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Electrophysiological correlates of visual backward masking in high schizotypic personality traits participants

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ABSTRACT

Visual backward masking is strongly deteriorated in patients with schizophrenia. Masking deficits are associated with strongly reduced amplitudes of the global field power in the EEG. Healthy participants who scored high in cognitive disorganization (a schizotypic trait) were impaired in backward masking compared to participants who scored low. Here, we show that the global field power is also reduced in healthy participants scoring high (n = 25) as compared to low (n = 20) in cognitive disorganization, though quantitatively less pronounced than in patients (n = 10). These results point to similar mechanisms underlying visual backward masking deficits along the schizophrenia spectrum.

1. Introduction

Patients with schizophrenia usually show deficits in behavioral paradigms. Visual processing impairments are of special importance because of their replicability, their relatively well-known neurobiological underpinnings, and their cultural independence (Silverstein et al., 2015). Particularly, visual backward masking (VBM) has been proven to be a powerful tool to understand visual deficits in schizophrenia (Bredgaard and Glenthøj, 2000; Green et al., 2011; Herzog and Brand, 2015; Kéri et al., 2000). For example, in the shine-through masking paradigm, a Vernier target is followed by first an inter-stimulus interval and then a grating mask (Fig. 1; Chkonia et al., 2010; Herzog et al., 2004). The time from the onset of the target to the onset of the mask is called the Stimulus Onset Asynchrony (SOA). Participants indicate whether the lower bar of the Vernier is either offset to the left or to the right. The shine-through paradigm is spatially (small Vernier offset) and temporally (short SOA) challenging. Patients with schizophrenia need on average much longer SOAs compared to controls in order to achieve comparable performance levels (Herzog et al., 2004). In addition, healthy relatives of patients need shorter SOAs compared to patients but longer SOAs compared to controls (Chkonia et al., 2010). This finding is particularly crucial for an endophenotype (Gottesman and Gould, 2003). In an EEG study, patients had on average reduced Global Field Power (GFP) amplitudes compared to controls (Plomp et al., 2013). We suggest that patients are unable to stabilize Vernier related activity across time, which is reflected by the reduced EEG (Herzog et al., 2013).

The schizophrenia continuum ranges from affected patients to healthy schizotypic individuals (Nelson et al., 2013). Importantly, the symptom dimensions observed in patient populations can also be observed in healthy schizotypy, consisting commonly in positive schizotypy, negative schizotypy, and cognitive disorganization (Debbane and Mohr, 2015; Kwapil and Barrantes-Vidal, 2015; Mason, 2015). In line with the fully dimensional model (e.g. Claridge and Beech, 1995), an individual may show personality expressions and cognitive disorganization similar to those observed in patients with schizophrenia, albeit quantitatively milder. Schizotypic personality traits are commonly assessed through self-report questionnaires (e.g., Schizotypal Personality Disorder, SPQ, Raine, 1991; Oxford-Liverpool Inventory of Feelings and Experiences, O-LIFE, Mason et al., 2005). In this tradition, schizotypy allows to study the etiology of schizophrenia by promoting the developmental approach and the identification of the

Abbreviations: CogDis, Cognitive Disorganization; O-LIFE, Oxford-Liverpool Inventory of Feelings and Experiences; GFP, Global Field Power; EEG, Electroencephalography; VBM, Visual Backward Masking; SOA, Stimulus Onset Asynchrony; CSD, Current Source Density

