Covert affective cognition and affective blindsight

de Gelder, B.; Vroomen, J.; Pourtois, G.R.C.

Published in:
Out of Mind

Publication date:
2001

Citation for published version (APA):
de Gelder, B., Vroomen, J., & Pourtois, G. R. C. (2001). Covert affective cognition and affective blindsight. In B. de Gelder, E. de Haan, & C. Heywood (Eds.), *Out of Mind: Varieties of Unconscious processes* (pp. 205-221). Oxford University Press.

CHAPTER 12

COVERT AFFECTIVE COGNITION AND AFFECTIVE BLINDSIGHT

BEATRICE DE GELDER, JEAN VROOMEN, AND GILLES POURTOIS

The notion that a significant part of our mental life proceeds in the absence of awareness and reflexive thought is one of the major intellectual themes since the start of empirical inquiries into mental processes. Evidence of information processing taking place outside the scope of introspection has accumulated systematically since the 1960s. Unconscious processing was found in areas of cognitive skills as diverse as reasoning, memory, language, and object recognition, all of which concerned cognitive information processing. Only recently has laboratory evidence also been provided for unconscious processing of emotional events. This new area, which one might call that of non-conscious or covert affective cognition, thus adds to the already long list of human abilities for which both an overt and a covert route is available. It takes a place next to implicit memory, blindsight, covert face recognition, and implicit language abilities. Recently and more radically, a new instance of covert affective cognition was found in patients with striate cortex lesion. Besides the well-known ability to report on unseen stimuli like line orientation or motion, we found that these patients can also discriminate between facial expressions presented in their blind field. This phenomenon, which we referred to as 'affective blindsight', is consistent with earlier reports of covert recognition in brain-damaged patients and non-conscious recognition of facial expressions in neurological intact perceivers. After presenting the major findings, we review some similarities and differences between affective blindsight and other instances of covert affective cognition. Its major contribution to understanding covert affective cognition lies in the insight it provides in alternative, subcortical routes for processing emotional stimuli.

Covert face recognition and deficits of facial affect recognition

Together with amnesia and blindsight, covert face recognition represents one of the oldest and best-documented domains of implicit processes. The notion of covert face recognition originally referred to the fact that loss of overt recognition of personal identity could go together with evidence for a normal SCR to familiar but not to unfamiliar faces (Bauer, 1984; see also Tranel and Damasio, 1987, 1988; Tranel *et al.*, 1995). To account for the phenomenon of covert face recognition, Bauer developed a so-called dual route model, based on the notion that overt recognition depends on the ventral route whereas covert recognition takes the dorsal route. Before that, Bear (1983) developed a model of emotional cognition that was more directly based on the notion of two visual streams developed by Ungerleider and Miskin (Ungerleider and Mishkin, 1982; Mishkin *et al.*, 1983). Bauer's model is sometimes presented as a picture of how affective aspects of the face are dealt with, but it has remained quite speculative and difficult to evaluate (for critical review, see Breen *et al.*, 2000). The model assumes that the SCR depends on covert processing of personal identity, but it is unclear how person recognition could be achieved within the dorsal stream. On the other hand, the two dimensions of facial information represented by expression recognition and person recognition are known to dissociate in patients with brain damage (Bornstein, 1963; Shuttleworth *et al.*, 1982).

Covert recognition of facial expression itself, independently of intact or impaired recognition of identity, has very rarely been reported. Specific loss of facial affect recognition requires that there are no deficits for processing affective information in other sensory modalities and that visual knowledge in memory, semantic processes, and mental imagery are intact. Interestingly, since recognition of facial expressions and of personal identity can dissociate at the overt level, it might also be the case that they dissociate at the covert one. We have reported one such case where the patient shows covert recognition of facial expressions but not of personal identity (de Gelder *et al.*, 2000). A question to be addressed below is whether covert recognition of facial affect in visual affect agnosia is similar to affective blindsight. If there are relevant similarities, a model like the one proposed by Bauer (1984) or by Breen *et al.* (2000) could be useful for a better understanding of affective blindsight. Recent evidence obtained with normal subjects indicates that a different approach including alternative, non-cortical pathways might better explain unconscious recognition of facial affect and might be more adequate to account for both the patient results and the normal data.

Covert recognition of facial expressions in normal subjects

In the last years new evidence coming from a variety of sources and techniques has provided strong support for the claim that facial expressions are processed outside awareness even in normal subjects. Emotional faces elicit differential autonomic responses when they are not consciously perceived as a consequence of backward masking (Ohman and Soares, 1993; Ohman, 1999; Ohman *et al.*, 1999). Moreover, when exposed to happy or angry faces under conditions that prevent conscious identification, perceivers still spontaneously mimic these expressions (Dimberg and Thunberg, 1998). Functional neuroimaging studies have provided preliminary evidence that processing of unseen emotional faces involves a subcortical system that includes superior colliculus, pulvinar, and amygdala (Morris *et al.*, 1996, 1997, 1998a, 1998b, 1999; Whalen *et al.*, 1998). This suggests that there might be a non-conscious system of affective cognition that consists of more than just a backup route, which is used when the normal processing routes are no longer available as a consequence of brain damage. The non-conscious recognition route would be part of an autonomous recognition system, possibly one with characteristics that are different from the conscious recognition system.

Whether or not masking creates a situation of non-conscious perception, which is the functional equivalent of blindsight, is currently a matter of debate (Macknik and

Livingstone, 1998). Evidence for covert processing in neurological intact subjects is provided by studies that prevent awareness through one or another experimental technique, the most common one being backward masking, creating a condition of covert or implicit perception. It remains unclear what role the various visual areas in the cortex play and what backward projections are still possible in neurological intact cases presented with masked stimuli. Studies using a masking paradigm with normal viewers can thus only provide partial evidence for the claim that subcortical routes are sufficient for perceiving facial expressions.

