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Reliability in reporting perceptual experience: Behaviour and electrophysiology in hemianopic patients

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ABSTRACT

Patients with hemianopia can present with the so called blindsight phenomenon: the ability to perform above chance in the absence of acknowledged awareness. Proper awareness reports are, thus, crucial to distinguish pure forms of blindsight from forms of conscious, yet degraded, vision. It has, in fact, been recently shown that 1) dichotomous and graded measures to assess awareness can lead to different behavioural results in patients with hemianopia and that 2) different grades of perceptual clarity show different electrophysiological correlates in healthy participants. Here, in hemianopic patients, we assessed awareness by means of the four-point Perceptual Awareness Scale (PAS) and investigated its neural correlates with Event Related Potentials (ERPs). Results showed that patients, in most of the cases, can rate the clarity of their perceptual experience in a graded manner. Moreover, graded perceptual experiences correlated with the amplitude of deflections in ERPs. These results call for the need to assess perceptual awareness with graded measures and for the importance to use electrophysiological data to correlate behaviour with neural processing.

1. Introduction

A lesion or disconnection of the primary visual cortex (V1) leads to the experience of a region of blindness in the corresponding portion of the visual field (Holmes, 1945). However, some patients, despite denying being able to see the stimuli presented to their impaired visual field, can accurately detect, localize and discriminate them (Poppel et al., 1973; Weiskrantz et al., 1974). This phenomenon has been termed “blindsight” (Weiskrantz et al., 1974), to signal the paradox of the absence of awareness (“blind”) in the presence of above chance performance (“sight”). Although this intriguing finding was at first taken with some scepticism, throughout the years it received robust and consistent evidence (Weiskrantz, 2009, 1996). Weiskrantz’ insight was to ask patients to guess about the stimuli (discrimination task) they were presented within their impaired visual field, and to use a commentary key about their awareness of the stimulus on a trial-by-trial basis, i.e. the so-called “commentary key paradigm” (Berlucchi, 2017; Weiskrantz, 1986). By putting together these two self-reports, it was, thus, possible to contrast accuracy in conditions in which patients reported to have seen the stimuli (aware trials) with those in which patients reported to have guessed about their presence (unaware trials).

The astonishing finding, that is the core of the blindsight Type I phenomenon (Celeghin et al., 2017; Weiskrantz, 1998a), was that when patients reported no awareness of the stimulus on the commentary key, they were, nevertheless, accurate about it in the discrimination task. In this respect, it is, thus, evident the crucial importance of patients’ reliable reports when using a commentary key paradigm. Indeed, to be classified as blindsight, above chance behaviour needs to be associated with a total loss of perceptual awareness. Along the years, however, some hemianopic patients were found to show some kind of awareness of the stimuli presented to their impaired visual field. This conscious experience of the stimuli can mainly be of two kinds (Mazzi et al., 2016): a non-visual knowledge/feeling that something has occurred in the impaired visual field (the so-called blindsight Type II; Weiskrantz, 1998a) or a conscious visual experience of the stimulus, although perceived in a degraded form (see Mazzi et al., 2017b for a recent review). In this respect, also reliability of the commentary key needs to be taken into account. Indeed, it has been claimed that the original commentary key paradigm, using only two report levels (aware and unaware), “might be too crude a distinction” (Weiskrantz, 1998b) and that more likely “awareness would fall on a continuum than a discrete scale” (Sahraie et al., 2010). Following this logic, it could, thus, be the case that “the “unaware” mode may contain some “smidgen” of awareness” (Weiskrantz, 1998b). If this is true, then, what is sometimes considered

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as a blindsight performance could instead be due to conscious, yet degraded, vision. Unfortunately, few studies have investigated this possibility (Mazzi et al., 2016; Overgaard et al., 2008). With respect to the most recent paper, a hemianopic patient (SL) was requested to discriminate several different features of stimuli presented in her impaired visual field and asked to rate her awareness with both a dichotomous and a continuous scale. Noteworthy, the patient showed blindsight performance on the dichotomous scale, which disappeared when using a graded scale, the Perceptual Awareness Scale (PAS; Ramsøy and Overgaard, 2004): her behaviour was therefore better explained as degraded conscious vision. The authors, in agreement with Weiskrantz' proposal, interpreted this discrepancy by suggesting that patients, when using a dichotomous scale, may be reluctant to acknowledge awareness for the kind of experience they have in their impaired visual field and they may, thus, produce false negative responses (i.e. stating that they did not see a stimulus). Conversely, a more graded scale would allow the patients to be less conservative in assessing awareness of the stimuli and, thus, produce more "aware" responses.

Together with behavioural responses, another very informative approach in the field of awareness is to look for the neural activity correlating with the presence/absence of conscious experience. In this respect, electroencephalography (EEG) and more specifically event-related potentials (ERPs), thanks to their high temporal resolution, seem to be the best candidates for this purpose.