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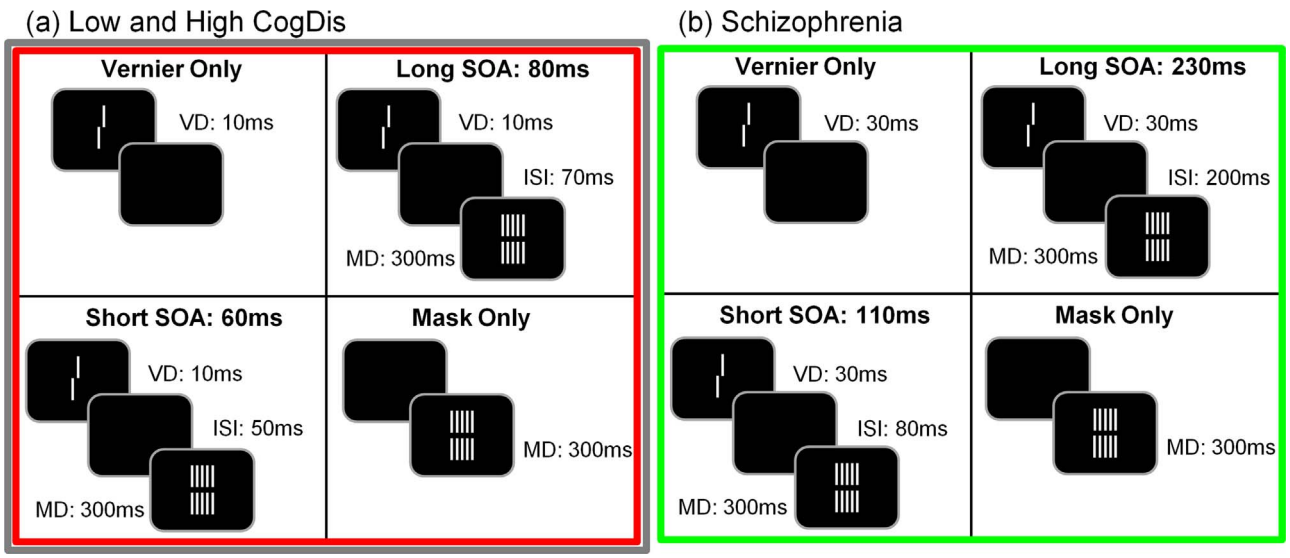

Fig. 1. In the Vernier Only condition, the Vernier was presented for 10 ms for both, the low and high CogDis groups (a) and for 30 ms for the patients (b). In the Short and Long SOA conditions, the Vernier was followed by a mask of 60 and 80 ms for the low and high CogDis groups, respectively, and of 110 and 230 ms, respectively for the patients. The task was to indicate whether the lower bar of the Vernier was offset either to the left or to the right. In the Mask Only condition, the mask was presented for 300 ms in both experiments. Abbreviations: VD = Vernier Duration, ISI = Inter-Stimulus Interval, SOA = Stimulus Onset Asynchrony, MD = Mask Duration. SOA = VD + ISI.

multidimensional heterogeneous structure (Ettinger et al., 2014; Kwapil and Barrantes-Vidal, 2015) as well as the assessment of individual differences in healthy cognition (Cohen et al., 2015; Mohr and Claridge, 2015; Schofield and Claridge, 2007).

Further evidence that VBM is a promising endophenotypic candidate comes from studies on healthy participants varying in the degree of self-reported schizotypy (Cappe et al., 2012; Shaqiri et al., 2015). University students scoring high in the schizotypy dimension cognitive disorganization (CogDis) needed longer SOAs than those who scored lower. More precisely, high CogDis students needed 80 ms on average to reach 75% of correct responses whereas low CogDis students needed 60 ms to reach the same performance level.

Here, we tested whether VBM deficits in healthy individuals with high scores of CogDis are reflected in lower EEG amplitudes compared to lower scoring people.

2. Methods

2.1. Healthy participants pre-selected for high and low cognitive disorganization

Fifty-three healthy students from either the University of Lausanne (UNIL) or the Swiss Federal Institute of Technology (EPFL) volunteered. Participants had normal or corrected to normal vision as determined with the Freiburg visual acuity test (FrAct). Participants reached a value ≥ 1.0 for at least one eye (Bach, 1996). In addition, participants were tested for ocular dominance and completed a standardized handedness questionnaire (Oldfield, 1971). All participants provided written informed consent prior to participation after having received detailed written information. Participants obtained financial compensation for their time. All procedures complied with the Declaration of Helsinki and were approved by the local ethics committee.

Schizotypy scores were determined by the O-LIFE short questionnaire (French version, Sierro et al., 2015) assessing the three schizotypy dimensions Cognitive Disorganization (CogDis, n = 11 items), Unusual Experience (UnEx, n = 12), and Introvertive Anhedonia (IntAn, n = 10). Over three years, participants were selected from a large set of first year students from the UNIL/EPFL (n = 1048, Sierro et al., 2016). From these data sets, we randomly selected the participants. The CogDis subscale varied from the lowest (0 point) to the highest (11 points) score. The two other subscales (UnEx and IntAn) were kept as low as possible, UnEx ≤ 4 and IntAn ≤ 3, except for a few participants at the beginning of the study (N = 9). The experimenter was blind to whether participants belonged to the low or high CogDis group until after the experiment. Three subjects were excluded for poor behavioral performance (< 70% of correct responses) in the Vernier Only condition. Five subjects were excluded for bad EEG data (see Section 2.6).

The 45 remaining participants (Table 1a) were separated into two groups depending on the CogDis scores by a median split (median = 6). Participants scoring from 0 to 5 were considered as low (N = 20) and

Table 1
Demographic measures of (a) the low/high CogDis participants and (b) the patients with schizophrenia.