Recognition of facial expressions in cortically lesioned patients

A more radical approach to studying the role of awareness in the perception of emotions is provided by the study of patients who have lost normal function of the visual cortex (V1) and conscious vision (Poppel *et al.*, 1973; Weiskrantz *et al.*, 1974; Blythe *et al.*, 1987). Some such patients show blindsight, the ability to correctly guess the presence of a stimulus, or some of the stimulus attributes of a visual display in the blind field (see Weiskrantz, 1986, 1996, 1997, 1999 for overviews). Patients with unilateral damage to the primary visual cortex are particularly interesting. With brain damage limited to one visual field, their handicap can easily go unnoticed in daily life and the full range of visual experiences is open for them. Moreover, experiments with these patients can be set up in such a way that processing in the intact hemisphere provides the perfect control for non-conscious processing in the damaged field.

The matter of blindsight for the valence or motivational significance of stimuli presented to the blind field had previously been addressed in animal research and led to negative conclusions (Cowey and Weiskrantz, 1963; Cowey, 1967). The experiments on non-conscious processing of facial expressions, which we describe below, were part of a study aimed at investigating whether the damaged visual abilities of patients could be indirectly boosted, as would be the case if the poorly processed visual information would bind with representations delivered by the patient's intact auditory skills. The kinds of cross-modal interactions, which we originally envisaged, were audiovisual integration in spatial localization (ventriloquism), audiovisual speech integration, and audiovisual perception of emotions (in order of likelihood of obtaining a positive outcome). It is worth noting that we have not been able so far to obtain positive evidence for covert audiovisual speech perception. The paradigm of cross-modal bias can be considered to be an indirect testing method (see Chapter 8). In that sense it is on a par with other indirect paradigms like, for example, priming or cueing that have been adopted successfully in studies of covert processes of residual processing abilities in brain damaged patients. Our goal was to find evidence for covert visual processing by measuring the impact of an unseen visual stimulus on the patient's performance in an auditory task (e.g. pointing to the location of a sound, discrimination of spoken syllables, or judging the emotional tone of voice of a spoken sentence). As we discuss below, we found positive evidence in the domain of cross-modal affect but not of speech. This led us to focus more extensively on the parameters affecting facial affect processing, which was studied successively with direct and indirect methods. All studies were done with GY, a well-known hemianopic patient. More recently, we tested two other patients (FA and DB) with a very similar lesion and obtained results very similar to the ones described here.

Direct evidence for non-conscious processing of facial expressions

The basic experiment with which we began our exploration consisted in presenting GY with facial expressions in the blind field and asking him to guess which one of two expressions was displayed (de Gelder *et al.*, 1999b). We used photographs as well as dynamic stimuli. In the latter case, GY was presented with short video clips showing a face that changed from a initial neutral resting position to either a happy or a fearful expression in the course of a short time (1.5 seconds). This first experiment showed that GY could discriminate systematically between two stimuli, labelling them correctly most of the time. This is not to say that he was flawless or that his performance was as good in the blind field as it was in the intact one. Compared to normals or to his performance in the intact field, there is clearly a functional loss. Therefore, the most parsimonious and straightforward explanation for this covert recognition seemed to be that of weakened or subthreshold representations that are generated following stimulation in the blind field but are too weak to cause conscious recognition. But, as we shall see in the course of further control experiments, the phenomenon was consolidated and an alternative interpretation based on the notion of two separate processing streams received increasing support.

Given GY's ability to discriminate between patterns of movement in the blind field, we needed to make sure that his discrimination of facial expressions was not based simply on his residual ability for movement discrimination (see Chapter 6). The best control consisted in presenting GY with the same video stimuli used in the initial study but to show the images upside down. When tested under these circumstances, GY could not reliably discriminate the stimuli and, interestingly, he complained that the task of guessing what was presented in the blind field was harder than usual. Of course, GY was not told that he would have to guess expression displayed by faces presented upside down. Other control experiments addressed different aspects of the performance. One possibility that has been raised repeatedly concerning the relatively good performance of blindsight patients is response bias. This risk is obviously exacerbated when direct test methods with two alternative forced-choice (2AFC) tasks are used. In a different version of the previous experiment, we presented GY with four different stimuli and gave him a choice among four response choices (happy, sad, angry, and fearful). His performance was at the same level of accuracy as in the previous test with the 2AFC tasks. Tackling another issue, discussed in more detail below, we investigated whether his performance would deteriorate with still pictures, which indeed it did.

It has been suggested that a colliculo-pulvinar visual pathway underlies the general residual visual abilities of blindsight patients (LeDoux, 1996; Morris *et al.*, 1999), and that the amygdala (Weiskrantz, 1956), pulvinar, and colliculus may be crucially involved. Recognition of unseen facial expressions is compatible with present views on how the brain processes facial expressions. The right hemisphere (e.g. inferior parietal cortex and mesial anterior infracalcarine cortex) is involved in the processing of facial expressions of some emotions (Adolphs *et al.*, 1996). Moreover, increased connectivity between right amygdala, pulvinar, and superior colliculus was demonstrated when fear conditioning with unseen faces was used (Morris *et al.*, 1999).

In summary, our first set of results established that GY can reliably guess facial expressions in his blind field. Interestingly, his performance was comparable to that of normal subjects and brain-damaged patients in some other respects that are relevant here. For example, he was better with dynamic than with still faces, as has been observed in some agnosic patients. More interestingly, his misidentifications showed the same types of confusions (most typically between happy and sad) as the ones observed in normals. Another interesting finding was that performance was better when presentation conditions were blocked rather than randomized across the two hemifields. In subsequent electrophysiological recordings, the opposite pattern was found. Better indicators of unconscious recognition were reported for random alternation of stimuli in the intact than in the damaged field.

How blind is guessing?