In literature, two components have been found to correlate with visual awareness: the Visual Awareness Negativity (VAN) and the Late Positivity (LP) (Koivisto et al., 2016; Koivisto and Revonsuo, 2003; Pitts et al., 2014; Railo et al., 2015), thought to reflect, respectively, the phenomenal content, i.e. the actual content of the perceptual experience, and access properties of perceptual awareness, i.e. the ability to report, remember or act on such perceptual experiences (Block, 2005). The VAN is a negative difference wave between "aware" and "unaware" trials, peaks at about 200 ms after stimulus onset and has a maximal amplitude at occipito-temporal electrodes contralateral to stimulus presentation (Koivisto et al., 2008a). The LP is another, positive, difference wave between "aware" and "unaware" trials with a latency between 300 and 400 ms after stimulus onset, mainly observed at centro-parietal sites (Del Cul et al., 2007). Interestingly, both these difference waves were found to be modulated by the clarity of conscious experience as measured with the PAS (Tagliabue et al., 2016): their amplitude increased as the quality of conscious experience of healthy participants increased. Putting together all these pieces of evidence, it would thus be of extreme interest to investigate whether similar results can be obtained in hemianopic patients when presented with stimuli in their impaired visual field. To do so, in the present paper, we asked four patients with visual field defects to discriminate the contrast of visual stimuli briefly presented within their impaired visual field. A graded scale, the PAS, was used as a commentary key in order to allow the patients to rate their phenomenal experience on different levels of awareness. Importantly, we also investigated whether these levels of awareness correlated with ERP difference waves, thought to reflect phenomenal (as detected by the VAN) and access (as detected by the LP) properties of awareness.

2. Method

2.1. Patients

Patient AM: A right-handed male patient, 66 years old, suffered from a bilateral altitudinal hemianopia on the upper part of his visual field (Fig. 1B) resulting from an ischemic stroke. MRI evidenced a bilateral lesion of the lingual gyrus extending to the lower bank of the primary visual cortex in the right hemisphere (Fig. 1A). For further details, see Mazzi et al. (2017a). The patient was tested 4 and half years after his neurological event.

Patient FB: A right-handed female patient, 50 years old, suffered from a left superior quadrantanopia (Fig. 1B) resulting from a haemorrhagic stroke. MRI evidenced a widespread lesion of the right temporal, parietal and occipital lobe involving the superior occipital gyrus and part of the middle occipital gyrus (Fig. 1A). For further details, see the paper by Sanchez-Lopez et al. (2017). The patient was tested 2 years after her neurological event.

Patient LF: A right-handed female patient, 51 years old, suffered from a left superior quadrantanopia (Fig. 1B) resulting from an ischemic stroke. MRI evidenced a lesion of the anterior portion of the right calcarine fissure up to the origin of the parieto-occipital fissure (Fig. 1A). For further details, see Bollini et al. (2017). The patient was tested 4 years after her neurological event.

Patient SL: A right-handed female patient, 49 years old, suffered from a right homonymous hemianopia (Fig. 1B) resulting from an ischemic stroke with haemorrhagic evolution. MRI evidenced a complete destruction of her left V1, including the lingual gyrus and the calcarine fissure (Fig. 1A). For further details, see Bagattini et al. (2015) and Mazzi et al. (2014). The patient was tested 7 years after her neurological event.

The patients gave their written informed consent prior to participate in the study and were free to withdraw at any time. The study was approved by the local Ethics Committee and conducted in accordance with the 2013 Declaration of Helsinki.

2.1.1. Stimuli

The stimuli were unilaterally displayed in the impaired visual field of each patient for 60 ms and consisted of 2° diameter grey circles, either lighter or darker than the grey background, which had a luminance of 6.66 cd/m^2. The two stimulus luminance values were chosen on the basis of a previous detection threshold session (AM: darker: 4.75 cd/m^2, lighter: 8.42 cd/m^2; FB: darker: 6.52 cd/m^2, lighter: 7.61 cd/m^2; LF: darker: 1.09 cd/m^2, lighter: 14.13 cd/m^2; SL: darker: 0.41 cd/m^2, lighter: 9.65 cd/m^2), see Tagliabue et al. (2016) for more details. The eccentricity of the stimuli located in the impaired field was tailored to the patients' visual field defects, according to their latest perimetry (AM: 2° above and 10° to the right of fixation; FB: 6° above and 4° to the left of fixation; LF: 8° above and 11° to the left of fixation; SL: 7° above and 12° to the right of fixation). Catch trials, in which no stimulus was presented, were also included in the experiment (10%) to monitor patients' false alarm rate.

2.1.2. Experimental procedure

The patients sat in a dimly lit testing room in front of a 17-inc CRT monitor (resolution 1024 × 768, refresh rate of 85 Hz) placed at a viewing distance of 57 cm, with their head laying on an adjustable chin rest. On-line monitoring of patients' eye movements was performed by an infrared camera to verify that they maintained fixation during the stimulus presentation. The trial sequence is depicted in Fig. 1C, see Tagliabue et al. (2016) for more details.