(a)	**Schizotypy**	**Low CogDis**	**High CogDis**	**Statistics**
	N	20	25	
	Age (years) ± SD	21.0 ± 2.73	20.8 ± 2.65	
	Gender (F/M)	15/5	18/7	
	Handedness (L/R)	2/18	4/21	
	Ocular Dominance (L/R)	5/15	8/17	
	CogDis[a] **± SD**	2.45 ± 1.15	8.00 ± 1.61	$t_{43} = -13.01$, $p < 0.001$*
	UnEx[b] **± SD**	2.55 ± 2.19	2.84 ± 2.41	$t_{43} = -0.42$, $p = 0.678$
	IntAn[c] **± SD**	0.95 ± 0.89	1.56 ± 1.12	$t_{43} = -1.98$, $p = 0.054$
(b)	**Schizophrenia**		**Patients**	
	N		10	
	Age (years) ± SD		39.5 ± 7.4	
	Gender (F/M)		1/9	
	Handedness (L/R)		1/9	
	Education level (years) ± SD		14.4 ± 1.35	
	Duration of illness (years) ± SD		16 ± 6.2	
	SANS[d] **± SD**		7 ± 5.5	
	SAPS[e] **± SD**		6 ± 1.9	
	CPZ[f] **± SD**		501 ± 474	

Average statistics: SD = standard deviation, F = Female, M = Male, L = left, R = right
*As aimed for, the two groups differed in the CogDis subscore only.
[a] Cognitive Disorganization.
[b] Unusual Experience.
[c] Introvertive Anhedonia subscale scores as measured with the sO-LIFE questionnaire.
[d] Scales for the assessment of negative symptoms.
[e] Scales for the assessment of positive symptoms.
[f] Chlorpromazine equivalent.

those scoring from 6 to 11 were considered as high CogDis (N = 25). A two-way mixed repeated measure ANOVA (rm-ANOVA) was computed with subjects as a repeated measure (2 groups × 3 subscales).

2.2. Schizophrenia patients

We included a set of 10 patients with schizophrenia for comparison of their EEG traces with those of the healthy individuals even though Vernier duration and offset size needed to be much larger to make the task possible at all. One in-patient and 9 out-patients participated in the study. All had normal or corrected-to-normal vision; with a visual acuity of ≥ 0.8 measured with the FrAct (Bach, 1996).

Patients were recruited from the Tbilisi Mental Health Hospital or the psycho-social rehabilitation centre. Diagnosis was made according to the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV), based on the Structured Clinical Interview for DSM-IV (Clinician Version). Psychopathology of the patients was assessed by an experienced psychiatrist (EC) by Scales for the Assessment of Negative Symptoms (Andreasen, 1984a) and Scales for the Assessment of Positive Symptoms (Andreasen, 1984b). All patients were treated with either clozapine, haloperidol, trifluoperazine, risperidone, olanzapine, or zuclopenthixol. Three patients were prescribed more than one antipsychotic drug. The chlorpromazine (CPZ) mean equivalent dose for the patients and group characteristics are depicted in Table 1b. General exclusion criteria were drug or alcohol abuse, or neurological or other somatic illnesses influencing subjects' mental state. All participants gave informed consent and were informed that they could quit the experiments at any time. All procedures complied with the Declaration of Helsinki and were approved by the local ethics committee.

2.3. Stimuli and apparatus

Stimuli were displayed on a (ViewSonic G90f + /b) CRT monitor. The screen resolution was 1280 × 1024 pixels with a refresh rate of 75 Hz. Healthy participants sat at 1.5 m away from the screen in a weakly illuminated Faraday cage. The stimuli were white with a luminance of 100 cd/m^2 on a black background (< 1 cd/m^2). For the patients, the stimuli were displayed on a Siemens Fujitsu P796-1 monitor with a screen resolution of 1024 × 768 pixels and a refresh rate of 100 Hz. Patients sat at 3.5 m from the monitor.

We presented Vernier stimuli consisting of two vertical bars separated by a vertical gap of 0.7′ (arc min). The lower bar was slightly offset either to the left or to the right from the upper bar. The horizontal Vernier offset was 0.9′. In three conditions, a mask consisting of 5 aligned Vernier stimuli followed the target. The horizontal spacing between mask elements was 2.2′. For the patients, the size of the Vernier vertical gap was 1′ and the horizontal offset 1.2′. The length between two mask elements was 3.33′.

