# Detached and distracted: ERP correlates of altered attentional function in depersonalisation

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**Abstract**

Depersonalisation (DP) is a psychological condition marked by feelings of disembodiment. In everyday life, it is frequently associated with concentration problems. The present study used visual event-related potentials (ERPs) in a Posner-type spatial cueing task with valid, invalid and spatially neutral cues to delineate the potential neurophysiological correlates of these concentration problems. Altered attentional functioning at early, sensory stages was found in DP patients but not in anxiety- and depression-matched psychosomatic patients without DP. Specifically, DP was associated with decreased suppression of stimuli at unattended locations, shown as absent processing costs for invalidly versus neutrally cued stimuli over P1 (135-150 ms). Attentional benefits at N1, and all attentional effects at later, cognitive processing stages (P2-N2, P3) were similar in both groups. We propose that this insufficient early suppression of unattended stimuli may result from atypical sensory gain control in DP.

**Key words:** Depersonalisation, EEG, ERPs, visual attention, Posner task, spatial cueing

## 1. Introduction

Depersonalisation and derealisation are aspects of a psychological condition that is characterised by feelings of detachment from one's own self and body and / or from one's surroundings (e.g., Michal et al., 2007; Simeon, 2004). For example, one might have the experience of being an outside observer to one's own thoughts, feelings, sensations and body (depersonalisation) or experience other people or objects as unreal, dreamlike, lifeless or as if through a fog (derealisation). In depersonalisation (DP) reality testing remains intact (e.g., Simeon, 2004).

Experiences like these can occur in healthy adults under conditions of stress or fatigue (Simeon, 2004; Trueman, 1984) or as a symptom of a mental disorder (e.g. panic disorder, post-traumatic stress disorder). When symptoms of DP are persistent, they may indicate the presence of depersonalisation-derealisation disorder, which causes clinically significant distress or impairments (Spiegel et al., 2011; American Psychiatric Association, 2013). The prevalence of DP in the general population is around 1-2% with both genders equally affected (Hunter et al., 2004; Lee et al., 2012; Simeon, 2004). The onset of the disorder is usually before age 25, and the symptoms often become chronic (Baker et al., 2003; Simeon et al., 2003).

One of the most frequent complaints in patients with DP is difficulties with concentration (Lambert et al., 2001; Hunter et al., 2003; American Psychiatric

Association, 2013). Indeed, standard neuropsychological tests suggest that DP is marked by broad alterations of the attentional and perceptual systems (Guralnik et al., 2000; 2007). Specifically, DP was associated with slower processing speed, impaired perceptual organisation, vulnerability to distracting stimuli, and impairments in immediate recall of verbal or visual information. A more recent study provided further evidence for reduced capacity to suppress stress-related physiological arousal (Lemche, Sierra-Siegert, David, Phillips, Gasston, Williams, & Giampietro, 2016).

Selective attention is a higher cortical function necessary to deal with the constant stream of information arising from our body and the physical world around us, in line with the current needs of our organism and the pressures that the external world places on us. Because of its limited processing resources, the brain has to focus on behaviourally relevant information, while ignoring the rest; a process referred to as selective attention (e.g., Posner, 1980; Hillyard et al., 1998).

A common and well established method to investigate selective attentional mechanisms is the spatial cueing paradigm (Posner and Cohen, 1984). In a recent study (Adler, Beutel, Knebel, Berti, Unterrainer, & Michal, 2014), we used this paradigm to investigate the behavioural mechanisms of spatial-selective attention in DP. We manipulated attentional demand by asking DP patients and healthy controls to perform an easy detection task and a more difficult

discrimination task. In both tasks, targets (Gabor patches) were presented in the left or right hemifield, and participants were asked to respond to all of them (detection task) or only certain ones (discrimination task). We measured covert attentional selection by comparing response times to validly predicted targets (targets at the location indicated by a preceding central cue) with response times to invalidly predicted targets (targets at the non-indicated location). This overall attention-directing effect was smaller for DP patients than for healthy controls in the more difficult discrimination task only. The inclusion of neutrally predicted targets (targets preceded by non-informative cues) in this study allowed us to measure the contribution of costs (differences between invalidly and neutrally cued trials) and benefits (differences between validly and neutrally cued trials) to the overall attention-directing effect. We found that, in the discrimination task, the DP group experienced fewer attentional costs (i.e., less slowing of response times in invalid compared to neutral trials) but the same benefits as healthy controls. These findings show that DP is associated with altered mechanisms of spatial attention, and particularly with a weaker suppression of events at unexpected locations under conditions of increased attentional demand. This may lead to increased distractibility, which may be the source of the concentration difficulties reported by DP patients in daily life. As we compared DP patients with healthy controls, it remains unclear, however, to what extent the attentional effect is specific to DP rather than explained by mental illness itself.

