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The Audio-Visual Abnormalities Questionnaire in Schizophrenia (AVAQ): Development and validation of a new instrument for assessing anomalies in sensory perception in schizophrenia spectrum disorders

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Abstract

Background—Anomalies in visual and auditory perception represent an important aspect of the symptomatic manifestation of schizophrenia (ScZ). However, there are currently no instruments available that allow the assessment of the full range of auditory and visual abnormalities using a self-report measure.

Methods—We developed the 85-item Audio-Visual Abnormalities Questionnaire (AVAQ) to assess abnormalities in auditory and visual processing. The AVAQ was validated in an online-sample of 355 healthy participants to establish the factorial structure, internal consistency and reliability of the instrument. In addition, participants completed the Autism-Spectrum Quotient (AQ) and the Schizotypal Personality Questionnaire (SPQ) to establish convergent validity regarding autistic and schizotypal traits.

Results—High internal consistency was observed for the total AVAQ-scale ($\alpha = 0.99$) as well as for the visual ($\alpha = 0.98$), auditory ($\alpha = 0.96$) and the audio-visual subscales ($\alpha = 0.83$). Principal component analyses demonstrated one factor comprising 78 items. The AVAQ was positively correlated with the SPQ ($r = 0.69$, $p < .001$) as well as the AQ ($r = 0.38$, $p < .001$). Correlations

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Contributors

PJU, BK and SS designed the study. NN and PU collected and analysed the data. All authors contributed to preparation of the manuscript

Conflict of interest

The authors report no conflict of interest.

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with the SPQ were highest for unusual perceptual experiences ($r = 0.72$, $p < .001$) and lowest for social anxiety ($r = 0.30$, $p < .001$).

Conclusion—The AVAQ demonstrated excellent reliability, internal consistency and construct validity. Accordingly, the instrument could be useful for characterizing sensory dysfunctions across the schizophrenia spectrum that could guide interventions as well as aid the development of biomarkers.

Keywords

Sensory Processing; Schizophrenia; Schizotypy; Autism; Basic Symptoms; Vision; Audition

1. Introduction

Schizophrenia is a severe mental disorder characterized by disruptions in thought, perception, emotion and behaviour with a typical onset during adolescence and early adulthood. A core aspect of the clinical presentation of the disorder is the presence of pronounced impairments in cognitive functions that precede the onset of psychosis and largely remain unchanged following treatment (Kahn and Keefe, 2013). Cognitive impairments are related to functional outcome and current psychosocial functioning (Green, 1996), highlighting the importance of characterizing the extent and mechanisms of cognitive dysfunctions in ScZ.

Traditionally, research into cognitive deficits has focused on impairments in higher cognitive processes, such as executive functions, working memory (WM) and attention, while impairments in early sensory processes were largely considered unimportant (Uhlhaas and Mishara, 2007; Javitt, 2009). More recently, there is emerging evidence that deficits in visual and auditory processes constitute a fundamental aspect of the pathophysiology of ScZ (Javitt and Freedman, 2015; Butler et al., 2008), and this is supported by several streams of research. Firstly, phenomenological evidence has consistently highlighted that changes in self-experiences often involve aberrant sensory perception in the prodromal and early stages of ScZ (Matussek, 1952; McGhie and Chapman, 1961) that can predict the onset of ScZ in at-risk individuals (Klosterkotter et al., 2001). Secondly, psychophysical data from both visual and auditory domains highlight basic disruptions in the registration and integration of sensory information (Javitt, 2009; Uhlhaas and Silverstein, 2005; Butler et al., 2008; Kéri et al., 2005; Silverstein and Keane, 2011). This is furthermore supported by a wealth of evidence from electro- and magnetoencephalographical (EEG/MEG) studies that have identified pronounced deficits in pre-attentive indexes of sensory processing, such as the P50, Mismatch Negativity and steady-state responses (Thune et al., 2016; Erickson et al., 2016; Bramon et al., 2004; Javitt et al., 2008). Data also indicate abnormal function as early as the retina in ScZ and in children at risk (Silverstein and Rosen, 2015; Demmin et al., 2018; Hébert et al., 2010).