Do response labels matter for successful guessing performance of blindsight patients? Ever since the guessing procedure was introduced to measure blindsight, it has been a source of some uneasiness on the side of the researchers relying on it. But an aspect of the guessing procedure that has not received much attention is the role of the specific response alternatives the patient is offered when instructed to guess. To explore this issue, we added one more slightly unusual experiment to this series. With instructions to blind-guess the identity of an unseen stimulus, does it actually matter for the patients whether or not they are provided with realistic choices for their discrimination of the unseen stimuli? We designed a new version of the previous experiment in which the stimuli were presented once with correct response alternatives and once with false ones. The results showed that GY could only reliably discriminate the stimuli when he was given the correct labels (de Gelder *et al.*, 1999b). What invisible hand guides guessing here? Heywood and Kentridge (2000) suggested that the patient might base his responses on sampling cues from his autonomic responses to non-conscious stimuli. One other possibility is that guessing when provided with correct reponse alternatives is facilitated by top-down influence from intact visual imagery, a possibility suggested by Milner (1998). Since GY has intact visual imagery for facial affect (van Raamdonck and de Gelder, in preparation) this explanation is in principle possible. But as we shall see, a critical role of back projections from mental imagery can be ruled out by the results from electrophysiological recordings during processing of facial expressions.

Indirect evidence for non-conscious processing of facial expressions

We now turn to studies where we have relied upon various paradigms that qualify as indirect methods for establishing blindsight which have in common that they do not require the patient to guess about a stimulus he/she does not see (de Gelder *et al.*, 2001; submitted). These various methods each highlight different functional and neurophysiological aspects of affective blindsight.

Spatial summation across hemifields

The first indirect method to be applied to the study of blindsight for visual stimili was based on the notion of interhemispheric summation (Marzi *et al.*, 1986). Interhemispheric transfer was investigated in a paradigm where normal subjects made a speeded response to a visual stimulus (a small checkerboard) presented either left or right of fixation. Double as contrasted with single stimulation led to a response facilitation as a consequence of interhemsipheric summation. Later studies (Miniussi *et al.*, 1998) have used EEG and have demonstrated latency modulations of two early visual components (the P1 and N1), known to be generated in extrastriate regions (Clark *et al.*, 1995; Martinez *et al.*, 1999). The presence of a redundant target elicited earlier P1 and N1 components compared with the P1 and N1 for single target presentation and the electrophysiological gain is about 10 ms. Moreover, using positron emission tomography (PET), Marzi *et al.* (1999) have shown that in normal observers interhemispheric transfer takes place through callosal fibres interconnecting the parietal cortices of the two hemispheres.

We used this paradigm and combined behavioural measures and electrophysiological recordings (de Gelder *et al.*, 2001). GY showed a pattern of ERPs comparable to that observed with normal subjects (Figure 12.1). Target detection in the intact field is faster with bilateral stimuli, which indicated that there was spatial summation and that stimuli presented in the blind hemifield facilitate detection in the intact field. The behavioural evidence was corroborated by the ERPs results showing an earlier P1 component for bilateral stimulation. The effect is restricted to the lower visual hemifield, a result consistent with data obtained with normal observers (Skrandies, 1987; Miniussi *et al.*, 1998) and in monkey neurophysiology (Van Essen *et al.*, 1984). There is thus a strong correlation between the behavioural data and the electrophysiological recordings. The summation effect seems to take place as early as 140 ms in the intact extrastriate regions. We suggested that interhemispheric transfer might take place via the intact posterior commissure or via subcortical commissures. This result illustrates that interhemispheric transfer is a useful

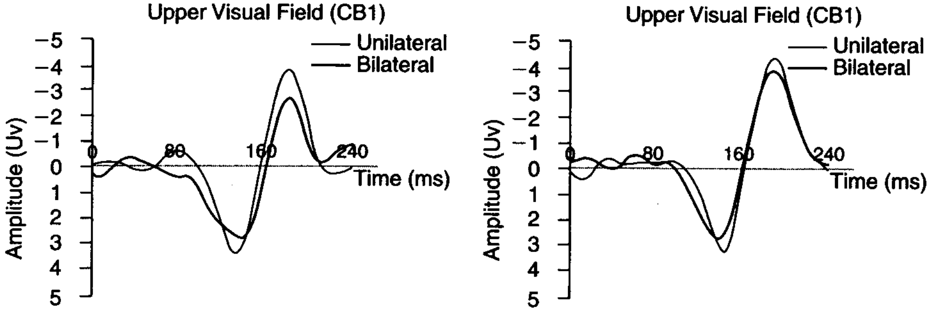

Figure 12.1 Grand average waveforms at occipitotemporal sites (CB_1 and CB_2) for unilateral and bilateral trials. Left : upper field stimulations, bilateral trials elicited comparabale early visual components (P1 and N1) than unilateral trials. Right : lower field stimulations, bilateral trials elicited an earlier visual component (P1) than unilateral trials.

tool for indirect measures of blindsight (Corbetta *et al.*, 1990) and can be used also with different stimuli as shown below.

A redundant target effect for faces in the blind field

Interhemispheric summation is usually taken to be a low-level phenomenon because it is observed when simple stimuli have to be detected. The summation paradigm is reminiscent of another phenomena, the redundant target effect (Miniussi *et al.*, 1998), defined as the fact that subjects are faster to detect a stimulus when an identical stimulus is present in the contralateral field. As the latter paradigm requires recognition of the stimulus, we did not know *a priori* whether it was feasible in a case of blindsight. However, if covert recognition was sufficient for obtaining a response facilitation (as it seems to be when neglect or extinction patients were tested; Marzi *et al.*, 1996), then the approach might present a useful welcome addition to the available indirect methods. We designed a behavioural experiment, which required only recognition of a facial expression in the intact field. The patient was instructed to respond as fast as possible, and informed that on some trials a stimulus would also be present in the blind field but that its presence was not relevant to the task. On trials where two faces were presented simultaneously in the intact and the blind field, the facial expressions could be either congruent or incongruent. We predicted that a response gain would specifically be associated with bilateral stimulation for congruent facial expression and this was what was observed (de Gelder *et al.*, 2001). Control experiments indicated that the response gain was due to recognition of the expressions and not to the presence of a face in the blind field.