To this end, the present study used a control group of psychosomatic patients without clinically significant DP symptoms, but similar average levels of anxiety and depression. We employed a variant of the discrimination task and spatial cueing paradigm used by Adler et al. (2014), and investigated the underlying neural mechanisms of selective attention in DP with electroencephalography (EEG). Visual stimuli evoke cortical event-related potentials (ERPs), which consist of typical components (P1, N1, P2, N2, P3). The sequence of these ERP components reflects the sequence of neural processes triggered by the stimulus (Luck et al., 2000). Early sensory processes (P1, N1) are followed by later cognitive stages (P2, N2, P3), which research has related to processes of decision making and response selection.

We hypothesised that DP patients would demonstrate fewer attentional costs than controls, both in response times and in ERPs. The central question of the present study was whether these effects occur on a cognitive level of information processing (mirrored in the P2, N2, and P3 components of the ERP) or are already observable at the level of sensory processing (i.e., at earlier stages of neuronal processing as mirrored in the P1 and N1 components). The latter might be expected because previous ERPs studies of DP symptoms (disembodiment and emotional numbing) observed effects at earlier rather than later processing stages (Quaedflieg, Giesbrecht, Meijer, Merckelbach, de Jong, Thorsteinsson et al., 2013; Adler, Schabinger, Michal, Beutel, & Gillmeister, 2016). For early,

sensory ERPs, previous studies have also shown that attentional costs are reflected over P1, while attentional benefits are reflected over N1 (e.g., Hillyard & Anllo-Vento, 1998; Luck & Hillyard, 1995; Rüsseler & Münte, 2005). We therefore expected to see reduced attentional suppression over P1 in DP compared to control patients.

## 2. Materials and Methods

### 2.1 Participants

The total sample consisted of 28 psychosomatic patients, recruited from the Department of Psychosomatic Medicine and Psychotherapy of the University Medical Center Mainz. Psychosomatic patients presented with a variety of psychological conditions (e.g., depression, anxiety, somatoform disorders). All participants completed the German versions of the Cambridge Depersonalization Scale (CDS; Sierra & Berrios, 2000; German version CDS-d: Michal et al., 2004), the Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996; German version: Hautzinger, Keller, & Kühner, 2006) and the State and Trait Anxiety Inventory (STAI; Laux, Glanzmann, Schaffner, & Spielberger, 1981). Excluded from this study were patients with an emotionally unstable personality disorder, a lifetime history of any psychotic disorder, current substance abuse or neurological disease. With regard to the individual extent of DP symptoms as

measured by the CDS-d, the participants were assigned to one of two groups. One group (N = 14) encompassed patients with a CDS-d score ≥ 65, i.e. with clinically relevant DP symptoms (Michal et al., 2004). On average, the reported age of onset of DP was 17.21 ± 4.58 years (range: 12-25 years); these participants constituted the DP patient group. The second group (N = 14) did not have clinically relevant DP symptoms (CDS-d score < 65); these patients constituted the Control patient group. Both groups were balanced for symptoms of depression and anxiety (see Table 1).

Table 1. Sample characteristics with results of t-tests for continuous variables, chi-square tests for categorical variables and Mann-Whitney-U test for ordinal variables.

| | DP patients (n = 14) Mean (SE) | Control patients (n = 14) Mean (SE) | Statistical comparison |
|---|---|---|---|
| Gender (male) | 10 (71.4%) | 10 (71.4%) | |
| Age (years) | 26.07 (1.62) | 26.93 (1.28) | p = .681 |
| Level of education | 2.29 (0.19) | 2.79 (0.11) | p = .085 |
| DP score (CDS-d) | 162.07 (12.84) | 13.00 (2.18) | p < .001 |
| Depression score (BDI-II) | 22.36 (2.03) | 21.64 (2.62) | p = .831 |
| Anxiety score (STAI-Trait) | 53.50 (2.18) | 58.21 (1.75) | p = .103 |

*Notes*: Level of education = mean highest level achieved, where 1 = lower secondary education (Hauptschule), 2 = intermediate secondary education (Realschule), and 3 = higher secondary education (Abitur); CDS-d = Cambridge Depersonalisation Scale, BDI-II = Beck Depression Inventory-II, STAI-Trait = State-Trait-Anxiety-Inventory (Trait).

In addition, all patients were receiving psychotherapeutic treatment at the time of participation in this study. Seven DP patients were additionally being treated with antidepressants (in one case supplemented by an anticonvulsive drug). Within the Control patients group, six patients were being treated with antidepressants (in one case supplemented by an anticonvulsive drug).

All patients had normal or corrected-to-normal vision. The study was approved by the ethics committee of the Statutory Medical Board of the State of Rhineland-Palatinate (Germany) and was conducted in accordance with the Declaration of Helsinki. Each participant gave written informed consent prior to the study and received a honorarium of 45 € for their participation.

**2.2 Stimuli and materials**

For stimulation we used Presentation (Neurobehavioral Systems, Berkeley, USA). The experiment was presented visually on a computer screen (EIZO ColorEdge CG223W, display size 22”) with a visual angle of α = 33.07° (viewing distance: 80 cm). All stimuli were presented in white colour on a black background. Both the fixation cross and the spatial cue were depicted centrally, and were both less than 1° of horizontal and vertical visual angle. Cues were defined as arrows, which pointed to the left (<), to the right (>) or in both directions (<>). Event stimuli emerged 6.44° left or right of the fixation cross

(measured from the fixation cross to the centre of the event stimulus).Targets were white ellipses (1.4° horizontal x 1° vertical visual angle) while non-targets were white circles (1.4° horizontal x 1.4° vertical visual angle).