Throughout the EEG recording session, hemianopic patients were requested to provide two off-line responses afterwards a fixed period following stimulus presentation: (1) a 2-alternative forced-choice (2AFC) response on stimulus contrast discrimination, by pressing a key for "lighter" and another key for "darker" than the background. The patients were asked to guess when no stimulus discrimination was possible (i.e. for catch trials or unseen stimuli). (2) A commentary key to rate the quality of their perception on the four-point Perceptual Awareness Scale (PAS; Ramsøy and Overgaard, 2004): 0) no experience of the stimulus, 1) a brief glimpse, meaning that the participant saw something but could not discriminate the brightness of the stimulus (lighter or darker than the background), 2) an almost clear experience and 3) a clear experience. See Tagliabue et al. (2016) for a more detailed procedure to ascertain patients' understanding of the scale.

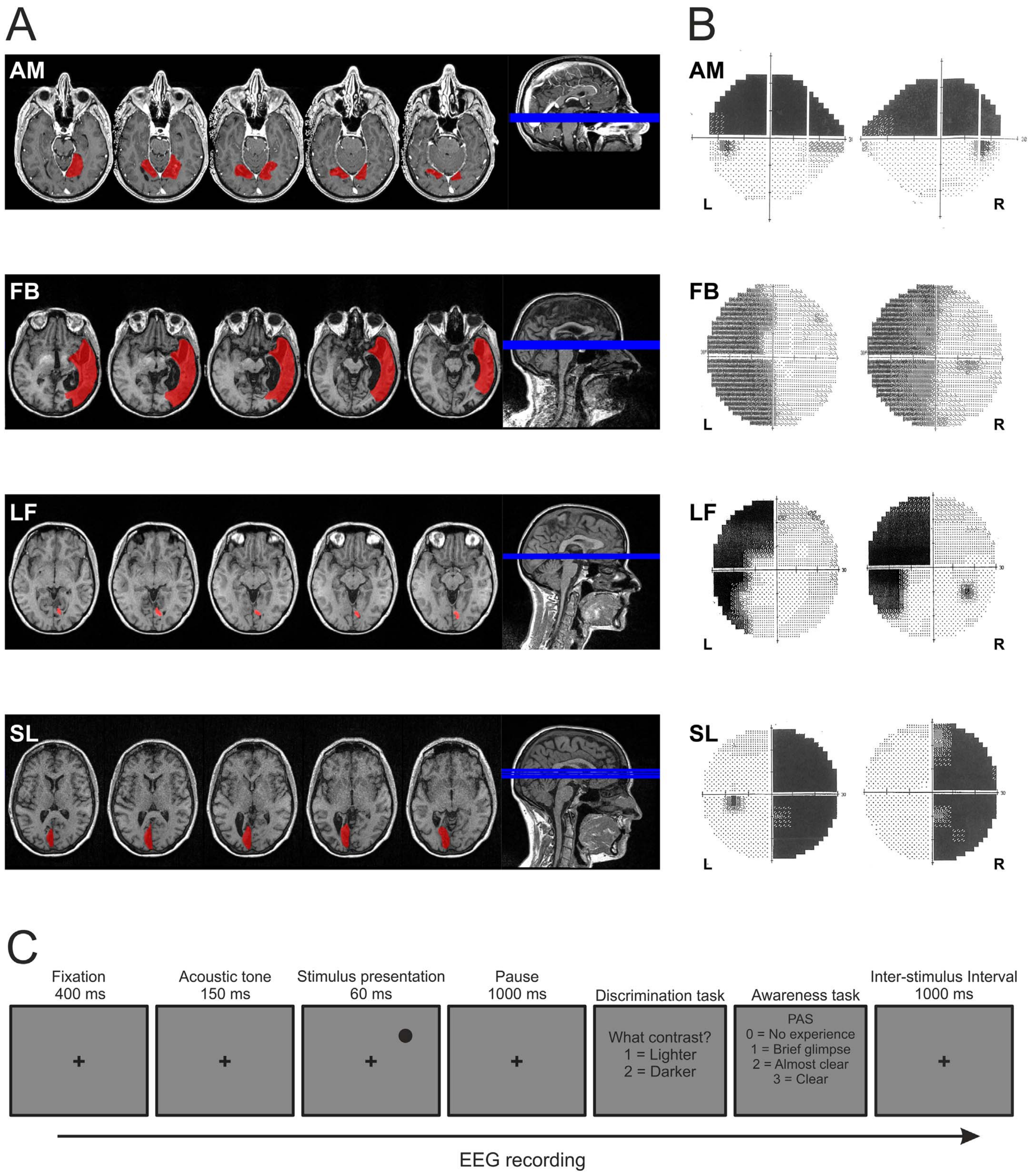

Fig. 1. A) Anatomical reconstruction of patients' brain lesions (according to neurological convention, i.e. where left hemisphere is on the left side of the image). B) Visual field defect of each patient. C) Single trial structure of the experimental procedure: A fixation cross was presented for 400 ms followed by a warning acoustic tone lasting 150 ms. Then, a random interval preceded stimulus presentation (60 ms) in the impaired visual field of patients. After a 1000 ms pause the patients had to discriminate the brightness of the stimulus (Discrimination task) and then rate the clarity of their perception on the PAS (Awareness task).