Finally, these data are complemented by anatomical and neurobiological findings indicating that: 1) circuit impairments, including dysfunctions in interneurons, alterations in synaptic density and reduction in cortical thickness extend into primary auditory and visual cortices (Selemon et al., 1995; Hashimoto et al., 2008; Reavis et al., 2017); and 2) retinal thinning

and other structural retinal anomalies have consistently been observed in ScZ (Yilmaz et al., 2016; Silverstein et al., 2018), highlighting the importance of early sensory stages for the understanding of the neurobiology of ScZ.

While the relevance of sensory dysfunctions for understanding the pathophysiology of ScZ has been increasingly recognized (Silverstein, 2016; Javitt and Freedman, 2015), few instruments are available that comprehensively characterize disruptions in auditory and visual processing. Changes in sensory perception are not part of standard assessments of psychopathology, such as the Positive and Negative Syndrome Scale (Kay et al., 1987) or Scale for the Assessment of Positive and Negative Symptoms (Andreasen, 1981). Similarly, changes in sensory processing are not incorporated into interview or self-report scales of cognitive functioning for use in ScZ (Keefe et al., 2006; Welch et al., 2017).

Semi-structured interviews, such as the Bonn Scale for Assessment of Basic Symptoms (BSABS) (Gross et al., 1987), have several items examining auditory and visual alterations that have been found to be associated with deficits in psychophysical performance (Keane et al., 2018; Kéri et al., 2005). The Structured Interview for Assessing Perceptual Anomalies (SIAPA) (Bunney et al., 1999) has been specifically developed to assess aberrant sensory experiences in ScZ. A limitation, however, of semi-structured interviews is the time-required to administer these measures which limit the use of such instruments for population-wide screening, for example. Finally, existing scales for the assessment of schizotypy (Chapman et al., 1978; Raine, 1991) as well as the Cardiff Anomalous Perceptions Scale (CAPS) (Bell et al., 2006) do not comprehensively assess sensory processing in the auditory and visual domains.

To address this important gap in the field, we developed the Audio-Visual Abnormalities Questionnaire (AVAQ). We focussed on alterations in visual and auditory dysfunctions as these two domains have been most consistently shown to be characterized by impairments in psychophysical and neuroimaging/electrophysiological parameters (Javitt and Freedman, 2015). Items of the AVAQ were generated through a review of existing phenomenological studies of sensory experiences (Matussek, 1952; McGhie and Chapman, 1961) and from the extensive experimental literature on visual and auditory processing deficits in ScZ (Uhlhaas and Mishara, 2007; Silverstein, 2016; Javitt and Sweet, 2015; Javitt, 2009). In addition, we also selected items from descriptions in semi-structured interviews, such as the BSABS and SIAPA (Gross et al., 1987; Bunney et al., 1999).

To obtain initial data for reliability, internal consistency and construct validity, we administered the AVAQ to a group of participants ($n = 355$) from the general population that completed the Schizotypal Personality Questionnaire (SPQ) and the Autism Spectrum Quotient (AQ.) (Baron-Cohen et al., 2001). The SPQ and AQ were administered to examine the relationships between sensory abnormalities and schizotypal and autistic traits, respectively. While autism spectrum disorders (ASDs) and schizophrenia spectrum disorders share similarities in auditory and visual processing (Dakin and Frith, 2005; Butler et al., 2008), we expected that AVAQ scores would correlate more strongly with SPQ-scores as compared with AQ-ratings, providing initial support for the construct validity of the AVAQ

for the assessment of auditory and visual processing dysfunctions in schizophrenia spectrum disorders.

2. Methods

Following the item-generation, 93 questions visual (61), auditory (27) and audio-visual (5) experiences, plus 5 catch questions to detect random responding, were included. The questionnaire was initially tested online in a sample of $n = 112$ participants from the subject pool of the Dept. of Psychology, University of Glasgow. Following this initial validation, eight items were removed either because of a) low item-total correlation b) correlation values of >0.3 with any of the other items in the AVAQ and c) difficulties in comprehension by participants.

The revised 85 item AVAQ-scale (Appendix 1) was then tested in a sample of 355 participants that were selected through two recruitment pathways: 1) 150 participants were recruited from the subject pool of the Dept. of Psychology, University of Glasgow and 2) 205 participants were recruited using the Amazon Mechanical Turk platform (see Table 1). All participants were reimbursed for their participation through experimental credits or monetary incentives.