### 2.3 Design and procedure

During the experiment participants sat inside a dimly lit, sound-attenuated and electromagnetically shielded EEG booth. A variant of the spatial cueing paradigm (Posner & Cohen, 1984) was used for the investigation of selective spatial attention. In each trial participants were asked to fixate on a fixation cross and to respond to targets (ellipses) while non-targets (circles) had to be ignored. Both targets and non-targets were presented in the left or right hemifield. A centrally presented spatial cue (arrow) preceded each stimulus event (target or non-target) indicating the likely location of the upcoming target. When observing a target, participants were asked to press the spacebar with their dominant hand as fast as possible within 1200 ms. Figure 1 shows the schematics of the trial sequence.

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Figure 1 about here

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The experiment consisted of 10 blocks with 78 trials each. After every other block, the participants received feedback concerning reaction times and error rates. A practice block (78 trials) preceded the experimental blocks. Thirty targets and 48 non-targets were presented in each block. However, the proportion of valid, neutral and invalid cueing conditions differed between target and non-target trials. As only non-target trials were included in ERP analyses, cue validity was counterbalanced for non-target trials (per block: 16 valid, 16 neutral, 16 invalid trials). In target trials with a directional cue (i.e., an arrow pointing left or right) the cue prediction was valid in 80% of the trials (per block: 16 valid trials, 4 invalid trials). Furthermore, some target trials included non-directional cues (i.e., arrows pointing both left and right; per block: 10 neutral trials). In all of the trials, the presentation side of the stimulus event (left vs. right) was equiprobable.

### 2.4 Response time (RT) and accuracy analyses

Only button presses occurring between 200 and 1000 ms after the onset of the 100-ms stimulus were used for RT analysis (Adler et al., 2014). For each participant, accuracy and RT data were calculated separately for the valid, neutral and invalid conditions.

Regarding accuracy data, hits were defined as (correct) button presses in response to targets. Correct rejections were correctly ignored non-targets and 'false alarms' were button presses in response to non-targets. Accuracy was calculated as the percentage of correct responses (i.e. hits and correct rejections) in relation to the total number of trials. Repeated-measures ANOVAs with the between-subjects factor *group* (DP patient group vs. Control patient group) and the within-subjects factor *validity* (valid vs. neutral. vs. invalid) were conducted separately for hits and false alarms.

Regarding correct RTs, a repeated-measures analysis of variance (ANOVA) with the between-subjects factor *group* and the within-subjects factor *validity* was conducted.

Where a significant effect of validity was found, pairwise post-hoc comparisons (Bonferroni adjusted) for all three levels of validity were calculated to clarify whether there were differences between each pairing of these conditions (i.e., attentional costs, benefits and total attention directing effect).

### 2.5 EEG Recording and ERP analysis

64 actiCAP scalp electrodes coupled with a BrainVision actiCHamp system (BrainProducts GmbH, Gilching, Germany) were used to record brain electrical

activity, which was amplified and sampled with a digitization rate of 500 Hz. The online band pass filter was 0.01-100 Hz while a digital low pass filter of 50 Hz and a notch filter of 50 Hz were applied offline. EEG was re-referenced offline to the average of the mastoids (TP9/TP10) and epoched from 100ms before to 500ms after target/non-target onset. Segments with artefacts (e.g. blinks) were removed after visual inspection.

ERPs were analysed only for non-target trials in order to prevent any motor signal confounds. First, epochs were averaged for each of the three attentional conditions (valid, neutral, invalid) for each participant. 140 segments (range across participants: 99-159) contributed to the average of the valid condition, 143 (range: 105-159) to the neutral average, and 142 (range: 105-160) to the invalid average. Then, mean amplitudes were computed for each of these conditions separately for both groups within several measurement windows. Each time window was centered around the peak of the respective ERP component. Visual components P1 (135-150 ms) and N1 (180-205 ms) as well as fronto-central P2-N2-complex (230-295 ms) and P3 (390-460 ms) were included in the analyses. Electrodes situated over the primary visual cortex contralateral to the stimulated side (PO3/4c, POZ, OZ, O1/2c) were clustered for statistical analyses of P1 and N1 (see e.g. Heinze et al., 1990; Kasai & Takeya, 2012), and fronto-central electrodes were clustered for analysis of P2-N2 and P3 (P2-N2: FC1, FC2, Cz,

FCz, Fz; P3: F1, F2, FC1, FC2; see e.g., Brydges, Fox, Reid, & Anderson, 2014; Smart, Segalowitz, Mulligan, & MacDonald, 2014).