The EEG experimental session was divided into 30 blocks of 33 trials each (15 lighter, 15 darker and 3 stimulus-absent trials), thus yielding a total of 990 trials. The order of the trials was fully randomized. The EEG experiment was programmed and run using E-prime (Psychology Software Tools, Inc., Pittsburgh, PA, USA; https://www.pstnet.com/eprime.cfm).

2.1.3. EEG recording and event-related brain potential (ERP) analysis

EEG signal was continuously recorded with BrainAmp system (Brain Products GmbH, Munich, Germany – BrainVision Recorder) using a Fast'n Easy cap with 59 Ag/AgCl pellet pin electrodes (EasyCap GmbH, Herrsching, Germany) placed according to the 10–10 International System (O1, Oz, O2, PO7, PO3, POz, PO4, PO8, P7, P5, P3, P1, Pz, P2, P4, P6, P8, TP7, CP5, CP3, CP1, CPz, CP2, CP4, CP6, TP8, T7, C5, C3, C1, Cz, C2, C4, C6, T8, FT7, FC5, FC3, FC1, FCz, FC2, FC4, FC6, FT8, F7, F5, F3, F1, Fz, F2, F4, F6, F8, AF7, AF3, AF4, AF8, FP1, FP2). Four additional electrodes were used for monitoring blinks and eye movements. Horizontal and vertical eye movements were detected respectively with electrodes placed at the left and right canthi and above and below the right eye. Other two extra electrodes served as ground (AFz) and online reference (right mastoid, RM). Electrode impedances were kept below 5 kΩ. The digitization rate was 1000 Hz with a time constant of 10 s as low cut-off and a high cut-off of 250 Hz. The EEG signal was processed off-line using EEGLAB toolbox version 14 (Delorme and Makeig, 2004) implemented in MATLAB (MathWorks Inc., Natick, MA, USA). Prior to the analysis, continuous raw data were downsampled to 250 Hz and high-pass filtered at 1 Hz. EEG was then re-referenced offline to the average of all scalp electrodes. Moreover, sinusoidal noise (50 − 100 Hz) due to power line was removed by means of the EEGLAB plugin CleanLine prior to data segmentation into 2-second epochs (1 s pre-stimulus). Trials affected by high amplitude artefacts were discarded based on visual inspection with the purpose of facilitating Independent Component Analysis (ICA) convergence. ICA was then performed by using the runica algorithm (Delorme and Makeig, 2004) to reject artefactual ICs related to eye blinks, saccades or muscle activity. Consequently, a low-pass filter of 40 Hz was applied. The epoch window was shortened to 1300 ms, starting 300 ms before the onset of the stimulus, and thereafter baseline corrected on this pre-stimulus period. Before averaging per PAS condition, all segments were visually inspected a second time and rejected when contaminated by any residual eye movements, blinks, strong muscle activity or excessively noisy EEG.

Electrophysiological data from patient FB could not be taken into consideration for analysis due to the huge number of blinks during stimulus presentation ($>$ 90% of trials). The presence of such a high number of artefacts drastically reduced the clean segments to be considered for averaging, thus resulting not to be enough for reliable ERPs. Therefore, statistical analyses were performed on three patients (AM, LF, and SL).

Due to the fact that the three patients included in the EEG analysis (AM, LF and SL) almost never used rating 3 on the PAS (i.e. clearly seen stimuli), the averaging was carried out for three different conditions only: PAS = 0 (correct lighter and darker trials classified as 0 on the PAS scale), PAS = 1 (correct lighter and darker trials classified as 1 on the PAS scale), PAS = 2 (correct lighter and darker trials classified as 2 on the PAS scale). Following EEG pre-processing, the number of trials used for the average was 27, 97 and 139 for PAS = 0, 248, 242 and 253 for PAS = 1, 109, 30 and 57 for PAS = 2, respectively for patients AM, LF and SL.

2.1.4. Statistical analysis

To determine whether patient's accuracy was significantly different from chance (50%), a non-parametric binomial test was performed for each level of the PAS. Moreover, a trend analysis across the different PAS levels was performed to determine whether an increase in the level of perceptual clarity was related to an increase of accuracy.

To run group level statistical analyses aiming to investigate possible electrophysiological differences between PAS ratings, the EEG signal was swapped between right and left hemisphere electrodes in patients AM and LF, as stimulus presentation was lateralized on the basis of the visual field defect of each patient. With this new data arrangement, electrodes placed over the left hemisphere always corresponded to those contralateral to the visual stimulus.