2.1. Schizotypal Personality Questionnaire

In addition to the AVAQ, participants completed the SPQ (Raine, 1991) which consists of 74 questions which assess dimensions of schizotypal personality disorder (SPD) as defined by the DSM-III-R: eccentric behaviour, ideas of reference, odd beliefs/magical thinking, unusual perceptual experiences, strange speech, constricted affect, lack of close friends, paranoia and anxiety. The SPQ was found to have good sampling validity, high internal reliability of 0.91, test-retest reliability of 0.82 and discriminant validity of 0.63 (Raine, 1991).

2.2. Autism Spectrum Quotient

We administered the adult version of the AQ (Baron-Cohen et al., 2001) to assess correlations between autistic traits and aberrant sensory processing. The test comprises 50 statements that cover five domains associated with ASDs: social and communication skills, attention, imagination, and tolerance of change. The AQ has been demonstrated to have moderate to high internal consistency on individual constructs and a coefficient alpha for the total questionnaire between 0.64 and 0.82 (Baron-Cohen et al., 2001; Hurst et al., 2007).

2.3. Procedure

Participants were invited through email invitations and advertisements online to complete the AVAQ, AQ and SPQ-questionnaires via a web interface. Upon accessing the experiment, participants provided informed consent before proceeding.

Data Analysis—The data were processed using RStudio, version 3.4.3. To assess the reliability of AVAQ, Cronbach's alpha was employed. In addition, a principal component analysis (PCA) was performed to investigate the internal structure of the questionnaire. The

relationships between AVAQ scores and schizotypal and autistic traits were individually tested using Pearson's r .

3. Results

Participants who had answered fewer than 90% of the questions on any of the three questionnaires (AVAQ, SPQ, AQ), or endorsed more than 2 AVAQ-catch questions were removed from the analysis ($n = 16$ participants). In addition, four participants who scored >3 SD above the mean on the AVAQ were excluded.

3.1. Demographic data and questionnaire data

Information regarding age and gender was not available for the MTurk sample. The percentage of native speakers as well as the history of reported mental disorders was larger compared to the University sample. In addition, the MTurk sample was characterized by higher AVAQ and SPQ-scores. Moreover, the increase in AQ-scores reached a trend level (see Table 1).

Normality tests (Shapiro-Wilk test) showed that AVAQ scores were not normally distributed ($p < .001$) (see Fig. 1). A similar observation was made for scores on the AQ ($p = .002$) and the SPQ ($p < .001$). There were no significant gender differences for AVAQ ($t = -1.132$, $p = .261$) or AQ scores ($t = -1.261$, $p = .211$). However, male participants scored marginally higher than women on the SPQ ($t = -1.028$, $p = .047$). Overall, the frequency with which items on the AVAQ were endorsed was low (average score per item: $= 0.67$, $SD = 0.2$) (Supplementary Material Fig. 1).

3.2. Principal components analysis

In order to investigate the underlying structure of the AVAQ, we performed a PCA with orthogonal Varimax rotation. The Kaiser–Meyer–Olkin (KMO) measure verified the sampling adequacy for the analysis ($KMO = 0.79$) which exceeded the acceptable limit of 0.5. Bartlett's test of sphericity indicated that correlations between items were sufficiently large ($\chi^2 (3160) = 7849.28$, $p < .001$) to perform a PCA.

An initial analysis was performed to obtain eigenvalues for each component in the data. Three of the components had eigenvalues over Kaiser's criterion of 1 and in combination explained 44.98% of the variance. Based on this observation and an inspection of the scree plots (Supplementary Material Fig. 2), three components were retained in the final analysis. The factor loadings were visually inspected and items were retained if they showed a high factor loading (> 0.35). The majority of items yielded high loading values on both components. Overall, these results suggest that one component encompassing 78 items underlies the factorial structure of the AVAQ.

3.3. Reliability

The internal consistency of the AVAQ was tested for the overall scale as well as for the individual subsections. Cronbach's alpha yielded good to excellent results for the total scale

($\alpha = 0.99$), the visual ($\alpha = 0.98$), the auditory ($\alpha = 0.96$) and the audio-visual subscales ($\alpha = 0.83$).