Separately for each time window, a repeated-measures ANOVA was calculated for the between-subjects factor *group* (DP patient group vs. Control patient group) and the within-subjects factor *validity* (valid vs. neutral vs. invalid). In case of a significant two-way interaction between group and validity, repeated-measures ANOVAs with the factor *validity* were calculated for the DP and the Control patient groups separately. Pairwise post-hoc comparisons between the three attentional conditions clarified whether there were amplitude differences between each pairing of these conditions (i.e., attentional costs, benefits, and total attention directing effects).

For all analyses, a significance level of $\alpha = .05$ was applied. Partial eta squares ($\eta^2$) are reported as a measure of effect size. Greenhouse-Geisser adjustment for non-sphericity were applied whenever appropriate. For brevity, statistically non-significant findings are only reported in full where relevant or informative.

## 3. Results

### 3.1 Behavioural Data

Overall response accuracy was 98% for DP patients and 98% for Control patients. Separate analyses of hits and false alarms showed that there were no main effects of group or of validity, nor interactions between them.

Mean RTs in correct trials are shown in Table 2. Statistical analysis of RTs revealed a significant main effect of validity, $F(2,52)=34.66$, $p<.001$, partial $\eta^2=.57$. RTs differed as a function of the attentional condition (valid vs. neutral vs. invalid) with shortest RTs in response to validly cued targets, intermediate RTs for neutrally cued targets and longest RTs for invalidly cued targets. No main effect of group or interaction between group and validity were found. Pairwise post-hoc comparisons of the estimated marginal means for the three attentional conditions (valid, invalid, neutral) showed significant costs (invalid > neutral, $p<.001$), benefits (valid < neutral, $p<.001$) and a total attention directing effect (invalid > valid, $p<.001$).

Table 2. Mean RTs (and SEs) in ms across attentional conditions and groups.

| | DP patients | | Control patients | |
|---|---|---|---|---|
| | Mean | SE | Mean | SE |
| Overall RT | 448.34 | 15.20 | 452.68 | 16.46 |
| Valid RT | 428.68 | 13.69 | 437.23 | 15.50 |

| | | | | |
|---|---|---|---|---|
| Neutral RT | 446.21 | 16.64 | 447.41 | 15.88 |
| Invalid RT | 470.13 | 17.31 | 473.41 | 18.41 |

### 3.2 ERP amplitudes

Figure 2 depicts the ERPs elicited by validly, neutrally and invalidly cued non-targets separately for DP and Control patients. In both groups a typical sequence of visual event-related components can be seen (P1, N1, P2-N2, P3). Differences between DP and Control patients are observable on P1, where a significant interaction between group and validity was found, $F(2,25)=3.52$, $p=.045$, partial $\eta^2=.22$. When analysing both groups separately, a main effect of validity was only observable in Control patients, $F(2,12)=11.84$, $p<.001$, partial $\eta^2=.66$, but not in DP patients ($F(2,12)=1.45$, $p=.27$, partial $\eta^2=.19$). For Control patients, pairwise post-hoc comparisons of the three attentional conditions (valid, invalid, neutral) showed a total attention directing effect (valid > invalid; $p=.033$) and attentional costs (invalid < neutral; $p=.003$), reflected in smaller P1 components for invalidly versus validly or neutrally cued stimuli. No benefits of spatial cueing were found (valid > neutral, $p=1.0$). Since it is known that attentional function is related to education, we needed to exclude the possibility that differing levels of education in our two patient groups could explain the differing P1 costs (see Table 1; level of education differed by $p=.085$). To this

end, we conducted a Pearson product moment correlation between P1 costs and level of education, which found that there was no relationship between these variables ($r=-.23$, $p=.233$). In other words, the slightly lower education of our DP patients could not account for the absence of attentional costs over P1.

For N1, no significant interaction between group and validity ($F(2,25)<1$, $p=.803$, partial $\eta^2<.02$) and no significant main effect of group were found. There was a significant overall main effect of validity ($F(2,25)=19.20$, $p<.001$, partial $\eta^2=.61$). Pairwise post-hoc comparisons revealed a total attention directing effect (valid > invalid[1]; $p<.001$) that was reflected in greater N1 amplitudes resulting from validly versus invalidly cued stimuli. Additionally, benefits of spatial cueing were present (valid > neutral[1], $p=.028$), while costs just missed significance (invalid < neutral[1], $p=.051$).

For the subsequent components (P2-N2 and P3), no significant interactions between group and validity ($F(2,25)<1$, $p\geq.478$, partial $\eta^2\leq.03$) and no significant main effects of group were found. For both P2-N2 and P3, we found a main effect of validity (P2-N2: $F(2,25)=64.63$, $p<.001$, partial $\eta^2=.84$; P3:

[1] Size of ERP amplitude is meant here; but note that the N1 and N2 are negative deflections, such that larger amplitudes are indicated by lower voltages.

$F(2,25)=10.53$, $p=.001$, partial $\eta^2=.29$). Pairwise post-hoc comparisons revealed significant total attention directing effects in both components (valid > invalid[1]; $p \leq .024$). While for P2-N2 this effect consisted of costs of spatial cueing (invalid < neutral[1], $p<.001$), over P3 benefits of spatial cueing were observed (valid > neutral[1], $p=.001$).