EEGLAB non-parametric permutation statistics (with 2000 permutations) were performed to assess statistical differences between PAS conditions. False discovery rate (FDR) correction was always applied to account for comparison from multiple electrode sites (significance level set at $p < 0.05$ after FDR correction). Specifically, the three conditions (PAS = 0, 1 and 2) were first compared and, subsequently, the unaware condition (PAS = 0) was separately pairwise compared with both PAS = 1 and PAS = 2.

The time windows chosen for the analyses (a 20 ms window from 198 ms to 218 ms for the VAN and a 400 ms window from 416 ms to 816 ms for the LP) were selected in line with previous literature (Koivisto et al., 2008b; Tagliabue et al., 2016) and by visually inspecting the peak latency of both the components of interest (VAN: greatest negative peak at 208 ms in electrode CP5; LP: greatest positive peak at 616 ms in electrode Pz).

3. Results

3.1. Behavioural results

All patients could use the different levels of the PAS, indicating that they could actually grade their own perceptual experiences along this awareness scale. Patients LF and SL never used PAS = 3, while FB never used PAS = 1 but used PAS = 3 a few times (12%). AM used all the levels of the PAS, with PAS = 3 used very few times (1%). Taken together, the mean percentage of responses for the different PAS levels were as follows: PAS = 0: 22%; PAS = 1: 43%; PAS = 2: 32% and PAS = 3: 3% as depicted in Fig. 2A. By inspecting the percentage of responses given by each patient at the different levels of the PAS (Fig. 2C), it seems reasonable to assert that all patients could rate their phenomenal experience in their “blind” field along different levels of clarity. However, FB seemed to use the scale in a different manner than the other three patients, i.e. she never used PAS = 1 and instead shifted to PAS = 2 to indicate her first level of conscious perceptual clarity of the stimuli. This hypothesis could be corroborated by the evidence that for all patients, the great majority of responses are reported for the second (used) level of the PAS (PAS = 1 for AM, LF and SL and PAS = 2 for FB), thus indicating some level of conscious experience for a stimulus not clearly perceived.

Binomial tests showed that patients' accuracy was not different from chance level for PAS = 0 and PAS = 1 (both $ps > 0.05$), whereas for PAS = 2 and PAS = 3 accuracy was above 50% (both $ps < 0.001$). Moreover, a trend analysis showed that patients' performance linearly increased as the perceived clarity of the stimulus increased ($R^2 = 0.90$. $F(1,3) = 231.047$; $p < 0.001$) (see Fig. 2B). These results indicate that, in the present group of patients, we could not find any sign of blindsight Type I (i.e. above chance accuracy when using PAS = 0) and that, to reliably report the contrast of the stimuli, the quality of perception needs to be at least almost clear (PAS = 2 or 3), while a brief glimpse is not enough, in line with previous research (Mazzi et al., 2016).

Importantly, all patients could accurately detect when nothing was presented, as they responded 0 (no experience of the stimulus) on the PAS in almost all the catch trials (AM: 98%; FB: 100%; LF: 98%; SL: 96%), i.e. when the stimulus was actually absent.

3.2. ERPs results

3.2.1. Visual awareness negativity

Fig. 3A shows the topographic scalp distribution of the VAN across PAS conditions in the time window from 198 ms to 218 ms after stimulus presentation. The comparison of ERPs in this time window between the three PAS ratings found a significant difference over a cluster of three left centro-parietal electrodes (P7, P3 and CP3, $p < 0.05$, one-way repeated-measures ANOVA with 2000 permutations and FDR