Stimulus completion across hemifields using chimeric faces

Studies of hemispherectomy patients have illustrated that presentation of two stimulus halves separately to the two hemifields initiates completion across the meridian leading to the perception of an integrated whole (Levy *et al.*, 1972). As a consequence, when the information provided to the two hemispheres is inconsistent (like, for example, when one half face is shown in one hemifield and a different one in the other), the conflict generates a response cost, or an inhibition on naming latencies in the intact field. With this technique we showed the impact of the half-face expression presented to the blind field on the rating of the half expression in the intact field. As predicted, pairs with incongruent expressions led to a response cost, slowing down recognition in the intact field. For reasons not yet understood, the effect was stronger for combinations with an angry expression (rather than a sad or a neutral one) in the blind field.

Cross-modal bias as a new indirect method for studying covert processing

A novel way of testing blindsight for facial expressions in the indirect mode is provided by cross-modal bias effects. Two well-known examples of cross-modal bias are ventriloquism (see Bertelson, 1998 for a review) and the McGurk effect (McGurk and MacDonald, 1976). The ventriloquist effect refers to the fact that synchronized sounds and light flashes with a different spatial location tend to be localized closer together. A situation similar to that of bimodal inputs for linguistic information is provided when affective information in face expressions and in tone of voice (affective prosody) are present simultaneously. When presented simultaneously with a facial expression and a sentence spoken with an affective prosody, perceivers integrate the two sources of information (Massaro and Egan, 1996; de Gelder and Vroomen, 2000b). The general idea is that subjects are presented simultaneously with information in two channels (like, for example, the auditory and the visual one) and instructed to respond to the stimulus in one channel while ignoring the other. Results show that information in one modality has an impact on the subjects' perception of the other one. For example, the perceivers' categorization of the face is biased by the prosodic information in the voice (de Gelder and Vroomen, 2000a; see de Gelder, 1999 for an overview). The other way round, when a sad voice is presented in combination with a face (that is either sad or happy or can take a number of intermediate values) and subjects are instructed to rate the affective tone of voice, they are influenced by the facial expression. Presenting the viewers with a concurrent visual or alternatively, an auditory task that captures attention does not reduce the size of the cross-modal bias (Vroomen *et al.*, submitted) (Figure 12.2).

Of course, the fact that attention is not necessary to integrate what the eye sees with what the ear hears does not mean that awareness does not play a role, because even with simultaneous presentation the subjects are still aware of the two inputs. Processing without explicit attention is not the same as covert processing. The dissociation between attention and awareness was nicely illustrated in a study by Kentridge *et al.* (1999) showing the effects of directing attention to an unaware stimulus. To be more confident that one is in fact studying non-conscious rather than unattended stimuli, one would have to create conditions that block conscious recognition of the visual stimulus, as was done in some of the masking studies performed with normal viewers, mentioned above. The question of the impact from an unseen stimulus can of course also be addressed in research on brain-damaged patients with visual agnosia, or more radically, with striate cortical lesions.

We tested a patient with visual agnosia in order to see whether there was covert recognition of facial expressions as measured by the impact of an unrecognized facial expression on voice prosody (de Gelder *et al.*, 2001). The patient (AD) suffered from bilateral occipitotemporal lesions and, besides major recognition problems in the domain of objects and faces, she was unable to recognize facial expressions in direct confrontation naming. It is worth noting that testing her with instructions like the ones used with blindsight patients did not bring about a change in her performance as her guessing performance remained at chance level. Whether she was asked what facial expression was shown or given a forced choice or encouraged to guess blindly did not make a difference to her performance. When presented with a stimulus pair consisting of a voice and a face and instructed to rate the face expression she appeared instead to base her judgement entirely on the information in the voice. On the other hand, when the task concerned the voice expression, her performance shows an impact from the face on the voice, which was entirely similar to that of normal subjects (Figure 12.3). Note that covert recognition of facial expressions in visual agnosia is still compatible with a dual-route model developed by Bear (1983) or Bauer (1984). Given this result, it was worth trying this indirect paradigm with a patient suffering from striate cortical lesion.

The experiment we designed with GY was an adaptation of our previous studies of cross-modal perception of affect in normal viewers (de Gelder and Vroomen, 2000b;

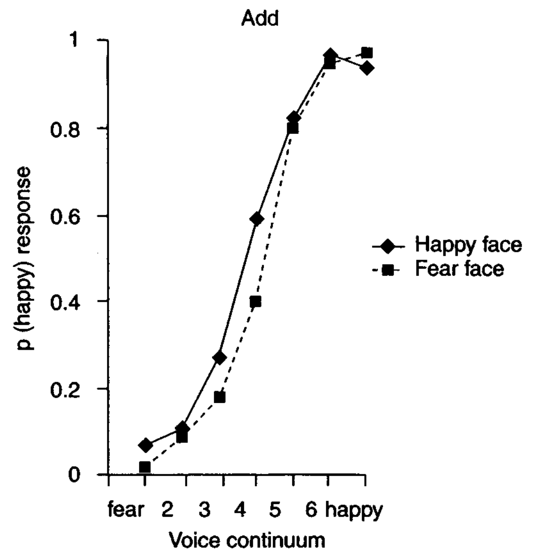

Figure 12.2 The proportion of happy responses as a function of the voice continuum when combined with a happy or fear face whilst normal subjects are presented an RVSP string. The cross-modal bias effect is still present despite the digit task (addition).

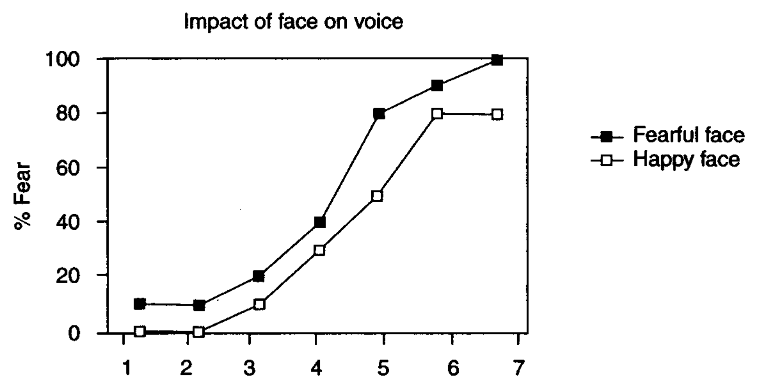

Figure 12.3 The impact of the face expressions on the voice judgments for patient AD. The horizontal axis represents the seven-step voice continuum 'Happy–Fear' (Happy on the left and Fear on the right). Percentages of fear reponses are given for the Fearful face condition and for the Happy face condition.