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Figure 2 about here

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## 4. Discussion

Using event-related-potentials within a spatial cueing paradigm we investigated potential effects of depersonalisation on the mechanisms of spatial selective attention. To this end, we compared a DP patient group with psychosomatic patients who had comparable levels of anxiety and depression but no DP symptoms. In line with Adler et al (2014), DP patients demonstrated reduced attentional costs. Our Control patients allows us to conclude that these attentional alterations are specific to DP rather than a consequence of mental illness per se (cf. Adler et al., 2014, who compared with healthy controls). More importantly, we show that reduced attentional costs in DP patients were confined

to the visual ERP component P1 (135-150 ms post stimulus onset). This suggests that DP affects early, sensory stages of selective information processing.

More specifically, Control patients had lower P1 amplitudes for invalid compared to neutral stimuli, which is a typical finding within the attentional literature (e.g., Hillyard & Anllo-Vento, 1998; Luck & Hillyard, 1995; Rüsseler & Münte, 2005). Patients with DP, however, showed no such attenuation of processing stimuli at invalidly cued locations over P1. No group differences were found for attentional effects at any of the subsequent ERP components (N1, P2-N2, P3). Both groups showed enhanced N1 and P3 for validly cued relative to neutral stimuli, demonstrating intact attentional benefits from spatial cueing (Hillyard & Anllo-Vento, 1998; Luck & Hillyard, 1995; Hillyard & Kutas, 1983; Luck, Hillyard, Mouloua, Woldorff, Clark, & Hawkins, 1994; Pérez-Edgar, Fox, Cohn, & Kovacs, 2006). Both groups also showed intact attentional costs over P2-N2, that is, an attenuation of processing for invalidly cued relative to neutrally cued stimuli. This "processing negativity" is thought to be associated with stimulus identification and feature classification (Eimer, 2014; Pérez-Edgar et al., 2006).

In the following we will discuss attentional mechanisms as reflected by visual ERPs in order to shed light on which aspects of cortical attentional functioning may be altered, and which may be preserved, in DP. This will be followed by a discussion of the clinical relevance of these findings.

Typically, P1 is the earliest visual component found to be affected by endogenous processes, including spatial and non-spatial selective attention (e.g., Mangun, 1995; Talsma et al., 2007; Taylor, 2002; for reviews see Gazzaley & Nobre, 2012; Eimer, 2014). It has been localised to neural generators in early visual extrastriatal cortex in middle occipital and fusiform gyrus (V3, V4; e.g., Di Russo & Pitzalis, 2013; Di Russo et al., 2002, 2003). The lack of P1 attentional attenuation in DP patients might indicate a reduced suppression of stimuli at to-be-ignored locations. A similar conclusion was drawn from our earlier behavioral findings (Adler et al., 2014). However, the present results extend this by indicating that reduced suppression takes place at the early, sensory stages of cortical processing. We propose that altered attentional functioning in DP encompasses the sensory gain control mechanism operating at this stage. Sensory gain control is described as attention-induced changes in the signal-to-noise-ratio of stimuli (Hillyard, Vogel, & Luck, 1998). The augmented signal-to-noise-ratio is thought to be a consequence of both a suppression of noise at unattended locations and an enhancement of stimuli at attended locations. Suppression, reflected in attentional costs, was found to be associated with changes over the P1 component (Hopfinger et al., 2004; Hillyard et al., 1998), whereas enhancement, reflected in attentional benefits, has been linked to changes over the subsequent N1 component (Luck et al., 1994; Talsma, Mulckhuyse, Slagter, & Theeuwes, 2007). To the best of our knowledge, this is

the first study to show that individuals with DP do not show suppression of stimuli at unattended locations at early (P1) stages of cortical processing.

Depersonalisation does not seem to affect signal enhancement aspects of sensory gain control (N1), or attentional mechanisms at later processing stages (P2-N2, P3). Over N1, both groups of patients showed benefits of attentional engagement, which reflect intact attentional orienting as well as an intact enhancement of stimuli at attended locations for both groups in our study (see Luck et al., 1994; Talsma et al., 2007; for similar findings in non-patients). This suggests that depersonalisation is not associated with weakened attentional orienting through the universal disregarding of spatial cues.

The total attention-directing effect found over N1 carried through to the P2-N2 complex for both groups, which is also in line with results from healthy controls (Eimer, 2014; Eimer & Forster, 2003; Eimer & Schröger, 1998; Karayanidis & Michie, 1996; Teder, Alho, Reinikainen, & Näätänen, 1993). In addition, we found that over the P2-N2 complex, attentional effects primarily reflected attentional costs. This suggests that the suppression of distracting input might be more relevant than the enhancement of an attended stimulus during post-perceptual processing stages, such as stimulus identification and feature classification (Eimer, 2014; Pérez-Edgar et al., 2006). These N1 enhancement and later suppression processes were clearly intact in both our patient groups.

