Brain and Cognition **44,** 425–444 (2000)
doi:10.1006/brcg.1999.1203, available online at http://www.idealibrary.com on IDEAL®

Covert Processing of Faces in Prosopagnosia Is Restricted to Facial Expressions: Evidence from Cross-Modal Bias

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Published online June 22, 2000

We present a single case study of a brain-damaged patient, AD, suffering from visual face and object agnosia, with impaired visual perception and preserved mental imagery. She is severely impaired in all aspects of overt recognition of faces as well as in covert recognition of familiar faces. She shows a complete loss of processing facial expressions in recognition as well as in matching tasks. Nevertheless, when presented with a task where face and voice expressions were presented concurrently, there was a clear impact of face expressions on her ratings of the voice. The cross-modal paradigm used here and validated previously with normal subjects (de Gelder & Vroomen, 1995, 2000), appears as a useful tool in investigating spared covert face processing in a neuropsychological perspective, especially with prosopagnosic patients. These findings are discussed against the background of different models of the covert recognition of face expressions.

Key Words: cross-modal bias; affective cognition; face expression; voice expression; emotions; prosopagnosia; covert recognition; implicit processing; consciousness.

INTRODUCTION

The face is the bearer of many messages. There is reason to think of these different aspects of facial information, like gender, familiarity, expression or speech, as functionally separated, with appropriate processing routes corresponding to each type of information (Bruce & Young, 1986). This complexity is reflected in disorders of face recognition (i.e., prosopagnosia). Prosopagnosia is a deficit in face recognition that can be limited to recognition of either previously familiar faces or unfamiliar faces. The deficit often extends to other aspects of face processing besides personal identity, such

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0278-2626/00 $35.00

as facial expression (Tranel, Damasio, & Damasio, 1995) and even facial speech (de Gelder, Vroomen, & Bachoud-Levi, 1998a, for recent evidence).

Research over the last decade established that in some prosopagnosic patients, loss of familiar face recognition is not absolute if the methods used are sensitive enough to bring to light residual abilities or so-called covert face processing (i.e., the ability to process faces in the absence of any overt recognition). When face recognition in prosopagnosic patients was tested in a covert mode, behavioral methods showed savings in relearning, better matching performance for previously familiar than for unknown faces (Bruyer, Laterre, Seron, et al., 1983), and priming (de Haan, Young, & Newcombe, 1987). Electrophysiological methods like galvanic skin conductance (Bauer, 1984; Tranel & Damasio, 1987) and evoked potentials (Renault, Signoret, Debruille, et al., 1989) also showed evidence of covert processing. Such evidence for the spared processing of faces in the covert mode has so far only been reported for the recognition of personal identity. Face agnosia is a complex phenomenon and not all cases of overt or explicit loss of identity recognition show evidence for spared covert abilities (Newcombe, Young, & de Haan, 1989). It is not yet clear in which cases an overt deficit combines with a spared covert ability (de Haan, Bauer, & Greve, 1992). Undoubtedly the locus of the impairment and the specific type of face agnosia matter greatly and these two may interact with visual knowledge, memory, and mental imagery for faces in ways that are not yet understood.

As is the case for other covert implicit recognition phenomena that have been reported over the last 2 decades (for overviews see Weiskrantz, 1997; Kohler & Moscovitch, 1997), different kinds of explanations have been offered. Implicit face recognition has been interpreted as evidence for separate systems implementing overt and covert representations (Bauer, 1984). It also has been interpreted as a matter of absence of integration between explicit and implicit representations not allowing for access to consciousness (Tranel & Damasio, 1988). Alternatively, implicit face recognition has been conceptualized in terms of degraded representational quality, which would make it impossible for impoverished representations to become conscious (Farah, O'Reilly, & Vecera, 1993), or as a consequence of processing representations disconnected from later stages in consciousness (Schacter, 1987; see Farah, 1996, for an overview of nonconscious face processing). The account offered by Bauer (1984) seems particularly relevant since it was developed to explain a case of covert processing in a patient suffering from prosopagnosia and from loss of emotional responsivity to visual stimuli (not restricted to faces). But this report concerned personal identity and did not actually investigate whether there was covert recognition of facial expressions in the patient and thus leaves unanswered the question of covert recognition of facial expression or the possible co-occurrence of both kinds of covert recognition.

