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Non-conscious recognition of affect in the absence of striate cortex

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FUNCTIONAL neuroimaging experiments have shown that recognition of emotional expressions does not depend on awareness of visual stimuli and that unseen fear stimuli can activate the amygdala via a colliculo-pulvinar pathway. Perception of emotional expressions in the absence of awareness in normal subjects has some similarities with the unconscious recognition of visual stimuli which is well documented in patients with striate cortex lesions (blindsight). Presumably in these patients residual vision engages alternative extra-striate routes such as the superior colliculus and pulvinar. Against this background, we conjectured that a blindsight subject (GY) might recognize facial expressions presented in his blind field. The present study now provides direct evidence for this claim. *NeuroReport* 10:3759–3763 © 1999 Lippincott Williams & Wilkins.

Key words: Awareness; Blindsight; ERPs; Facial expression; P1

Introduction

Evidence about the absence of conscious awareness in processing emotional information has emerged recently from a number of areas. Neuroimaging studies have shown amygdala activation to emotional stimuli, most notably to fearful faces [1,2]. Subcortical reactions to emotional stimuli have also been registered when stimulus awareness was prevented by backward visual masking of the emotional stimuli [3], including in a fear conditioning paradigm [4]. A prosopagnosic patient unable to recognize facial expressions as a consequence of focal brain damage in the occipito-temporal areas nevertheless showed a sizable impact of facial expressions on recognition of voice affect [5]. Such studies share a similarity with reports of processing of elementary visual stimuli in the absence of awareness in patients with striate cortex lesions (blindsight). These patients can make accurate guesses about the attributes of stimuli presented to their blind field of which they have no awareness.

The pathways of retinal origin that are most likely to be engaged by visual processing in the absence of striate cortex are the superior colliculus and the pulvinar. Neuroimaging studies [4] have provided evidence for selective involvement of these structures in conscious *vs* non-conscious recognition of facial expressions. Thus far, studies of residual visual abilities in patients with blindsight have mostly investigated covert perception of elementary visual information such as presence of a spatial frequency grating, discrimination of simple shape (such as O *vs* X) [6], detection of orientation or of direction of movement [7] or of colour [8–11]. Recently blindsight has been reported for some high level vision stimuli such as words [12]. Given the existence of alternative visual pathways that remain after loss of the pathway to striate cortex with data from studies showing non-conscious processing of emotional information, we conjectured that there might exist non-conscious recognition of facial expressions in such a case.

Here we report the first study of recognition of unseen emotional stimuli in a well-studied 43-year-old blindsight subject, GY (see [13] for a recent list of studies with GY and details about the lesion), who has a right half-field of blindness as a result of damage to his left occipital lobe at the age of 8. Behavioural methods were used to test whether he could discriminate different facial expressions and, if so, whether his good performance reflected covert recognition of the facial expressions rather than discrimination of two patterns of movement, and whether the actual conscious content of the alternative response labels he was given were important for his performance. As a follow-up we provide evidence for visual processing in the blind field obtained with event related potentials (ERPs).

Materials and Methods

Stimuli and tasks: Stimuli consisted of four video fragments showing a female face pronouncing the same sentence with four different facial expressions (happy, sad, angry, fearful). These materials were subsequently used in different presentation conditions. Presentation was either random between left/right visual fields or blocked, the image size could either be small ($10.2 \times 8.2°$) or large ($12.5 \times 10.7°$), and depending on the experiment the forced choice alternatives were either happy *vs* sad, or angry *vs* fearful. Mean luminance of the screen in between stimulus presentations was 1.5 cd/m^2. Mean luminance of the face was 20 cd/m^2 and for the grey frame around the image was 21 cd/m^2. Horizontal separation between the fixation point and the outer edge of the face was 3.6°, for the eye it was 5.1°, and for the center of the face it was 6.4°. Stimulus duration was 1.63 s. All of the responses were made verbally.

In the first experiment a total of 8 blocks were run using different stimulus pairs (happy/sad, angry/sad, angry/fearful), different stimulus sizes (small or big), and different presentation conditions (randomized over left (LVF) or right (RVF) visual fields, or in blocks of trials to either field). In the second experiment, four different video fragments (happy/sad/angry/fearful) were presented in a four-alternative forced-choice design and shown in the RVF. They were presented randomly in two blocks of 72 trials each (18×4 categories). Instructions specified to label the videos as happy, sad, angry or fearful. The duration of each was 1.63 s. In the third experiment, all stimuli were the small size happy/fear faces, with presentation blocked or randomized. In the fourth experiment, The videos were of the same small-sized moving videos as described before with a 6.4° horizontal separation between the fixation point and the centre of the face. All videos were presented in the right visual field with the sound off, in blocks of 60 trials, 30 for each of the two categories being used (happy/sad or angry/fearful). The categories were presented in random order. The two blocks with congruent labels were presented first (first happy/sad, then angry/fearful), and they were followed by the two blocks with non-congruent labels (first angry/fearful videos with happy/sad labels, then happy/sad videos with angry/fearful labels). This series of four blocks was presented twice, so the whole test consisted of eight blocks. Instructions were identical to those of the previous experiments. GY was not informed about the non-congruence between the stimuli and the labels he was instructed to use.