The same was true for attentional effects over P3, which is thought to reflect the comparison of sensory information with memorised representations (e.g., target representations) (e.g., Kok, 2001; Linden, 2005; Polich, 2007). Our results for P3 indicate that memory comparison is accompanied by an enhancement of the stimulus at the attended location, rather than by suppression of irrelevant information, for both groups of patients *(*see Eimer & Schröger, 1995; Müller & Hillyard, 2000; for similar findings in non-patients*)*. Stimulus enhancement may be beneficial for selecting the correct behavioral response (button press vs. no button press).

In summary, data from our control group conforms to the typical patterns of ERP effects related to the performance of visual spatial attention tasks in healthy people. In contrast, DP patients showed distinct attentional alterations over the P1 component, which can be interpreted as diminished early-stage suppression of sensory input from irrelevant locations. As a consequence, stimuli outside the current attentional focus may be more likely to attract attention in people with DP. At the same time, such stimuli are not more likely to attract further stimulus processing (e.g., for stimulus classification) as they did not affect later, cognitive or post-perceptual processing mechanisms, reflected by similar attentional costs over P2-N2 in patients with and without DP.

Adaptive and coherent behaviour strongly depends on a functional balance between top-down and bottom-up driven attention (Corbetta & Shulman, 2002; Berti & Schröger, 2003; Spalek, Falcon, & di Lollo, 2006; Adler, Giabbiconi, & Mueller, 2009), and our results show that DP may be associated with an imbalance in favour of bottom-up modes. It can be expected that within the present paradigm the spatially informative cue guides attention to the predicted location in a top-down manner. An invalidly cued event, however, induces a bottom-up, sensory-driving capturing of attention to the opposite side. Therefore, smaller attentional costs (invalid vs neutral cued events), as observed in DP compared to control patients, suggest a stronger impact of the bottom-up mode of attention. This relative imbalance is supported by neural abnormalities in these pathways in DP patients (Corbetta & Shulman, 2002; Natale, Marzi, & Macaluso, 2010; Simeon, Guralnik, Hazlett, Spiegel-Cohen, Hollander, & Buchsbaum, 2000), and may be responsible for a stronger responsiveness to sudden events. Decreased suppression over P1 may thus be a precursor for the increased distractibility of DP patients (Guralnik et al., 2000, 2007; Lemche et al., 2016), and their reported difficulties with concentration.

Future studies could now directly investigate bottom-up driven attentional processes in depersonalisation, for example through the use of an exogenous cueing paradigm (e.g., Posner et al., 1984), or a direct examination of the

functional integrity of sensory gating. For example, studies could investigate auditory P50, an early evoked neural response to paired auditory stimuli that is maximal over the vertex and is suppressed by stimulus repetition. This inhibitory gating at P50 has been shown to be reduced in schizophrenia, which is also marked by alterations in other measures of sensory function (including visual P1; for a review see Javitt & Freedman, 2014).

In the present study, attentional alterations from DP affected P1 but did not have a (negative) impact on response times, which were comparable across groups. Rather than concluding that DP is unrelated to greater distractibility, we suggest that such impairments occur only when the underlying neurophysiological changes exceed a certain threshold. Discrepancies between ERPs and behaviour like this are typically attributed to the greater sensitivity of ERP measures compared to behavioural responses (Bar-Haim, Lamy, & Glickman, 2005; Quaedflieg et al., 2013; see also Javitt & Freedman, 2014; Richards, 2000; Xu, Li, Diao, Fan, & Yang, 2016). Quaedflieg et al. (2013) showed ERP effects related to early emotional processing differed between low and high DP groups, while the corresponding behavioural measure (emotion-induced blindness, EIB) did not. The authors argued that this might be due to the use of a traditional EIB paradigm with stimuli that were possibly not emotionally intensive enough to bring out behavioural differences. Similarly, our attentional paradigm used stimuli

that induced DP-related changes at the electrophysiological level, but were possibly not distracting enough to induce further changes in behaviour. In line with this, we previously found that differences between DP and control groups were present only under conditions of high attentional demand (Adler et al., 2014). It is therefore likely, that the observed underlying cortical effects lead to concentration problems only in specific conditions, such as when the surrounding environment is more attentionally demanding (e.g., contains more complex stimuli in multiple sensory modalities). This is the case in every-day life. In an experimental task with increased attentional demands, one would expect that attentional suppression over P1 increases in the Control group, but not in the DP group. This interpretation is also in line with the fact that DP is not associated with general intellectual impairment but with deficits in very specific functions (Guralnik et al. 2000; Guralnik et al. 2007; Lemche et al., 2016).

Our findings raise several interesting questions. What causes the association between DP and decreased attentional suppression of irrelevant stimuli, and to what extent can it be claimed that the potentially ensuing greater distractibility may be driven by purely bottom-up attentional mechanisms?

