-4	0	the road of the beer paid out the spiritual	-4	0
the boy was able to climb the mountain	-4	0	the car was early to hate the actor	-4	0
the bride smiled at the photo of her wedding	-4	0	the gown laughed at the candle of her autumn	-4	0
it was the women that complained when the old bingo hall was closed	0	-4	it was the money that exclaimed when the last eagle wall was turned	0	-4
the traffic on the expressway was very heavy	0	-4	the pocket on the landlady was very single	0	-4

the building had a nest in its roof	0	-4	the research had a goat in its moon	0	-4
he reminded his parents about the game of football	0	-4	he arrested his minutes about the heart of bathroom	0	-4
the whole sky was full of birds	0	-4	the high leg was clear of views	0	-4
they thought that the house was haunted	0	-4	they might that the fact was drifted	0	-4
the audience was quiet once the song had started	0	-4	the shoulder was famous once the salt had happened	0	-4
the rice was cooked in a large saucepan	0	-4	the cave was signed in a young headache	0	-4
some ice was added to the whisky	0	-4	some snow was agreed to the butter	0	-4
the police returned to the museum	0	-4	the effect supposed to the consumer	0	-4
the camel was kept in a cage at the zoo	0	-4	the atom was meant in a fringe at the chunk	0	-4
the luggage was kept in a large warehouse	0	-4	the badger was called in a young steamer	0	-4

a spoon was used to stir the cup of tea	0	-4	a porch was called to fade the beer of gold	0	-4
he guessed the answer to the question in the exam	0	-4	he dressed the pressure to the number in the vessel	0	-4
she grew tomatoes in her greenhouse	0	-4	she paid umbrellas in her farmyard	0	-4
they told the truth about the fight to the teacher	0	-4	they found the space about the cheese to the fire	0	-4
the author wrote the book that year	0	-4	the darling held the end that way	0	-4

Appendix C: Participant instructions for experimental task

"In each trial, you will hear a sentence presented in noise. It will be a bit challenging to hear the sentences, but you will get the hang of it. Try to understand as much of the sentence as you can. Then the screen will change and you will be prompted to type out all of the words you heard from the previous sentence. Do not worry too much about punctuation, capitalization or spelling. Just focus on typing out as much of the sentence as you can. If you do not hear any of the words, type "none" and proceed to the next trial by pressing Enter. But use NONE as a last resort. Please try your best. If you hear some but not all of the words, you can just type the ones you heard and skip over the others. For example, if the sentence is "The children went to the baseball game" but you were not able to hear children or baseball, you would type "The went to the game." You will be given the opportunity to take one break throughout the task. Do you have any questions? The first 4 sentences will be trials, during that time please tell me if you are at all uncomfortable or have any questions before the real part of the assessment starts after."

Appendix D: Scoring instructions for researchers

Intelligibility

A word is correct if:

- it appeared in the original sentence
- it is a homonym of the word that appeared in the original sentence and any spelling errors are okay

A word is incorrect if:

- it appears in the wrong order
- it is a morphological variant, phonological variant, or intrusion (see below)

Errors

Morphological variants: the root word is constant but the affixes change
Ex: tense change, plural (can → can't, is → was, found → founded)

Phonological variants: single consonant/vowel/phoneme substitution/omission/addition, rhyme error
Ex: Rhyme (assault → salt, minute → it),
Letter omission/addition (badger → badge, moon → moo),
Phoneme substitution (cold → called, they → there)
Syllable omission/addition (day → today, grandchild → child)

Intrusions: Words not in the original sentence that are neither morphological nor phonetic variants
Ex: more than one phoneme/letter different (closed → clothes, this → that, when → once)

Curriculum Vitae

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Popa, A., Ladowski, D., MacKinley, M., Dempster, D., Palaniyappan, L., Johnsrude, I. *Inviting Hallucinatory Percepts during speech-listening to detect cognitive changes in early psychosis.* London Health Research Day, London, Canada, 2018.

Brain Health Network Brain Fair 2017. *How does psychosis change your thinking?*

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