ERP recording and processing: Visual event-related brain potentials were recorded on two separate occasions using a Neuroscan with 64 channels. GY was tested in a dimly lit, electrically shielded room with the head restrained by a chin rest 60 cm from the screen, fixating a central cross. Four blocks of 240 stimuli were presented. Stimuli consisted of complex gray-scale and coloured static normal front faces taken from the Ekman series [14]. Three types of facial expressions appearing randomly either in the good visual field or in the blind visual field were presented (neutral, happy and fearful), for a total of 48 experimental conditions (2 visual hemi-fields $\times$ 2 colours $\times$ 3 emotions $\times$ 2 genders $\times$ 2 identities) each repeated 20 times. Stimulus duration was 1250 ms and the inter-trial interval was randomized between 1000 and 1500 ms. Stimuli were presented with the internal edge of the stimulus at 4.76 of the fixation cross in the center of the screen. Size of stimulus was 6×10 cm. Mean luminance of the room was < 1 cd/m^2, 25 cd/m^2 for the face and <1 cd/m^2 for the screen in between stimulus presentations. When presented in his blind or good visual fields, GY was instructed to discriminate (or guess in the blind field) the gender of the faces by pressing one of two keys.

Horizontal EOG and vertical EOG were monitored using facial bipolar electrodes. EEG was recorded with a left ear reference and amplified with a gain of 30 K and bandpass filtered at 0.01–100 Hz. Impedance was kept below 5 kΩ. EEG and EOG were continuously acquired at a rate of 500 Hz. Epoching was performed 100 ms prior to stimulus onset and continued for 924 ms after stimulus presentation. Data were re-referenced off-line to a common average reference and low-pass filtered at 30 Hz. Amplitudes and latencies of visual components were measured relative to a 100 ms pre-stimulus baseline.

Results

Experiment 1: Our first study used a total of 8 blocks consisting of different stimulus pairs (happy/sad, angry/sad, angry/fearful). The task was a 2AFC and GY was instructed to guess the facial expression shown to his blind field. GY was always flawless with stimuli presented to his intact left hemifield (LVF). When asked to report verbally what he saw in his damaged right hemifield (RVF), GY frequently reported detecting the offset and onset of a white flash, but he never consciously perceived a face or even a moving stimulus. Overall, 333 trials were presented in his right (blind) visual field (Table 1), and he was correct on 220 of them (66%, $Z = 5.86$, $p < 0.005$).

Table 1. Covert recognition of facial expressions

Stimulating pair	Image size	L/R presentation	Correct	p
Happy/fearful	Small	Randomized	22/27	< 0.001
Happy/fearful	Large	Randomized	18/28	NS
Happy/fearful	Small	Blocked	37/58	<0.05
Happy/fearful	Large	Blocked	37/58	< 0.05
Angry/sad	Small	Randomized	15/27	NS
Angry/sad	Small	Blocked	39/54	< 0.01
Angry/fearful	Small	Randomized	15/27	NS
Angry/fearful	Small	Blocked	37/56	< 0.05

Experiment 2: The second experiment used four different video fragments (happy/sad/angry/fearful) presented in a four-alternative forced-choice design and shown in the RVF. GY correctly labeled the videos as happy, sad, angry, or fearful on 38 of 72 trials in the first block (52%, with the chance level at 25%; $Z = 5.30$, $p < 0.005$) and in 41 of 72 trials in the second block (57%; $Z = 6.12$, $p < 0.005$; Table 2). The happy and sad videos were recognized, as before, better than the angry and fearful videos. The overall performance was far above chance ($Z = 8.17$, $p < 0.005$). GY thus also performed well in a complex design that required more than a simple binary decision.

Experiment 3: The third experiment was carried out to assess whether movement was an important parameter for GY's performance or whether he can recognize stationary face expressions (stills). We used a 2AFC task and GY was instructed to guess the facial expression shown to his blind field. Performance with the video fragments was compared with those for still shots and for upside-down presentation. Table 3 shows that performance was better with moving stimuli than with still ones. Movement seems therefore to play an important role for GY in distinguishing facial expressions. This issue is further examined in the next experiment using congruent *vs* non-congruent labels, where movement was present throughout all presentations.