3.4. Correlation of the AVAQ with Autistic and Schizotypal traits

We examined correlations between the AVAQ, SPQ and the AQ (Fig. 2, Table 2). The SPQ correlated significantly with the total AVAQ score ($r = 0.69$) and subscales (visual: $p < .001$, auditory: $p < .001$, auditory-visual: $p < .001$). Moreover, the overall AVAQ score showed significant correlations with all subscales of the SPQ: ideas of reference ($r = 0.57$, $p < .001$), social anxiety ($r = 0.30$, $p < .001$), magical thinking ($r = 0.65$, $p < .001$), unusual perceptual experiences ($r = 0.72$, $p < .001$), eccentric behaviour ($r = 0.45$, $p < .001$), lack of close friends ($r = 0.48$, $p < .001$), strange speech ($r = 0.57$, $p < .001$), constricted affect ($r = 0.48$, $p < .001$) paranoia ($r = 0.57$, $p < .001$).

There were also significant correlations between AVAQ and AQ scores ($r = 0.38$). However, the correlation with the AQ was found to be significantly lower than that with the SPQ (Hotelling's t -test, $p < .001$). The correlations between the visual, auditory and auditory-visual subscales of the AVAQ with the AQ were also significant ($r = 0.37$, $r = 0.39$, $r = 0.33$, all $p < .001$). Analysis examining the correlations between AVAQ, SPQ and AQ in the two different samples showed that the relationship between the measures was similar across the two populations, although the correlations between AQ-SPQ-ratings and AVAQ scores were larger in the Mturk sample (Supplementary Material Fig. 3) (University sample: SPQ/AVAQ: $r = 0.55$, $p < .001$, AQ/AVAQ: $r = 0.34$, $p < .001$; Mturk: SPQ/AVAQ: $r = 0.74$, $p < .001$; AQ/AVAQ: $r = 0.42$, $p < .001$.)

4. Discussion

We developed a new questionnaire to assess auditory and visual sensory abnormalities in schizophrenia spectrum disorders. Alterations in sensory processing are being increasingly recognized given the emerging evidence for profound impairments in the basic registration of sensory information (Javitt, 2009) and their relationship to impaired higher cognitive processes (Dias et al., 2011) and psychosocial functioning in ScZ (Thomas et al., 2017). Accordingly, a self-report instrument to assess auditory-visual abnormalities could be of value to assess the extent of sensory dysfunctions which in turn could potentially be relevant for guiding interventions as well as for establishing correlations with psychophysical, electrophysiological and neuroimaging measures of auditory/visual processing.

The AVAQ showed high reliability (0.99) and internal consistency for the overall questionnaire as well as for its subscales. Individual item-total correlations did not fall under the value of 0.35. One reason for the large Cronbach's alpha is the high number of questionnaire items in the AVAQ, a scenario that has shown to improve internal reliability (Sijtsma, 2009). The internal consistency of the AVAQ was also confirmed: A PCA with 2 components showed a substantial overlap with almost all items loading on both components. Therefore, it was concluded that 78 items of the AVAQ formed a single consistent and reliable measure of audio-visual processing. Similar results have been recently obtained in regards to sensory abnormalities in ASDs where sensory dysfunctions were accounted for by

a single factor and the degree of sensory deficits correlated highly with AQ-scores ($r = 0.78$) (Robertson and Simmons, 2013).

Convergent validity of the AVAQ was demonstrated through significant correlations with the SPQ and its subscales. We observed large correlations between AVAQ and SPQ scores SPQ ($r = 0.69$), suggesting that aberrant auditory and visual experiences are closely linked to schizotypy. These data are furthermore supported by correlations between AVAQ and specific SPQ-subscales, such as unusual perceptual experiences ($r = 0.70$) that exceeded correlations with other subscales, such as social anxiety ($r = 0.29$), highlighting the construct validity of the AVAQ as a measure of aberrant perceptual experiences. Importantly, these correlations were replicated across two independent online-samples, providing further support for the robust relationship between schizotypy and sensory dysfunctions.

Interestingly, correlations between the AVAQ and AQ, while significant, were substantially lower than those observed for correlations with the SPQ. Aberrant sensory experiences are an integral part of ASDs that involve alterations in the processing of configural information, contrast and motion (Dakin and Frith, 2005) similar to those observed in ScZ (Butler et al., 2008). The current data suggest that while there is an overlap between sensory dysfunctions, ASD and schizotypal traits, there may also be distinguishing aspects of sensory disturbances between the two phenotypes.