Covert processing of facial expression in prosopagnosic patients has not been documented so far and this study is the first to present evidence of spared recognition of facial expressions. To approach this issue we used a methodology which is indirect in the sense that it is not the focus of the patient's task and yields a mandatory processing of the facial expression. Our point of departure was the observation that emotions are expressed in the face as well as in the voice, a situation familiar from everyday life, when most often the two channels that convey affective messages are present concurrently. In previous research with normal subjects de Gelder and Vroomen (1995, 1996) have studied how facial expressions are processed in bimodal input situations where the faces are not just presented in isolation and judged on their own but accompanied by voice fragments carrying an emotion. This methodology is familiar since studies of audiovisual speech and of the McGurk effect (i.e., the combination of a visual with an auditory syllable changes the way the auditory syllable is perceived). Adapting this methodology for understanding the processing of audiovisual speech to the case of recognizing audiovisual emotions, we observed that performance on a visual expression categorisation task on faces was actually modulated by simultaneous presentation of prosodic information, presenting a new instance of the well-known cross-modal bias effect (see Bertelson, 1998, for an overview). They also obtained the effect in the reverse situation, when participants were asked to rate a voice expression in the presence of a concurrently presented face. The effect is very robust and it was still obtained when subjects were told to ignore the auditory input (de Gelder & Vroomen, 1995; 2000) or when they were performing a demanding visual digit detection task while listening to the voice and ignoring the face expression (de Gelder, Vroomen, & Driver, in preparation). The cross-modal bias effect thus qualifies as perceptual, mandatory, and automatic, as was argued for similar phenomena like ventriloquism and audiovisual speech (see de Gelder, Vroomen, & Bertelson, 1998a, for further details and Bertelson, 1998, for discussion). In line with those behavioral results, we demonstrated in an electrophysiological study dedicated to studying the time course of the audiovisual integration that there was an early impact of the visual stimulus on the auditory one occurring around 174 ms (de Gelder, Bocker, Tuomainen, Hensen, & Vroomen, 1999).

The combination of these characteristics makes the cross-modal bias effect a good tool for studying covert processing of facial expressions in prosopagnosia. For this purpose we tested prosopagnosic patient AD, who showed complete loss of explicit recognition of face identity and face expression (Bartolomeo, Bachoud-Levi, de Gelder, et al., 1998). We also studied whether implicit processing would be limited to facial expressions or whether it could also be found for processing personal identity.

CASE PRESENTATION

AD is a 74-year-old retired secretary with bilateral lesions of the antero-inferior parts of the occipital lobe. In May 1995 AD suffered from a hema-

TABLE 1
Performance of AD on Several Face Perception Tasks and in Voice Expression Recognition

Task	Number correct/number of items
Face	
Face classification	17/48*
Facial decision	14/20*
Facial features	05/27*
Recognition of famous faces	01/20*
Gender decision	12/20*
Age decision	11/30*
Face expression	
Still faces	08/24*
Video pictures	17/24*
Voice	
Expression	27/30

* Significantly different from control subjects.

toma located across the occipito-temporal sulcus, involving the middle occipital gyrus and the inferior temporal gyrus (Brodmann areas 18, 19, and 37). She presented a right homonymous hemianopia and showed a mild anomia, without any comprehension or repetition deficit, that subsided after a few weeks. No other linguistic deficits were present and she presented pure alexia. In December 1995 she suffered from a second, right-sided hematoma, almost symmetrical to the first. The lesion was centered on the middle occipital gyrus, just posterior to the occipito-temporal sulcus, involving area 19 and the white matter underlying area 18. After the occurrence of the second stroke, AD was unable to recognize familiar faces and common objects by sight and complained of seeing the world in shades of gray. Goldmann perimetry showed a central scotoma and a residual right paracentral scotoma. Visual evoked responses with a black and white pattern were normal for latency and amplitude. She was severely visual agnosic but tactile naming, copying, and drawing from memory were flawless. Mental imagery was preserved for all domains of higher vision (Bartolomeo, Bachoud-Lévi, de Gelder, Denes, & Degos, 1998), including color (Bartolomeo, Bachoud-Lévi, & Denes, 1997). Her auditory processing was intact but she had an impaired lipreading ability (de Gelder, Vroomen, & Bachoud-Levi, 1998a). Data from this last study are particularly relevant because spoken language processing including lipreading was also investigated with a cross-modal method similar to the one used here for emotion processing.