Table 2. Confusion matrix of GYs response to happy, sad, angry, or fearful videos

Video	Response			
	Happy	Sad	Angry	Fearful
Happy	27	2	6	1
Sad	1	24	5	6
Angry	3	11	13	9
Fearful	2	12	6	15

Experiment 4: To test whether performance was critically dependent on the veridical response labels being used, GY was tested a few months after Experiments 1–3. In the congruent blocks, GY had to identify the happy/sad videos with the labels happy/sad, or to identify the angry/fearful videos with the labels angry/fearful. In the non-congruent blocks, he was given the response labels angry or fearful, while, unknown to him, the happy/sad videos were presented, or conversely, he was given the labels happy/sad, while the angry/fearful videos were shown.

GY did not report experiencing anything strange or different between congruent and non-congruent blocks. As before, he reported to detecting a white flash with an onset and an offset, but nothing more than that. However, performance was better with congruent labels.

In the first block, with congruent happy/sad videos and labels, GY was correct on 46 of 56 trials (four trials discarded for the presence of eye movements): 21 of 28 happy faces were recognized as

Table 3. Perceiving facial expressions or discriminating movement

Stimulus	Orientation	Presentation	Correct	p
Dynamic	Upright	Randomized	20/28	< 0.05
Still	Upright	Randomized	19/27	< 0.05
Dynamic	Inverted	Randomized	18/28	NS
Still	Inverted	Randomized	16/28	NS
Dynamic	Upright	Blocked	51/56	< 0.001
Still	Upright	Blocked	26/53	NS
Dynamic	Inverted	Blocked	26/56	NS
Still	Inverted	Blocked	27/54	NS

happy, and 25 of 28 sad faces were recognized as sad ($\chi^2(1) = 23.62$, $p < 0.001$). On second testing, he was correct on 47 of 60 trials: 24 of 30 happy faces were recognized as happy, and 23 of 30 sad faces were recognized as sad ($\chi^2(1) = 19.28$, $p < 0.001$).

On the first test with congruent angry/fearful videos and labels, GY was correct on only 26 of 60 trials: 15 of 30 angry faces were recognized as angry, and 11 of 30 fearful faces were recognized as fearful $\chi^2(1) = 1.08$, NS). On the second test, however, he improved considerably, and was correct on 40 of 60 trials: 21 of 30 angry faces were recognized as angry, and 19 of 30 fearful faces were recognized as fearful ($\chi^2(1) = 6.69$, $p < 0.01$. It thus appeared that the angry/fearful videos were more difficult than the happy/sad videos, but his performance improved on second time testing. Overall, GY was correct on 159/236 trials (67%; $\chi^2(1) = 28.51$, $p < 0.001$).

When presented with non-congruent angry/fearful videos and happy/sad labels (Table 4, top half) there was a clear majority of sad responses but without any relation with the video that was shown ($\chi^2(1) = 0.00$, NS). The majority of sad responses presumably comes from an association of the negative emotion in both angry and fearful videos with the sad label. Using the non-congruent happy/sad videos and angry/fearful labels (Table 4, bottom half) the relative frequencies of the two response labels show very little relation to the presented videos ($\chi^2(1) = 1.11$, NS). With non-congruent labels, there was thus no systematic link between choice of response labels and the presented stimuli.

Event related brain potentials to facial expressions: The subject gave 92.8% correct responses in the good visual field and 51.4% in the blind visual field when discriminating the gender of static faces. This latter result is compatible with his difficulty in discriminating static faces in his blind field (see above).

Figure 1 shows grand-average visual ERPs for happy and fearful faces together at Oz site for left visual field presentation and right visual field presentations. Visual stimulations in the normal visual hemifield gave a first positive deflection peaking at 148.62 ms (amplitude 4.83 μv), followed by a subsequent negative visual component (latency 240.02 ms; amplitude −4.50 μv). Visual stimulations in the blind visual hemifield yielded a similar occipital positive component, delayed in time (164.04 ms) and slightly reduced in amplitude (4.44 μv). Moreover, a subsequent negative component was also seen (latency 276 ms; amplitude −1.50 μv) when GY was stimulated with faces in the blind visual hemifield.