In our studies with patients, we have mostly used a 25 elements grating mask. However, controls are in the ceiling regime with a 25 elements mask. For this reason, we preferred to use a 5 elements mask which leads to stronger masking as compared to the 25 elements mask (Hermens et al., 2008). Four conditions were presented: Vernier Only, Long SOA, Short SOA and Mask Only (Fig. 1a). In the Vernier Only condition, the Vernier was presented for 10 ms. In the Short and Long SOA conditions, the Vernier was presented for 10 ms followed by a mask for 300 ms with an SOA of 60 and 80 ms, respectively. In the Mask Only condition, the mask was presented for 300 ms with an SOA of 0 ms. The Vernier was randomly pre-defined (left or right), but not physically presented, in order to compute the accuracy. For the patients, the Vernier duration was set to 30 ms. The Long SOA condition was set to 230 ms and the Short SOA condition to 110 ms (Fig. 1b).

Eleven blocks of 80 trials (20 trials/condition) were presented. Conditions were randomized within a block. In total for the CogDis groups, there were 220 trials per condition. For the schizophrenia patients, there were only 8 blocks (160 trials/condition) in order to shorten the duration of the experiment.

2.4. Procedure

The task was to indicate whether the lower bar of the Vernier was offset either to the left or to the right by pressing one of two hand-held buttons. Participants were instructed to be as accurate as possible. Accuracy (d′) was computed for each condition and each group with correction for extreme values (Hautus, 1995). Statistics and effects sizes were computed using JASP (version 0.7.1.2).

2.5. EEG recording and data processing

In Lausanne, the EEG system (BioSemi Active Two system) had 192 Ag-AgCl sintered active electrodes evenly distributed across the scalp while in Tbilisi the number of Ag-AgCl sintered active electrodes was 64. Otherwise the EEG systems were similar. The sampling frequency was 2048 Hz. Data were examined during the experiment in order to detect noisy or defective electrodes. Signal was analyzed off-line and down-sampled to 512 Hz using the Deci-Biosemi tool. The analysis was performed using the Cartool software by Denis Brunet (http://www.brainmapping.unige.ch/cartool; Brunet et al., 2011). The 50 Hz noise was removed with a notch filter. In addition, high- (1 Hz) and low- (40 Hz) pass Butterworth filters were applied.

We extracted EEG epochs from 100 ms before the stimulus onset (baseline) to 400 ms after stimulus onset. Signal was average-referenced. Epochs in which potentials exceeded 75 μV were rejected. We did not apply any exclusion criterion based on reaction time. Data were inspected visually and epochs with muscle contractions artifacts were also rejected. The amount of rejected epochs was less than 10%. Valid (hits and misses) trials were averaged for each condition and each subject. The individual averages were baseline corrected. Unstable and noisy electrodes were interpolated using a 3D spline of degree 2. The proportion of interpolated electrodes was less than 10% for each subject. Grand average were computed for each condition and each group of subjects. Two occipital electrodes were extracted for display purposes in order to visualize the different components of the evoked potential (Supplementary Fig. 1).

2.6. Global field power analysis

Global Field Power (GFP) is the standard deviation of potentials across all electrodes at any given time point and is reference independent (Lehmann and Skrandies, 1980). GFPs were computed for each subject and each condition separately. Individual GFPs were then analyzed in MATLAB (R2010b, The MathWorks Inc., Natick, MA). GFP distributions (at each time frame) were skewed (χ^2). The GFPs were log-transformed at each time point to obtain a normal distribution of the amplitudes. The mean log-transformed GFP across all healthy subjects (N = 50) was computed for each condition. Subjects with GFPs outside 3 standard deviations from the mean at any time point (and for more than 10 ms total) were considered as outliers (N = 5) and excluded. GFPs of the remaining subjects (N = 45) were then averaged for the high and low CogDis group separately (Fig. 3 show the original GFP, for the log-transformed GFP see Supplementary Fig. 3). Statistics were computed using the Statistical Toolbox for Electrical Neuroimaging (STEN) developed by Jean-François Knebel (http://www.unil.ch/line/Sten) on the log-transformed GFP. Two way rm-ANOVAs were computed for each time frame in a 2 groups (high and low CogDis) by 4 conditions (Vernier Only, Mask Only, Long SOA and Short SOA) design. An effect was considered significant ($\alpha < 0.05$) when at least 9 consecutive time frames (about 18 ms) were significant (Blair and Karniski, 1993). This approach has been shown to partially control for multiple comparisons and false positives in EEG analyses (Knebel and

Murray, 2012; Knebel et al., 2011). For the patients (N = 10), individual GFPs were averaged for each condition.