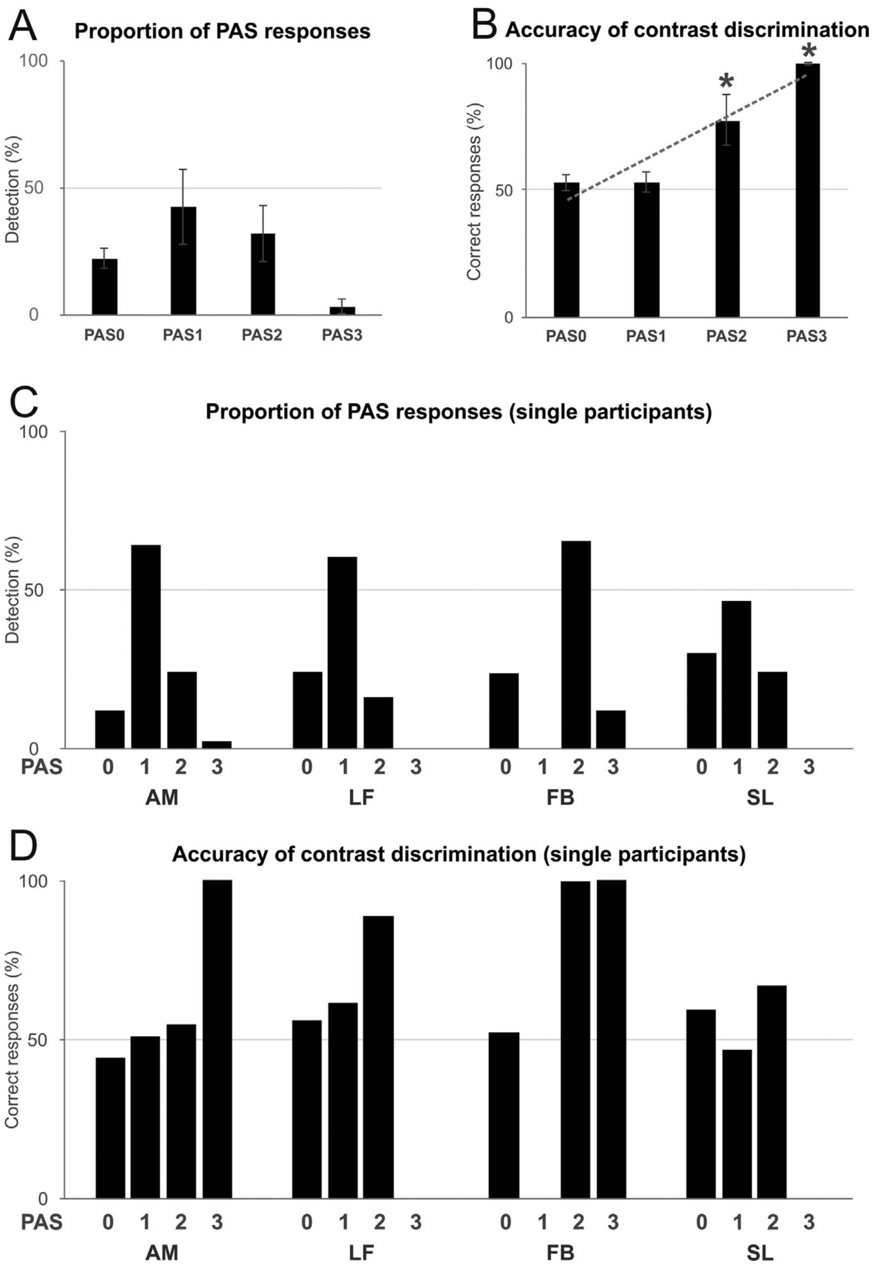

Fig. 2. Behavioural results A) Mean proportion of PAS responses as a function of PAS level. B) Mean percentage of correct responses for all PAS ratings. C) Single patients' percentage of responses at the different levels of the PAS. D) Single patients' percentage of correct responses as a function of PAS level.

correction), as depicted in Fig. 3A.

Moreover, the pairwise comparison between PAS = 0 and PAS = 1 revealed a significant difference over a cluster of electrodes comprising P3, CP1, CP3, CP5, C3 and T8 (again mostly distributed over lateral centro-parietal sites, $p < 0.05$, paired *t*-test based on permutation analysis and FDR correction). The same analysis comparing PAS = 0 versus PAS = 2 showed a significant difference at electrodes P3, P5, P7, CP3, CP5 and C3 ($p < 0.05$).

3.2.2. *Late positivity*

Fig. 3B shows electrical potential maps of the LP mean amplitude across PAS conditions in the time window from 416 ms to 816 ms after stimulus presentation. When considering the comparison between the three PAS levels, no significant differences were observed (see right map of Fig. 3B). Given the small size of our sample ($n = 3$), we decided to perform the pairwise comparisons as well, even though the multi-level analysis did not highlight any differences between conditions, following the logic that this lack of significance might be due to a false negative result. When comparing PAS = 0 with PAS = 1, a significant difference was evident at electrodes PO7, O1, Oz, O2, PO8, C1 and F8, while the comparison between PAS = 0 and PAS = 2 revealed a significant cluster of electrodes including P7, P3, FC1, O2, CP6, C6, FC6, F6, FP2, FT8 (all *p*s < 0.05, paired *t*-test based on permutation analysis and FDR correction). In both cases, the significant clusters were not totally coherent with the typical centro-parietal topography of LP.

4. Discussion

In the present paper, we tested the ability of hemianopic patients to rate the quality of their conscious experience along a graded scale and investigated whether these ratings correlated with specific ERP deflections. Four hemianopic patients took part in the experiment. They were presented with visual stimuli in their "blind" visual field and requested to provide first a 2AFC response on the stimulus feature (i.e. contrast) and then to rate the quality of their perception along a 4-level scale (the PAS, Ramsøy and Overgaard, 2004). At behavioural level, all the patients could, in a portion of trials, report the presence of a visual stimulus and reliably rate their conscious experiences along the levels