It may be proposed that stimuli in irrelevant locations attract atypical sensory gain from the bottom up. However, it is likely that pure stimulus characteristics are

less important for this process than the circumstances in which these stimuli appear. Previous studies have shown that DP patients experience their symptoms more strongly in certain situations (e.g., in noisy environments, and in social or emotionally taxing situations) (Simeon et al., 1997). As such situations may be seen as more stressful, patients with DP may perceive the same stimuli as more threatening in these, relative to other, situations. For example, our experimental task may have induced performance pressures that led patients with DP to attach greater relevance to stimuli in irrelevant locations as they may be perceived as potentially threatening. In line with this idea, P1 responses to simple geometric stimuli can be enhanced following the presentation of emotional faces in observers with high levels of fear of negative evaluation (a core symptom of social anxiety) (Rossignol et al., 2013; for similar findings see also Kolassa, Kolassa, Bergmann, Lauche, Dilger, Miltner, & Musial, 2009; Peschard, Philippot, Joassin, & Rossignol, 2013). From this and the present results we hypothesise that the greater distractibility experienced in DP is not a purely sensory-perceptual process but determined by the way in which a situation is experienced by the patient. In other words, top-down effects like this may add to modulated attentional processing in DP. It is worth noting that top-down effects on sensory distraction are well documented in healthy participants (see, for instance, Berti & Schröger, 2003).

Further studies could also investigate the interaction between attentional and situational or emotional processes, as well as their potential relationship with the bodily self in depersonalisation. There are indications that such interactions may play a role in mediating DP symptomatology. For example, yoga or meditation can help some patients with DP, while others benefit from physical exercise (Simeon et al., 2004). All these activities are body-related, but also contain important attentional components. The increased focus on one's own bodily states may alleviate symptoms of disembodiment or self-estrangement, and may even alleviate other DP symptoms, such as the attentional distractibility found in our study. Future studies may want to probe the likely complexities of these relationships, as well as the neural correlates with which they are associated.

### 4.1. Limitations

The present study is not without limitations. For example, a larger sample of DP patients ($N > 14$) would allow us to generalise our findings of DP-related attentional differences to all DP patients more confidently. While attentional effects, where present, were clearly significant ($p \leq .001$) within a group as well as overall, the critical difference in DP patients was a lack of attentional suppression (a null effect). To assist the generalisation of our findings more broadly, it would also have been useful to include a healthy control group, as in

our previous behavioural study (Adler et al., 2014). The comparison with patients who differed only in DP symptomatology, and not in other factors such as anxiety or depression, was critical to exclude the possibility that differences between groups could be due to reduced mental health rather than to DP in particular. The inclusion of healthy controls might have helped to measure whether both DP and non-DP patients differ from healthy controls in attentional processing over certain ERP components, which our behavioural study was not able to show. While we think it is unlikely to have uncovered qualitative differences, since all patients showed ERP effects of attention comparable to those reported in the literature on healthy adults (with the exception of P1 suppression in the DP patient group), comparisons with healthy controls could have delineated interesting quantitative differences in attentional effects.