2.7. Distributed electrical source imaging

Inverse solutions were computed at the time interval corresponding to the significant main effect of Group in the GFP in order to identify the underlying sources producing the group difference. We used the Distributed Electrical Source Imaging method (Grave De Peralta Menendez et al., 2004) with the 152-Montreal Neurological Institute template. A space of 4022 solution points was defined into the brain template (Chicherov et al., 2014). The current densities of the underlying sources were estimated with the Local Auto-Regressive Average (LAURA) algorithm (Grave De Peralta Menendez et al., 2004; Menendez et al., 2001; Plomp et al., 2009, 2010). A rm-ANOVA was computed for each solution point (design 2 × 4, as for GFP) on the current densities using the STEN. Multiple comparisons were partially corrected using a spatial criterion, i.e., the clusters must contain at least 15 significant neighboring solution points (Knebel and Murray, 2012). All significant solution points ($\alpha < 0.01$) were displayed in Fig. 4. The current densities were averaged across the significant region for each group.

3. Results

3.1. O-LIFE short questionnaire

As aimed for, the two groups differed significantly in the CogDis dimension only (main effect of Group: $F_{1,43} = 41.50$, $p < 0.001$, $\eta^2 = 0.491$, main effect of Score: $F_{2,86} = 76.16$, $p < 0.001$, $\eta^2 = 0.476$, interaction effect: $F_{2,86} = 40.99$, $p < 0.001$, $\eta^2 = 0.256$; post-hoc in Table 1a). The two other dimension scores (UnEx and IntAn) were not significantly different between the two groups. Cohen's d between the low and high CogDis group is equal to 3.903 for the CogDis dimension, 0.125 for the UnEx dimension, and 0.596 for the IntAn dimension.

3.2. Accuracy: d'

Contrary to our previous study (Cappe et al., 2012), we did not find any differences in performance between the low and high CogDis group (see Section 4.1). Results are shown in Fig. 2. We did not consider the Mask Only condition for the rm-ANOVA because there was no Vernier. Main effect of Group: $F_{1,43} = 0.019$, $p = 0.891$, $\eta^2 = 0$, main effect of Condition $F_{2,86} = 307.787$, $p < 0.001$, $\eta^2 = 0.877$, interaction effect $F_{2,86} = 0.235$, $p = 0.791$, $\eta^2 = 0.001$. Participants were at ceiling in the Vernier Only condition. The performance levels for the Long and Short SOA conditions are lower than expected (i.e., 75%) for reasons explained in the discussion. Patients had much longer SOAs compared to the CogDis participants, which explains their better performance level.

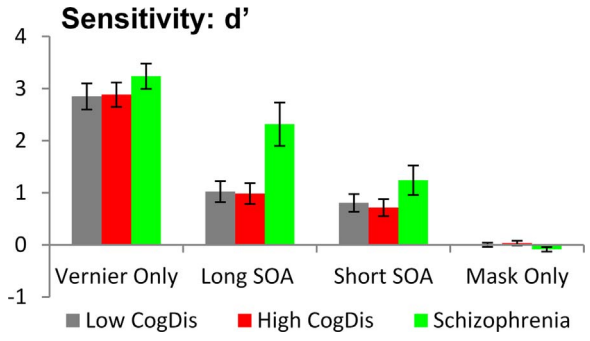

Fig. 2. The high (red) and low (gray) CogDis groups performed in a comparable way in all conditions. Patients (green) performed as well in all conditions, as expected. Vertical bars are the standard error of the mean. Reminder: SOAs are longer for patients with schizophrenia (Fig. 1). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

3.3. Global field power

Global Field Power (GFP) measures the overall brain activity (Murray et al., 2008). GFP averages for the low, the high CogDis group and the patients are shown in Fig. 3.

We made two observations. First, N1 peak amplitudes of patients are lower than amplitudes for the high and low CogDis group, even though the SOAs were much longer, the Vernier offset size was larger and the overall performance was better. It should be noted that in the Long and Short SOA conditions, the N1 peak of patients is delayed compared to the one of the low and high CogDis participants due to the different stimuli duration between the clinical and healthy populations.

Second, N1 peak amplitudes of the high CogDis group are significantly lower compared to the low CogDis group. There is a main effect of Group from 199 ms to 220 ms corresponding to the N1 peak (maximal *F*-value at 207 ms: $F_{1,43} = 4.54$, $p = 0.039$, $\eta^2 = 0.095$). There is also a main effect of Condition for almost the entire epoch. No interaction effect was found. Differences in amplitude between the high and low CogDis groups at the peak location (main effect of Group averaged across time) are shown in the Supplementary Fig. 2. GFP amplitudes were highest for the Vernier Only condition. For the Mask Only condition, the amplitudes difference between the two groups is smaller suggesting that the main effect of Group is weaker for this condition.