The present electrophysiological data clearly show that early visually evoked activity can be found in ventro-lateral extrastriate cortex when stimuli are presented to the blind hemifield of a hemianopic subject. The first positive activity is entirely compatible (by latency and topography) with the P1 component generated in lateral extrastriate areas, near the border of Brodman areas 18 and 19 [15–17]. The second negative activity is compatible with a N1 component generated in the occipito-parietal and occipito-temporal cortex [16]. It has been suggested that the P1 component reflects processing in

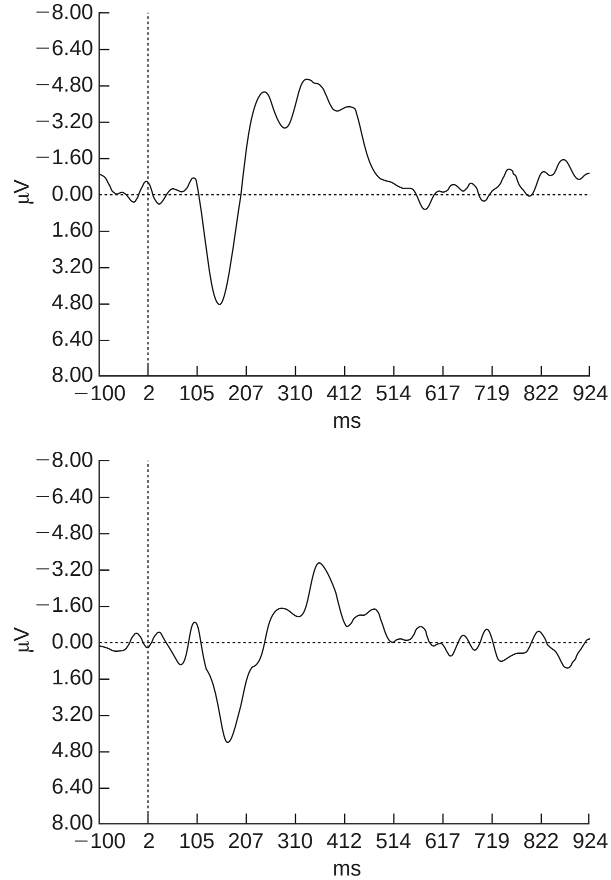

FIG 1. Grand-average visual ebvent-related potentials (VERPs) at Oz site for happy and fearful faces together. The upper part of the figure shows VERPs for presentations in the good visual hemifield, the lower part for presentations in the blind visual hemifield.

Table 4. GY's labeling of the videos with congruent and incongruent labels

Video	Response	
Angry/fearful videos		
	Happy	Sad
Angry	24	36
Fearful	24	36
Happy/sad videos		
	Fear	Angry
Happy	33	27
Sad	32	28

the ventral stream and that the N1 component processing in the dorsal stream [19]. Although reduced and delayed, neuronal activity elicited by stimulation of the blind visual hemifield is entirely comparable with face-related activity elicited by stimulation of the good visual hemifield.

Discussion

We have shown that a blindsight subject could discriminate successfully among different facial expressions and that this performance reflected actually a covert recognition of the facial expressions rather than a discrimination of two patterns of movement. Moreover, the actual conscious content of the alternative response labels he was given were particulary important for his performance since the subject performed better with congruent labels than with incongruent ones when the movement factor was kept constant. These observations are further supported by the electrophysiological results demonstrating that GY may activate the ventral visual pathway bypassing V1. An early visual activity is elicited in response to stimulation in the blind hemifield, and this activity is comparable and symmetric to the activity elicited in the other hemisphere in response to stimulations in the good visual hemifield. A delayed and reduced P1 and N1 components are indeed elicited at occipital sites (e.g. electrode Oz) in the left hemisphere in GY. The P1 component has been shown to be generated in extrastriate occipital regions but with a significant striate contribution as well [17]. The presence of a P1 component delayed in time and reduced in amplitude when GY was stimulated in his blind visual hemifield may be viewed as reflecting the absence of contribution of the left striate cortex lesioned in GY which should normally be involved in generating this early visual component in normal subjects [16,17]. Without further research it cannot be concluded just which specific features of the facial stimuli were critical for generating the pattern of ERPs recorded here, but the results show that such stimuli presented in the blind visual hemifield of an hemianopic subject activate the ventral visual pathway via anatomical routes that bypass V1. Connections from the retina to extrastriate areas via the pulvinar or the collicular–pulvinar pathway may yield such an early activity [4,18].

Conclusion

This study is the first to show processing of facial expressions in the absence of awareness in a subject with striate cortex lesion. Our report provides empirical evidences for the conjectures recently made by Morris *et al.* [4], suggesting a possible visual pathway bypassing V1 and involving the superior colliculus and the pulvinar which remain functional in a blindsight patient.

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