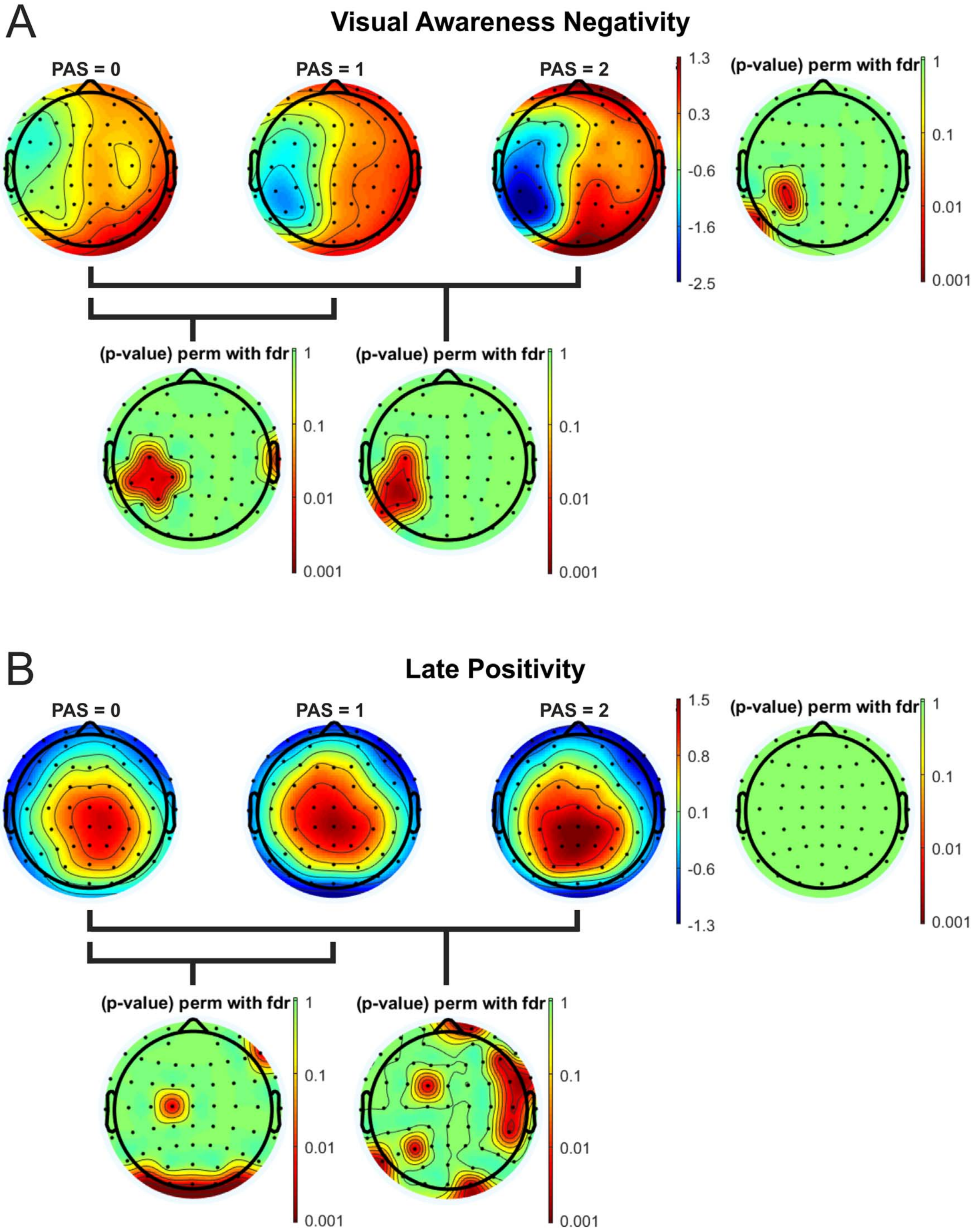

Fig. 3. ERP results. The three maps on the top left of each panel represent the topographic scalp distribution of VAN and LP (µV) across PAS conditions (PAS = 0, PAS = 1, PAS = 2). The map on the right indicates the regions of significant difference when comparing all the PAS ratings ($p < 0.05$, repeated-measures one-way ANOVA with 2000 permutations and FDR correction). Maps on the bottom of each panel show electrodes with significant differences, respectively between PAS = 0 and PAS = 1 (left) and PAS = 0 and PAS = 2 (right) ($p < 0.05$, paired *t*-tests with 2000 permutations and FDR correction). A) VAN (20 ms time window: from 198 to 218 ms). B) LP (400 ms time window: from 416 to 816 ms).

of the scale. Interestingly, all patients but one (FB) used consecutive levels of the PAS, thus showing a graded experience with different levels of clarity in line with those described by the PAS. Patient FB, instead, did not use the intermediate level of the PAS describing her experience as a brief glimpse (PAS = 1), but she rather rated her first level of conscious experience as an almost clear stimulus. Importantly, thus, all patients could use the different levels of the PAS, but not all patients used the scale in the same manner. These findings reinforce the idea that a graded scale could, better than a dichotomous one, reflect the subjective experience patients report for stimuli presented to their “blind” field. On the other hand, though, these findings highlight that a graded scale appears to be a more difficult rating tool when applied to patients and that not all of them use it in the same way. As a consequence, then, when using these kinds of scales, researchers need to also take into account the patient's ability to correctly label different levels/grades of their phenomenal experience in a proper way.