The current data thus provide further support for the relationship between auditory and visual dysfunctions and schizophrenia spectrum disorders. One question that arises from these findings is whether sensory dysfunctions reflect alterations that precede or even cause impairments in higher cognitive processes. Data from studies in clinical high-risk participants have indicated that sensory dysfunction itself is predictive of the later emergence of psychosis (Klosterkotter et al., 2001) and impacts higher cognitive functions in established ScZ (Haenschel et al., 2007; Dias et al., 2011). Moreover, there is emerging evidence that basic visual impairments, such as in visual acuity, may predict later onset of ScZ (Hayes et al., 2018). Accordingly, future studies should systematically examine the prevalence of sensory dysfunctions across the illness course of ScZ to identify their relationship to impairments in cognition as well as to the development of psychosis.

Secondly, we believe it will be important to establish the extent to which self-reported sensory dysfunctions as assessed by the AVAQ correlate with psychophysical impairments and neuroimaging/electrophysiological parameters. There is preliminary evidence to suggest that psychophysical impairments correlate with items of the BSABS (Kéri et al., 2005), for example, highlighting the possibility that alterations in self-experienced sensory processing are directly linked to underlying cognitive deficits and possibly neural circuit impairments.

Finally, while the current version of the AVAQ contains 85 items that comprehensively assess distinct aspects of auditory and visual processing in schizophrenia spectrum disorders, we feel that the time that it takes to complete the questionnaire (~20–30 min) may be too long for large-scale studies or for routine clinical use. Accordingly, future studies need to determine whether a subset of items will be sufficient to distinguish reliably, for example, ScZ-patients from controls or from patients with other diagnoses. This would

facilitate the use of the AVAQ as a screening instrument to identify at-risk populations or patient subgroups with pronounced sensory dysfunctions.

5. Summary

We introduce the AVAQ as a measure of auditory and visual sensory dysfunctions in schizophrenia spectrum disorders. The questionnaire is the first self-report measure for sensory deficits in schizophrenia spectrum disorders. Our validation data show that the measure is highly reliable with excellent internal consistency and construct validity. Specifically, we provide novel data on the close relationship between schizotypy and self-reported aberrant auditory and visual perception that highlight that sensory deficits may be at the core of schizophrenia spectrum disorders. Future studies are required to substantiate this hypothesis through the systematic investigation of auditory and visual dysfunctions during different illness stages and their relationships to the development of psychosis and cognitive impairments.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Fig. 1.

Here shows the distribution of AVAQ scores in the whole sample.

Fig. 2.
Scatter-plot showing the relationship between total AVAQ and SPQ/AQ-scores.

Table 1.

Demographic and questionnaire information

	University Sample	MTurk	Statistics
Gender (M/F)	106/44	-	-
Mean Age(SD)	22.5 (7.7)	-	-
Years of education(SD)	14.6 (3.9)	14.1(4.6)	0.22
History of mental disorders (%)	27 (18)	84 (41)	0.001
AVAQ (SD)	39.1 (27.2)	65.7 (51.1)	0.001
AQ (SD)	19.2 (7.03)	20.7(6.9)	0.07
SPQ (SD)	27.9 (13.9)	32.5 (20.2)	0.02

Table 2.

Correlations between AVAQ and SPQ/AQ scores.

	AVAQ scores				P
	Visual	Auditory	Audio-visual	Total	
SPQ					
Ideas of reference	0.56	0.53	0.56	0.57	< .001
Social anxiety	0.29	0.31	0.24	0.30	< .001
Magical thinking	0.63	0.66	0.61	0.65	< .001
Unusual perceptual experiences	0.71	0.70	0.66	0.72	< .001
Eccentric behaviour	0.44	0.44	0.37	0.45	< .001
Lack of close friends	0.46	0.49	0.41	0.48	< .001
Strange speech	0.56	0.55	0.47	0.57	< .001
Constricted affect	0.46	0.51	0.39	0.48	< .001
Paranoia	0.57	0.54	0.49	0.57	< .001
Total	0.67	0.68	0.60	0.69	< .001
ASQ					
Total	0.37	0.39	0.33	0.38	< .001