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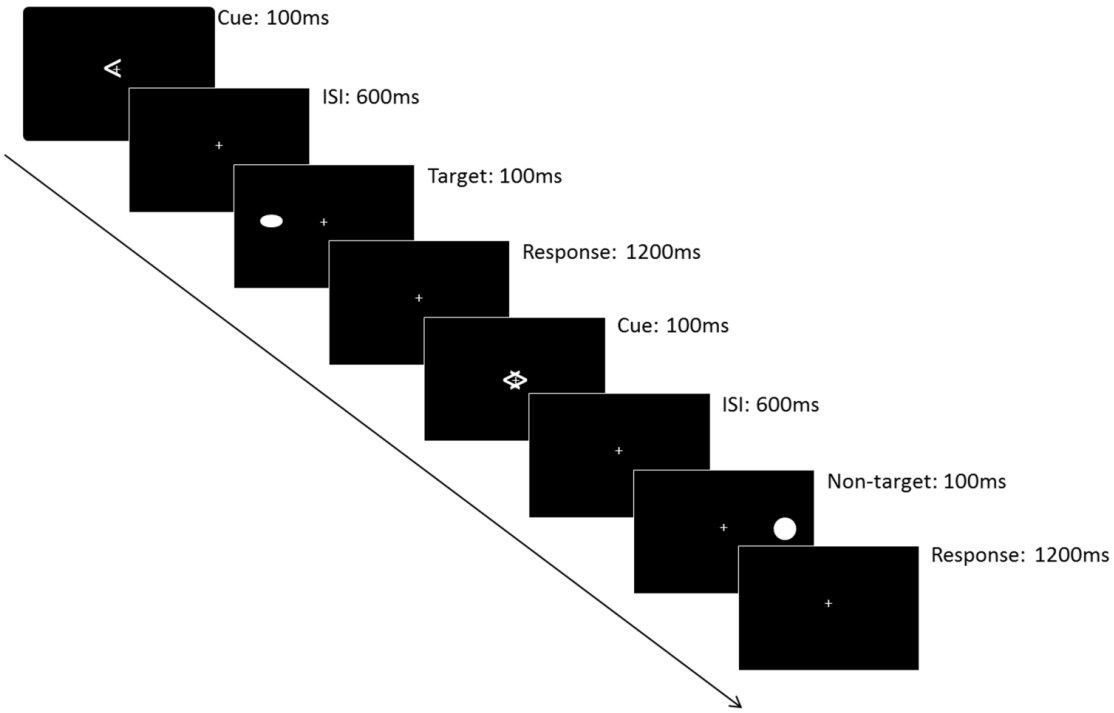
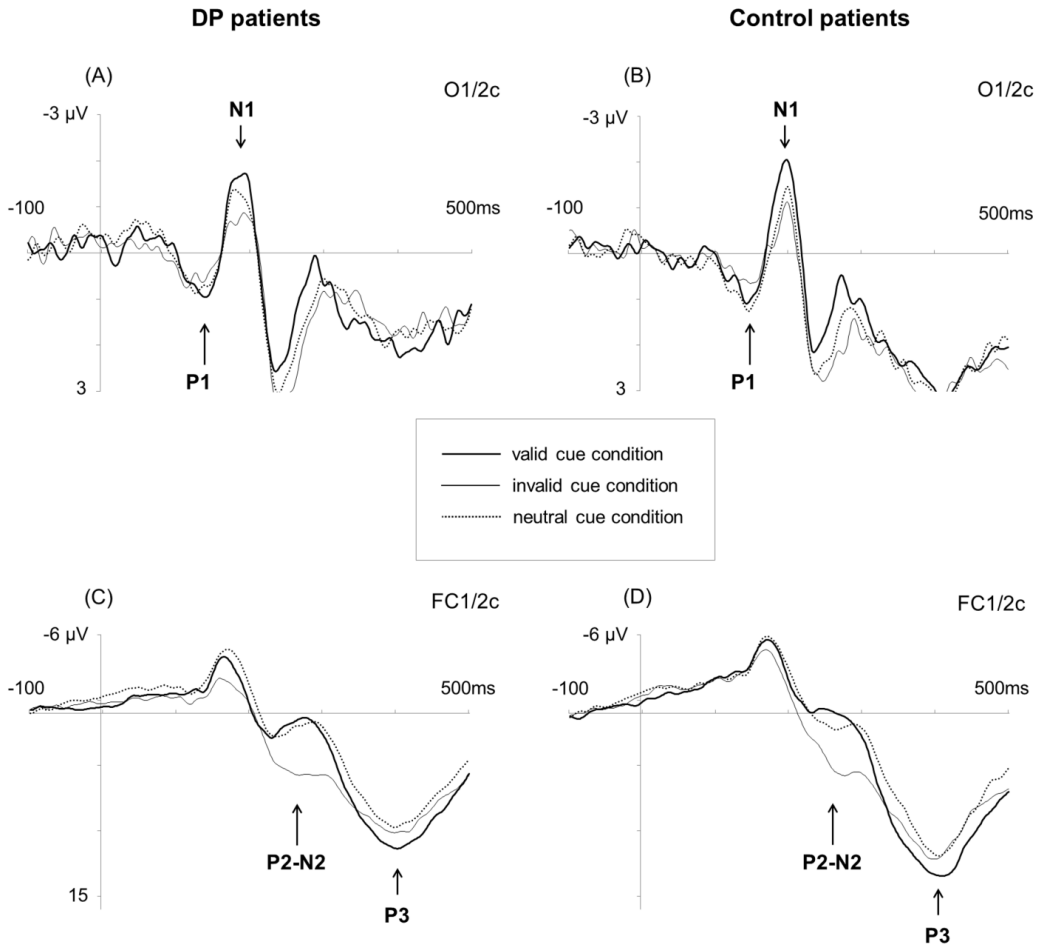
Figure legends

**Figure 1.** Trial sequence showing two different trial types (target preceded by valid cue, non-target preceded by neutral cue) and the timing of events.

**Figure 2.** ERPs for DP patients (A and C) and Control patients (B and D) group in response to non-target stimuli in valid (thick line), invalid (thin line) and neutral (dotted line) trials. For components P1 and N1 the ERPs at O1/2c are shown (A and B) representing the analysed cluster of electrodes located over visual cortex (PO3/4c, POZ, OZ, O1/2c). For components P2-N2 and P3 the ERPs at FC2 are shown (C and D) representing the analysed fronto-central electrode cluster (P2-N2: FC1, FC2, Cz, FCz, Fz; P3: F1, F2, FC1, FC2).


Cue: 100ms
ISI: 600ms
Target: 100ms
Response: 1200ms
Cue: 100ms
ISI: 600ms
Non-target: 100ms
Response: 1200ms


DP patients
Control patients
(A)
O1/2c
-3 μV
N1
-100
500ms
P1
3
(B)
O1/2c
-3 μV
N1
-100
500ms
P1
3
valid cue condition
invalid cue condition
neutral cue condition
(C)
FC1/2c
-6 μV
-100
500ms
P2-N2
P3
15
(D)
FC1/2c
-6 μV
-100
500ms
P2-N2
P3