Pourtois *et al.*, 2000). In order to design a task where the facial expression could play a role without being consciously perceived, a face stimulus was present together with a vocal stimulus but where the patients' task was restricted to the message in the voice. Construction of these stimulus pairs started with videotape fragments showing a speaker articulating a short, semantically neutral sentence with the face and the voice expression either anger or fear. Next, the original auditory information was removed and replaced with the audio track taken from the video fragment with a different actor and a different emotional expression. Video sequences were only shown in the blind field and the task always consisted of a rating of the affective tone of the voice. The results indicated that congruence between the face and the voice considerably speeded responses to the voice expression.

Time course of the cross-modal bias effect

ERP studies of audiovisual emotion perception have shown that multisensory integration takes place early in the sensory processing (de Gelder *et al.*, 1999a; Pourtois *et al.*, 2000). Information about the time course of integration, and thereby indirectly about the time course of processing of a facial expression in the blind field, allows one to assess whether visual information presented in the blind hemifield modulates auditory processing. We recorded visual and auditory event-related brain potentials when static facial expressions (angry versus sad) were presented simultaneously with congruent auditory fragments. Three main conditions were used in each hemifield (visual only, auditory only, and audiovisual). The specific brain activity generated in response to audiovisual events was computed from the formula $[AV - (A + V)]$, where AV is audiovisual, A is auditory, and V is visual (Barth *et al.*, 1995). In the intact hemifield, two significant interaction periods (Rugg *et al.*, 1995) were found (120–140 ms and 220–250 ms), a result compatible with data obtained with normal observers (Schroger and Widmann, 1998; Giard and Peronnet, 1999). In the blind hemifield (Figure 12.4), two significant interaction periods were found at occipital leads (80–110 ms and 190–230 ms). Latency, amplitude, and topographic analyses suggest that these interaction periods may reflect modulation of visual extrastriate components (e.g. P1 and N1). These results indicate that visual information presented in the blind hemifield modulates his auditory processing and that these amplitude modulations take place already at early stages. The time window within which evidence of audiovisual integration is obtained rules out clearly that recognition of an unseen face could be due to a top-down process of the kind taking place in mental imagery (Farah, 1989).

Neuropsychological and neurophysiological studies (Nahm *et al.*, 1993; Murray and Mishkin, 1985; Murray and Gaffan, 1994) indicate that the amygdala plays a key integrative role in the construction and retention of cross-modal associations. Using event-related functional magnetic resonance imaging (fMRI), Dolan *et al.* (submitted) showed perceptual facilitation at the behavioural level (i.e. a fearful voice facilitated recognition of a fearful facial expression) and found a significant modulation of neural responses in amygdala and fusiform cortex. This indicates that the amygdala is crucial for emotional cross-modal sensory convergence. On this account, this route is equally functional in GY as it does not depend on striate cortex (de Gelder *et al.*, submitted) and it could thus account for cross-modal effects. As this route is presumably specific for affective information, it may explain that no cross-modal effects could so far be obtained with speech perception.

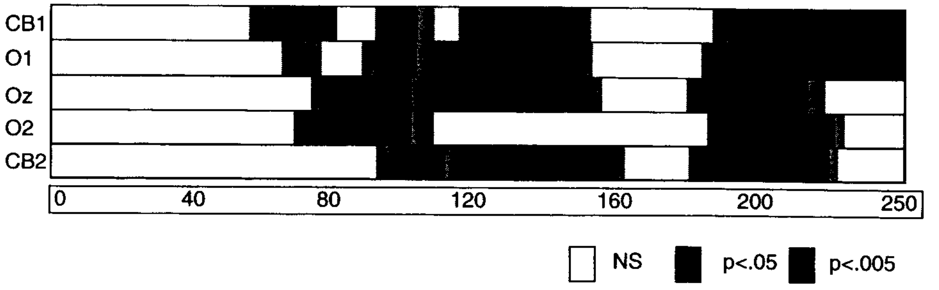

Figure 12.4 Statistical significances of the interaction effects are given as a function of time (250 ms post-stimulus) at five occipitotemporal electrodes for right (blind) visual hemifield in GY (Student's *t*-tests comparing the amplitude of the difference wave [AV−(A+V)] against zero at each latency). The distribution of the significant effects suggest the existence of two main interaction patterns (80–120 ms and 180–220 ms) in visual areas controlateral to the visual stimulations (as evidenced for CB_1).

Dynamic or still faces, a matter of methods?

Our original study indicated that only dynamic facial expressions could reliably be discriminated. But the results summarized in the last part support the existence of affective blindsight obtained with still faces. This suggests that compared with the direct guessing task where the same still faces were used but recognition was barely above chance, indirect methods seems to be more sensitive. As a matter of fact, research on covert processes with indirect methods has often yielded results that could not be found with direct tests. This might be due to a number of factors. One is that indirect testing methods in general are more sensitive. They are often reported to provide evidence for spared abilities that does not show up with direct measures, a situation abundantly illustrated by spared memory abilities in amnesic patients (e.g. Tranel and Damasio, 1987). This increased sensitivity is consistent with the most common explanation of covert processing to which we have already referred above. In that scenario, the increased in sensitivity between indirect and direct testing is due to the fact that, in patients with brain damage, representations are damaged or weakened and therefore require a higher threshold of stimulation or a more sensitive measure (Farah, 1994). But this may not be the most appropriate explanation.