3.4. Distributed electrical source imaging

Underlying sources for the time interval of interest (199–220 ms) are located in temporal visual areas (Supplementary Fig. 4). Statistical analysis of the inverse solutions (199–220 ms) reveals significant differences in activations between the low and high CogDis groups, mainly in the supplementary motor cortex and the cingulate cortex (Fig. 4).

4. Discussion

Schizophrenia is a complex disease strongly influenced by genetic factors (Kavanagh et al., 2014; Kendler, 2014). However, genetic studies did not identify clear cut genetic causes, likely because of the complex, non-Mendelian inheritance. For this reason, there is a search for endophenotypes, which are in between the genetic causes and the clinical diagnostics. VBM has been proven to be a promising paradigm (Chkonia et al., 2010). For example, performance of unaffected relatives is worse than the performance of controls (Herzog et al., 2004) and adolescents with psychosis have deteriorated performance when compared with unaffected class mates (Holzer et al., 2009).

Schizotypy is a trait with seriously affected individuals being found in patients, and the least extreme expression being found in the general population (Debbane and Mohr, 2015; Kwapil and Barrantes-Vidal, 2015; Nelson et al., 2013). As in patients, schizotypy traits cluster in the three dimensions of positive symptoms, negative symptoms, and cognitive disorganization (Mason, 2015). In previous studies, we showed that unaffected university students with high as compared to low scores in CogDis have lower VBM performance levels (Cappe et al., 2012; Shaqiri et al., 2015). Supporting the notion of a schizophrenia spectrum, the performance differences for these CogDis groups are much smaller than between patients and controls.

Neurophysiologically, masking deficits are well reflected in the EEG with strongly reduced amplitudes in patients (Butler et al., 2001, 2007; Plomp et al., 2013; Wynn et al., 2005). Here, we asked the question whether these masking deficits are also reflected in changes in the EEG in healthy participants scoring high versus low in CogDis. The GFP amplitudes of patients were clearly lower than for low and high CogDis