At electrophysiological level, three patients (AM, LF and SL) were analysed. Results showed the presence of both components (VAN and LP) found to be associated to conscious experience (Koivisto and Revonsuo, 2003; Tagliabue et al., 2016). Interestingly, the VAN, the early negative component thought to reflect the actual content of conscious experience, was modulated by the levels of the PAS: i.e. increasing in amplitude as the clarity of the patients' perception increased. The importance of this evidence relates to the fact that, like in healthy participants (Tagliabue et al., 2016), it is possible to find an early neural correlate in temporal and centro-parietal electrodes, contralateral to stimulus presentation, correlating with different qualia elicited by the same external visual stimulus. Moreover, in addition to what can be found in healthy participants, the finding of the present study is even more interesting as it establishes the possibility to find neural correlates for conscious vision within the "blind" field of hemianopic patients. The use of a continuous scale, thus, can provide more evidence on the different grades of perceptual conscious experience and ensure that patient's performance reflects a pure form of blindsight (when patients report no awareness of the stimuli but their performance is above chance), and not some sort of degraded vision (Mazzi et al., 2016) in which their performance correlates with the clarity of their perception.

Conversely, the LP, the late positive component thought to reflect post-perceptual processes (Koivisto and Revonsuo, 2010), although detectable at all PAS levels, was not modulated by awareness ratings over those cortical areas reported in the literature: i.e. it did not significantly increase in amplitude as the clarity of the patients' perceptual experience increased. One possible explanation for the absence of this effect could be that patients, when responding to the PAS, did not have enough perceptual evidence to elicit specific distinct levels of conscious access, due to their abnormal visual experience following cortical damage. Given that the three patients included in the analyses almost never used the level 3 of the PAS (i.e. a clear experience), the phenomenal properties of the stimulus appeared overall too poorly distinguishable when an explicit descriptive report through the different levels of the PAS was required. According to this possible explanation, patients' performance in accurately reporting the stimulus feature was at chance level for two (PAS = 0 and PAS = 1) out of three levels of the PAS. It might, thus, be possible that the actual features of the stimulus cannot be completely accessed to and, as a consequence, the LP component cannot be modulated by the different levels of clarity in giving a specific response. This hypothesis seems to be in line with the formulation of the role of the VAN and LP components recently proposed by Koivisto and colleagues (Koivisto et al., 2016): awareness seems to emerge at the N200 time window (i.e. at the VAN time window) while the accumulation of evidence needed for the subject to make a decision and select a response emerges at the P300 time window (i.e. at the LP time window). Within this theoretical framework, weak but different phenomenal contents of awareness can emerge and be detected by the VAN component, while, at the same time, the amount of evidence accumulated with these different phenomenal contents may not be distinct enough to show a modulation of the LP with respect to the PAS levels used. A note of caution, however, needs to be reported. Indeed, the lack of the LP modulation could simply reflect a false negative effect due to low statistical power in analysing ERPs from only three patients. To solve this problem, more patients need to be studied in future research. Moreover, an important investigation, trying to correlate LP modulation with accuracy (and, thus, post-perceptual processes like the certainty in giving a specific response about stimulus features), should focus on patients showing blindsight. This would, indeed, be essential to relate the presence/absence of access to perceptual awareness (as reflected by the LP component) and above chance accuracy.

Another important implication for the present results stands on the neural correlates of perceptual awareness in the "blind" field. It is, indeed, important to understand what neural structures and mechanisms subserve conscious vision in the absence of direct visual input, as this would provide more information on which areas are necessary for visual awareness. The present findings seem to advocate for a role of the extrastriate cortex in mediating conscious vision in the absence of a functioning primary visual cortex (V1). Indeed, the three patients included into the ERP analysis (AM, LF and SL) suffered from a partial (AM and LF) or complete (SL) lesion of V1. However, these patients can consciously report visual stimuli presented in the corresponding "blind" portion of their visual field and, more importantly, the quality of their phenomenal experience (as measured with the PAS) correlates with activity at temporal and centro-parietal electrodes of the damaged hemisphere. These findings reinforce the idea that the role of V1 in conscious vision needs to be redefined (Silvanto, 2015, 2014, 2008; Silvanto et al., 2008). Indeed, several pieces of evidence (see the review by Mazzi et al., 2017b) seem to show that, although V1 is important for normal conscious vision, at least in creating the conditions for awareness to arise, it is not always essential for it: awareness can in fact arise also in the absence of a functioning V1.

In conclusion, the results of the present paper, in accord with Weiskrantz' legacy, highlight the importance of commentary keys and the use of self-reports in characterizing the phenomenal contents hemianopic patients experience in their "blind" field. Moreover, these data establish the importance of adding electrophysiological measures to correlate these perceptual experiences with neural activity.

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Conflicts of interest

None.

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