The relationship between overt and covert phenomena in the cognitive versus the affective domain

In recent overviews of possible links between implicit and explicit processes, a number of alternatives are envisaged (for example, Farah, 1994; Kohler and Moscovitch, 1997; Weiskrantz, 1997). The most conservative view is that covert recognition can be a manifestation of weakened or otherwise impaired representations. Partly in response to his deficit, the patient may adopt a more conservative response criterium. A different approach consists in postulating a disconnection between the visual processes and consciousness (Schacter, 1987). Finally, some authors have suggested that some cases of covert processing provide evidence in favour of two distinct knowledge systems, one implicated in conscious and the other in non-conscious knowledge. Which of these alternatives is most likely to provide an account of affective blindsight? Or does the affective side of blindsight and of covert emotional processes in general beg a different set of questions above and beyond the ones raised by its cognitive cases? How different is affective blindsight from previous cases of covert processing such as amnesia, blindsight, and covert face recognition?

There is increasing evidence that a more radical and complex model based on two separate systems also best fits the recent evidence about different parameters affecting overt and covert visual processes in blindsight (Kohler and Moscovitch, 1997; Weiskrantz, 1997). The finding that the patients' performance followed different psychometric functions for the two response modes (Weiskrantz *et al.*, 1995, 1999) argues against the interpretation that non-conscious knowledge is based on residual visual experience of the conscious type.

An important point to note is that the relationship between overt and covert processes in models of neurological intact observers and brain-damaged patients is different from some instances of covert processes in the cognitive domain. In blindsight for colour or for motion, in letter-by-letter reading, and in numbsense, the routes taken are indeed often alternative ones in the sense that they are not normally used by neurological intact subjects. However, the processing routes evoked to explain affective blindsight are the very same ones that are responsible for processing of affective information in normal subjects. In other words, independent of whether visual cortex is intact, affective information is processed at least in part by subcortical structures that function autonomously.

The matter of qualitative differences between conscious and non-conscious processes could be a more sensitive one, play at more levels, and require a different set of control conditions and procedures in the case of affective blindsight than in that of cognitive blindsight. For example, the common procedure of forced guessing has been criticized in the past because of perceptual bias on the side of the observer. This is obviously also a concern for testing of affective blindsight, but the notion of a possible response bias could take a different dimension in the case of covert affective processes. With testing in the cognitive domain one assumes that the patient is guessing about the unseen stimuli or attributes and may adopt a decision strategy that overrules or at least interferes with his/her automatic response. For example, when the instructions turned attention away from the perceived light flash and encouraged strict guessing, the patients' performance was better (Marcel, 1998). But in the case of affective stimulation, covert processing may elicit a range of autonomic reactions. This opens the possibility that the patient might be monitoring his or her behavioural responses or even attending to autonomous responses and picking up some cues from there (Heywood and Kentridge, 2000). We are currently investigating this issue by recording GSR and other autonomic responses and comparing them to explicit and implicit behavioural responses.

At the very crudest, the notion of separate circuits for covert, autonomous and overt, reflexive processes raises the possibility of some leakage between the two. As investigated extensively by Weiskrantz and collaborators, hemianopic patients sometimes report awareness of some stimulation like a light flash with a sudden stimulus onset/offset in the blind field. Such dim awareness is sometimes referred to as phenomenal awareness or event awareness to distinguish it from visual perception or recognition. In such cases, a conflict may arise between the covert processes initiated by stimulation presentation and automatic activation of the mental images associated with the response labels provided by the task and the instructions. This issue may be more critical for affective than for cognitive blindsight.

Some unanswered questions

The study of non-conscious processing of emotions and affective blindsight could significantly contribute to understanding affective processes in the brain and mind. Our studies have not yet focused on different aspects of selectivity. For example, it is not clear whether the routes taken by processing of emotional faces in the blind field are special for fearful facial expressions as opposed, for example to happy ones. An alternative possibility would be that the covert route is not special for faces, but for balance or affective message irrespective of visual courier representation.

A similar question can be raised about integration of emotional signals from separate input modalities. Are fear signals conveyed by ear and eye integrated better or faster or in any special fashion compared to happy or sad signals from different sensory modalities?

Affective blindsight studies can significantly contribute to providing an answer to this question.

References

Adolphs, R., Damasio, H., Tranel, D., and Damasio, A.R. (1996) Cortical systems for the recognition of emotions in facial expressions. *J Neurosci* 16, 7678–87.

Barth, D.S., Goldberg, N., Brett, B., and Di, S. (1995) The spatio-temporal organization of auditory, visual and auditory-visual evoked potentials in rat cortex. *Brain Res* 678, 177–90.

Bauer, R.M. (1984) Autonomic recognition of names and faces in prosopagnosia: a neuropsychological application of the knowledge test. *Neuropsychologia* 22, 457–69.

Bear, D.M. (1983) Hemispheric specialization and the neurology of emotion. *Arch Neurol* 40, 195–202.

Bertelson, P. (1998) Starting from the ventriloquist: the perception of multimodal events. In Sabourin, M., Craik, F.I.M., and Robert, M. (eds), *Advances in Psychological Science*, Vol. 1, *Biological and Cognitive Aspects.* Hove: Psychology Press, pp. 419–39.

Blythe, I.M., Kennard, C., and Ruddock, K.H. (1987) Residual vision in patients with retrogeniculate lesions of the visual pathways. *Brain* 110, 887–905.

Bornstein, B. (1963) Prosopagnosia. In Halpern, L. (ed.), *Problems of Dynamic Neurology.* Jerusalem: Hadassah Medical School, pp. 283–318.

Breen, N., Caine, D., and Coltheart, M. (2000) Models of face recognition and delusional misidentification: a critical review. *Cogn Neuropsychol* 17, 55–71.

Clark, V.P., Fan, S., and Hillyard, S.A. (1995) Identification of early visual evoked potential generators by retinotopic and topographic analyses. *Human Brain Mapping* 2, 170–87.

Corbetta, M., Marzi, C.A., Tassinari, G., and Aglioti, S. (1990) Effectiveness of different task paradigms in revealing blindsight. *Brain* 113, 603–16.

Cowey, A. (1967) Perimetric study of field defects in monkeys after cortical and retinal ablations. *Q J Exp Psychol* 19, 232–45.