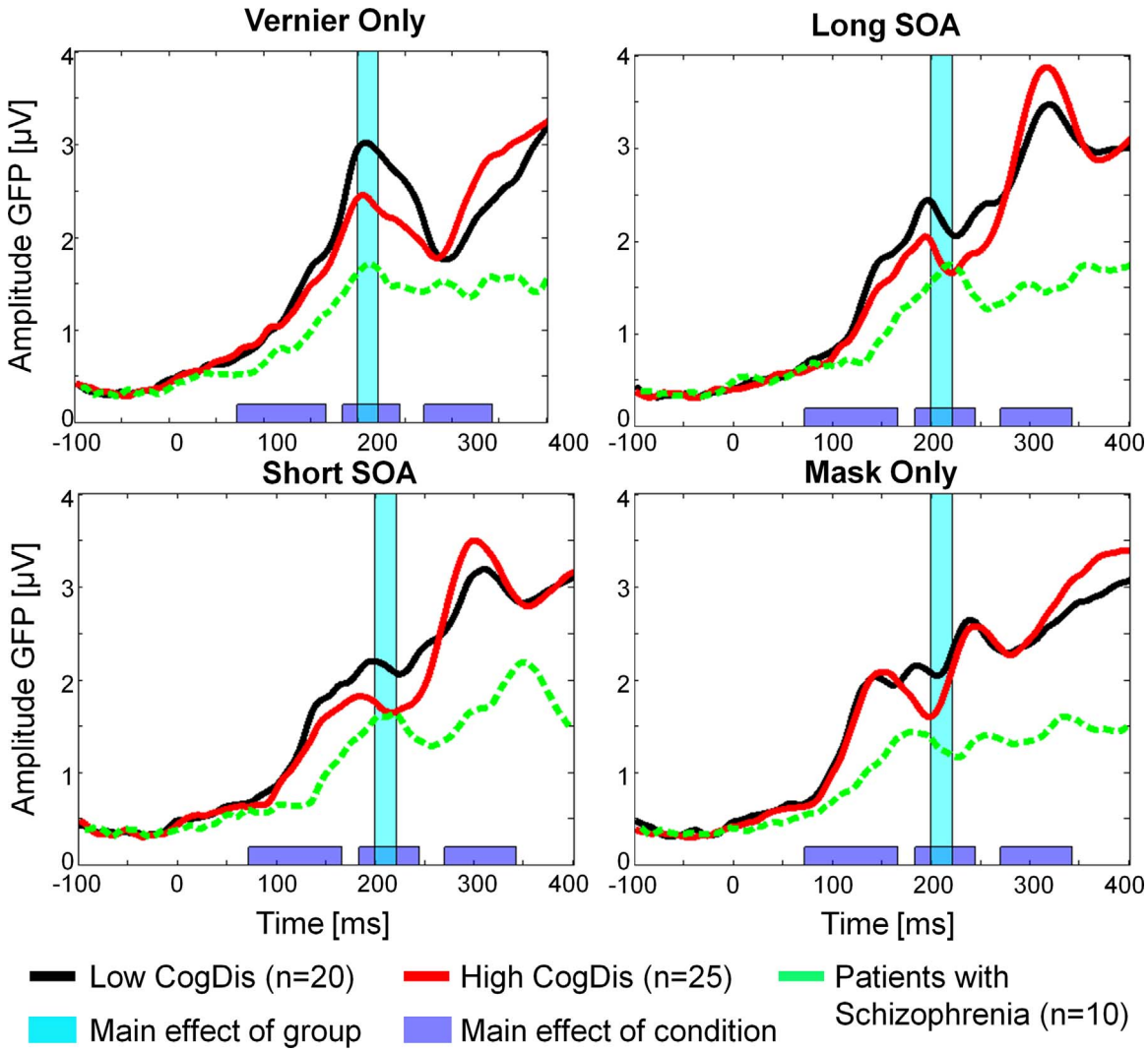

Fig. 3. Grand averages of the GFP in the 4 conditions. GFP for the low CogDis group is shown in black and the high CogDis group in red. The GFP of patients is shown by the dashed green curve. At 0 ms, the Vernier was presented or the mask in the Mask only condition. We computed a rm-ANOVA for each GFP time frame (2 groups: low versus high CogDis × 4 conditions). Patients with schizophrenia were not included in the statistical tests. Blue bars indicate the time interval with a significant difference in the rm-ANOVA. Small boxes: main effect of Condition. Long box: main effect of Group. No interaction effect was observed. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

participants even though patients had much longer SOAs. We determined the GFP in the patients mainly for comparison reasons, to give an impression how strongly amplitudes are reduced. We found that the amplitudes of high and low CogDis participants differed at around 200 ms. This time interval corresponds well to our previous study (Plomp et al., 2013) where differences between patients and controls occurred at the same time (it should be mentioned that we used a masking grating with 25 elements in the previous study to ease the task for the patients). The difference in both studies occurs at the N1 component, which is usually thought to reflect spatial processing, such as texture processing (Bach and Meigen, 1998; Vogel and Luck, 2000). We suggest that the reduction in the N1 component reflects impaired spatio-temporal processing in the patients and, to a lesser extent, in the high CogDis participants. This holds true for all three conditions, where the Vernier target was presented (Vernier Only, Long SOA and Short SOA). Surprisingly, there is also a reduction in the Mask Only condition, but the difference is smaller (Supplementary Fig. 2). Hence the group difference is less obvious for the Mask Only condition. It seems that the deficits are related to the Vernier discrimination itself and its short duration rather than to the appearance of the mask.

In previous studies, we found evidence for masking deficits related to the cholinergic system. The cholinergic system can enhance faint stimuli. In this line, we found that one single nucleotide polymorphism of the cholinergic nicotinic receptor, α7 subunit gene, correlated with masking performance (Bakanidze et al., 2013). In addition, the cholinergic deficits are in line with the fact that patients are usually heavy smokers (Aubin et al., 2012). We proposed that VBM performance is impaired in schizophrenia because the cholinergic system cannot stabilize fragile visual information by recurrent processing, i.e., enhancing Vernier related activity (Herzog et al., 2013). For this reason, neural activity is low, as well reflected in the EEG.

Here, we provided evidence for similar mechanisms in high CogDis participants. We found lower GFP for a short interval around 200 ms in the high CogDis group compared to the low scoring group. After this period, the high CogDis group has higher GFP amplitude than the lower group at around 300 ms in the Long and Short SOA condition (Fig. 3). However, the latter results were not significant. Still, we like to speculate that this signal reflects a compensation mechanism. We propose that in healthy controls neural activity related to the brief Vernier is strongly amplified to make it less vulnerable to the subsequent mask.