Cowey, A. and Weiskrantz, L. (1963) A perimetric study of visual field defects in monkeys. *Q J Exp Psychol* 15, 91–115.

de Gelder, B. (1999) Recognizing emotions by ear and by eye. In Lane, R. and Nadel, L. (eds), *Cognitive Neuroscience of Emotions.* Oxford: Oxford University Press, pp. 84–105.

de Gelder, B. and Vroomen, J. (2000a) Perceiving emotions by ear and by eye. *Cogn Emotion* 14, 289–311.

de Gelder, B. and Vroomen, J. (2000b) Bimodal emotion perception: integration across separate modalities, cross-modal perceptual grouping or perception of multi-modal events? *Cogn Emotion* 14, 321–4.

de Gelder, B., Böcker, K.B.E., Tuomainen, J., Hensen, M., and Vroomen, J. (1999a) The combined perception of emotion from voice and face: early interaction revealed by human electric brain responses. *Neurosci Lett* **260**, 133–6.

de Gelder, B., Vroomen, J., Pourtois, G., and Weiskrantz, L. (1999b) Non-conscious recognition of affect in the absence of striate cortex. *Neuroreport* **10**, 3759–63.

de Gelder, B., Pourtois, G., van Raamsdonk, M., Vroomen, J., and Weiskrantz, L. (2001) Unseen stimuli modulate conscious visual experience: evidence from inter-hemispheric summation. NeuroReport 12, 385–391.

de Gelder, B., Pourtois, G., Vroomen, J., and Bachoud-Lévi, A.-C. (2000) Covert processing of facial expressions in prosopagnosia: evidence form cross-modal bias. *Brain Cogn* **44**, 425–44.

de Gelder, B., Pourtois, G., Vroomen, J., and Weiskrantz, L. (submitted) Behavioural and electrophysiological evidence of cross-modal integration in human blindsight.

Dimberg, U. and Thunberg, M. (1998) Rapid facial reactions to emotional facial expressions. *Scand J Psychol* 39, 39–45.

Dolan, R., Morris, J., and de Gelder (submitted) A mechanism for cross-modal binding of emotion in voice and face.

Farah, M.J. (1994) Perception and awareness after brain damage. *Curr Opin Neurobiol* 4, 252–5.

Farah, M.J. (1989) The neural basis of mental imagery. *Trends Neurosci* 12, 395–9.

Giard, M.H. and Peronnet, F. (1999) Auditory-visual integration during multimodal object recognition in humans: a behavioral and electrophysiological study. *J Cogn Neurosci* 11, 473–90.

Kentridge, R.W., Heywood, C.A., and Weiskrantz, L. (1999) Attention without awareness in blindsight. *Proc R Soc Lond B Biol Sci* **266**, 1805–11.

Heywood, C.A. and Kentridge, R.W. (2000) Affective blindsight? *Trends Cogn Sci* 4, 125–6.

Kohler, S. and Moscovitch, M. (1997) Unconscious visual processing in neuropsychological syndromes: a survey of the literature and evaluation of models of cousciousness. In Rugg, M.D. (ed.), *Cognitive Neuroscience.* Cambridge, MA: The MIT Press, pp. 305–72.

LeDoux, J.E. (1996) *The Emotional Brain: the Mysterious Underpinnings of Emotional Life.* New York: Simon & Schuster.

Levy, J., Trevarthen, C., and Sperry, R.W. (1972) Reception of bilateral chimeric figures following hemispheric deconnexion. *Brain* 95, 61–78.

Liberman, A.M. and Mattingly I.G. (1985) The motor theory of speech perception revisisted. *Cognition* 21, 1–36.

Macknik, S.L. and Livingstone, M.S. (1998) Neuronal correlates of visibility and invisibility in the primate visual system. *Nat Neurosci* 1, 144–9.

Marcel, A.J. (1998) Blindsight and shape perception: deficit of visual consciousness or of visual function? *Brain* 121, 1565–88.

Martinez, A., Anllo-Vento, L., Sereno, M.I., *et al.* (1999) Involvement of striate and extrastriate visual cortical areas in spatial attention. *Nat Neurosci* 2, 364–9.

Marzi, C.A., Tassinari, G., Aglioti, S., and Lutzemberger, L. (1986) Spatial summation across the vertical meridian in hemianopics: a test of blindsight. *Neuropsychologia* 24, 749–58.

Marzi, C.A., Smania, N., Martini, M.C., *et al.* (1996) Implicit redundant-targets effect in visual extinction. *Neuropsychologia* 34, 9–22.

Marzi, C.A., Perani, D., Tassinari, G., *et al.* (1999) Pathways of interhemispheric transfer in normals and in a split-brain subject. A positron emission tomography study. *Exp Brain Res* 126, 451–8.

Massaro, D.W. and Egan, P.B. (1996) Perceiving affect from the voice and the face. *Psychonom Bull Rev* 3, 215–21.

McGurk, H. and MacDonald, J. (1976) Hearing lips and seeing voices. *Nature* 264, 746–8.

Milner, A.D. (1998) Insights into blindsight. *Trends Cogn Sci* 7, 237–8.

Miniussi, C., Girelli, M., and Marzi, C.A. (1998) Neural site of the redundant target effect electrophysiological evidence. *J Cogn Neurosci* 10, 216–30.

Mishkin, M., Ungerleider, L.G., and Macko, K.A. (1983) Object vision and spatial vision: two cortical pathways. *Trends Neurosci* 6, 414–17.

Morris, J.S., Friston, K.J., and Dolan, R.J. (1997) Neural responses to salient visual stimuli. *Proc R Soc Lond B Biol Sci* 264, 769–75.

Morris, J.S., Frith, C.D., Perrett, D.I., *et al.* (1996) A differential neural response in the human amygdala to fearful and happy facial expressions. *Nature* 383, 812–15.

Morris, J.S., Friston, K.J., Buchel, C., *et al.* (1998a) A neuromodulatory role for the human amygdala in processing emotional facial expressions. *Brain* 121, 47–57.

Morris, J.S., Ohman, A., and Dolan, R.J. (1998b) Conscious and unconscious emotional learning in the human amygdala. *Nature* 393, 467–70.

Morris, J.S., Ohman, A., and Dolan, R.J. (1999) A subcortical pathway to the right amygdala mediating 'unseen' fear. *Proc Natl Acad Sci USA* 96, 1680–5.

Murray, E.A. and Gaffan, D. (1994) Removal of the amygdala plus subjacent cortex disrupts the retention of both intramodal and crossmodal associative memories in monkeys. *Behav Neurosci* 108, 494–500.

Murray, E.A. and Mishkin, M. (1985) Amygdalectomy impairs crossmodal association in monkeys. *Science* 228, 604–6.

Nahm, F.K., Tranel, D., Damasio, H., and Damasio, A.R. (1993) Cross-modal associations and the human amygdala. *Neuropsychologia* 31, 727–44.

Ohman, A. (1999) Distinguishing unconscious from conscious emotional processes: methodological considerations and theoretical implications. In Dalgleish, T. and Power, M. (eds), *Handbook of Cognition and Emotion.* Chichester: John Wiley & Sons, pp. 321–52.

Ohman, A. and Soares, J.J.F. (1993) On the automaticity of phobic fear: conditioned skin conductance responses to masked phobic stimuli. *J Abnorm Psychol* 102, 121–32.

Ohman, A., Flykt, A., and Lundqvist, D. (1999) Unconscious emotion: evolutionary perspectives, psychophysiological data, and neuropsychological mechanisms. In Lane, R. and Nadel, L. (eds), *Cognitive Neuroscience of Emotions.* Oxford: Oxford University Press, pp. 296–327.

Poppel, E., Held, R., and Frost, D. (1973) Residual visual function after brain wounds involving the central visual pathways in man. *Nature* 243, 295–6.

Pourtois, G., de Gelder, B., Vroomen, J., Rossion, B., and Crommelinck, M. (2000) The time-course of intermodal binding between hearing and seeing affective information. *Neuroreport* 11, 1329–33.

Rugg, M.D., Doyle, M.C., and Wells, T. (1995) Word and non-word repetition within and across-modality: an event-related potential study. *J Cogn Neurosci* 7, 209–27.

Schacter, D.L. (1987) Implicit memory: history and current status. *J Exp Psychol [Learn Mem Cogn]* 13, 501–18.

Schroger, E., and Widmann, A. (1998) Speeded responses to audiovisual signal changes result from bimodal integration. *Psychophysiology* 35, 755–9.

Shuttleworth, E.C., Syring, V., and Allen, N. (1982) Further observations on the nature of prosopagnosia. *Brain Cogn* 1, 307–22.

Skrandies, W. (1987) The upper and lower visual field of man: electrophysiological and functional differences. In Autrum, H., Ottoson, D., Perl, E.R., Schmidt, R.F., Shimazu, H., and Willis, W.D. (eds), *Progress in Sensory Physiology*, Vol.8. Berlin: Springer-Verlag, pp. 1–93.

Tranel, D., and Damasio, A.R. (1987) Evidence for covert recognition of faces in global amnesic. *J Clin Exp Neuropsychol* 9, 15.

Tranel, D., and Damasio, A.R. (1988) Non-conscious face recognition in patients with face agnosia. *Behav Brain Res* 30, 235–49.

Tranel, D., Damasio, H., and Damasio, A.R. (1995) Double dissociation between overt and covert face recognition. *J Cogn Neurosci* 7, 425–32.

Ungerleider, L.G. and Mishkin, M. (1982) Two cortical visual systems. In Ingle, D.J., Goodale, M.A., and Mansfield, R.J.W. (eds), *Analysis of Visual Behavior*. Boston: MIT Press, pp. 549–86.

Van Essen, D.C., Newsome, W.T., and Maunsell, J.H. (1984) The visual field representation in striate cortex of the macaque monkey: asymmetries, anisotropies, and individual variability. *Vision Res* 24, 429–48.

van Raamsdonk, M. and de Gelder, B. (in preparation) Interhemifield summation obtains only for non-conscious recognition of facial expressions. In preparation.

Vroomen, J. and de Gelder, B. (2000) Crossmodal integration: a good fit is no criterion. *Trends Cogn Sci* 4, 37–8.

Vroomen, J., Driver, J., and de Gelder, B. (Submitted) Cross-modal integration of emotions: independent of attentional resources. Submitted.

Weiskrantz, L. (1956) Behavioral changes associated with ablation of the amygdaloid complex in monkeys. *J Comp Physiol Psychol* 49, 381–91.

Weiskrantz, L. (1986) *Blindsight: a Case Study and Implications.* Oxford: Oxford University Press.

Weiskrantz, L. (1996) Blindsight revisited. *Curr Opin Neurobiol* 6, 215–20.

Weiskrantz, L. (1997) *Consciousness Lost and Found.* Oxford: Oxford University Press.

Weiskrantz, L. (1999) Blindsight: implications for the conscious experience of emotion. In Lane, R. and Nadel, L. (eds), *Cognitive Neuroscience of Emotions.* Oxford: Oxford University Press, pp. 277–95.

Weiskrantz, L., Warrington, E.K., Sanders, M.D., and Marshall, J. (1974) Visual capacity in the hemianopic field following a restricted occipital ablation. *Brain* 97, 709–28.

Weiskrantz, L., Barbur, J.L., and Sahraie, A. (1995) Parameters affecting conscious versus unconscious visual discrimination with damage to the visual cortex (V1). *Proc Natl Acad Sci USA* 92, 6122–6.

Weiskrantz, L., Cowey, A., and Barbur, J.L. (1999) Differential pupillary constriction and awareness in the absence of striate cortex. *Brain* 122, 1533–8.

Whalen, P.J., Rauch, S.L., Etcoff, N.L., McInerney, S.C., Lee, M.B., and Jenike, M.A. (1998) Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge. *J Neurosci* **18**, 411–18.