Next, we computed inverse solutions to identify the underlying brain regions for the period around 200 ms, where we found a significant group difference in the GFP. We compared the current

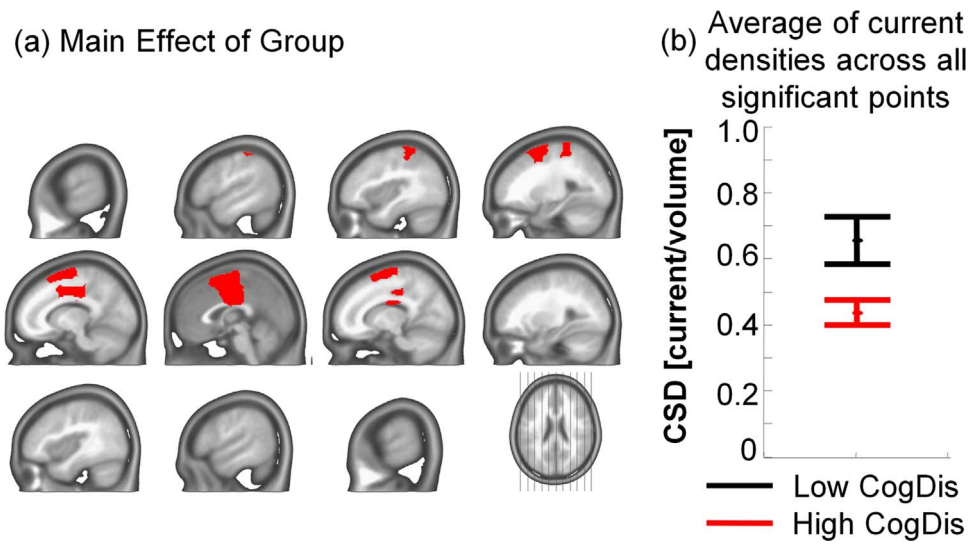

Fig. 4. Inverse solutions for the time interval (199–220 ms) where a significant main effect of group was found (indicated in Fig. 3, light blue). A 2 groups × 4 conditions rm-ANOVA was computed on the sources estimation (current source density; CSD). (a) Main effect of group. The red regions indicate where there was a significant difference (sagittal view). (b) Averaged current densities ("neuronal activity") for the regions displayed in red in (a). Vertical bars represent the 95% confidence interval. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

densities of 4022 sources and found a significant difference of group in the supplementary motor area (SMA) and the cingulate cortex (Fig. 4). These areas are different to what we found previously in patients and controls (Plomp et al., 2013). However, the results are in line with a recent meta-analysis which also found reduced activity in the SMA region in patients compared to controls (Alústiza et al., 2016). The cingulate cortex (especially the anterior part) is involved in many cognitive or affect-related functions (Devinsky et al., 1995) and is often reported as altered in schizophrenia and continuum-related studies (Cannon, 2015; Takahashi et al., 2002).

4.1. Limitations

Our sample size is rather small which may explain the non-significant performance difference between high and low CogDis participants compared to our previous studies (Cappe et al., 2012; Shaqiri et al., 2015). The other reason for the non-significant effect is that we needed to adopt a different protocol. In the previous studies, we used an adaptive procedure, which determined an individual threshold for each participant. Because of the EEG recordings, we needed to present the same stimuli to all observers, resulting in a much less sensitive paradigm. Another reason for the loss of performance sensitivity may be fatigue because observers performed 880 trials in this study and only 160 in the previous ones (Cappe et al., 2012; Shaqiri et al., 2015). In addition, the stimulus size was more challenging in the present study (Vernier offset size: 0.7′) as compared to Cappe et al., 2012 (Vernier offset size: 1.15′). Furthermore, participants were selected according to their CogDis score while keeping the two other subscales comparable in order to not significantly vary between the high and low CogDis group. In Cappe et al., 2012, participants' UnEx and IntAn scores varied "spontaneously". This indeed seems to have led to a higher variation in the previous as compared to the current study. These differences in the positive and negative subscales may also have an effect on the masking performance.

GFP differences between high and low CogDis were much weaker than between patients and controls. However, we clearly observed the same tendency in high CogDis participants and patients. We are aware that the effects within the general population are much smaller than when comparing the general population with the clinical population. We removed 5 participants based on a 3 standard deviation threshold because they were increasing the variance in the sample. Indeed, results were not significant when we included all participants. The group difference is however visually present (Supplementary Fig. 5).

4.2. Conclusion

In visual backward masking, patients with schizophrenia show reduced amplitudes around 200 ms (Plomp et al., 2013). Participants scoring high in CogDis, also show reduced GFP amplitude at 200 ms but to a lesser degree. We suggest that the reduced EEG amplitudes reflect a deficit in enhancing faint stimuli, potentially related to dysfunctions of the cholinergic system.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.psychres.2017.04.051.

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