A set of object and face perception tasks has been reported previously (Bartolomeo et al., 1998, see Table 1) and is briefly summarized here.

To evaluate the visual perception of drawings, AD was submitted to a battery (Agniel et al., 1992) including a matching, a categorical association and an identification task. Additional object decision tasks (e.g., matching, naming, and pointing of simple visual forms and linear drawings) were also administred. She correctly performed the matching task of the battery but failed on the overlapping figures task and the association tasks. Her object naming was severely impaired as well as her pointing to line drawings. With line drawings of common objects (from the set of Snodgrass & Vanderwart, 1980), she was strongly impaired in tasks of confrontation oral naming (48,75% of correct responses) and gave no alternative signs of recognizing (e.g., by miming of use) the objects she could not name. Pointing was similarly affected. She could not match pictures as to function (e.g., stamp–envelope) or category membership (e.g., fork–knife), but performed the same tasks flawlessly on the basis of oral presentations. Finally, tactile naming of real object was intact, which confirms the specifically visual character of the deficits.

Face recognition was tested using tasks of classification, facial decision, and detection of facial features. AD was profoundly impaired in overt recognition of familiar and unfamiliar faces (e.g., the classification of photographs by gender or by age). With photographs of unknown faces, she performed at chance level in both gender decision (12/20 correct) and age decision (11/30). However, her knowledge and mental imagery of faces were intact. AD's performance was flawless when questioned about the shape of the mouth or the length of the nose of a particular face.

Prior to the tests of expression recognition, we examined whether AD would suffer from integrative agnosia, as was argued for agnosic patient HJA (Riddoch & Humphreys, 1987). We found this not to be the case. Her drawing and copying skills are quite fluent. Furthermore, experimental evidence was provided for intact structural form processing both for objects and for faces in this patient (de Gelder, Bachoud-Levi, & Degos, 1998c). Matching of objects and faces was severely impaired when the stimuli were shown in canonical upright orientation but not when these same stimuli were presented upside down. We have argued that a superior performance with inverted than with upright stimuli suggests intact processing of the whole stimulus or of the configuration (rather than part by part processing, as for example in integrative agnosia). Such intact structural encoding is potentially important for (spared) recognition of facial expressions (Davidoff & Landis, 1990).

The present report concerns covert processing of personal identity and of facial expression. Aside from comparing and contrasting the performance on tests investigating each of these, a number of other related tasks were administered in order to allow a better interpretation of the results: tasks of knowledge and mental imagery for facial expressions and tasks of recognition of vocal expressions. Our report is organized into two main sections, one concerning identity and the other facial expression. Complementary information from related tasks is reported under one of these two main headings.

PROCESSING OF PERSONAL IDENTITY

Previous reports of patient AD provided information about a complete loss of explicit face recognition (de Gelder, Bachoud-Lévi, & Degos, 1998c). In order to assess whether there was any spared covert recognition of faces, we used three different tasks, a familiarity decision task, a face/name interference task, and a name relearning task.

Processing of Familiarity

Given the patient's inability to name any famous or familiar faces, it was worth asking whether there would be any residual impression of familiarity manifested in a task that required only a forced choice judgment of which face in a pair of two that looked familiar. The task used 40 stimuli (20 famous and 20 unknown faces). Patient AD was presented with 20 pairs and asked to point to the photograph that looked familiar. Her performance was at chance [23/40, χ^2 (1) = .45, NS]. Errors were equally divided for familiar faces recognized as unfamiliar and vice versa.

Face/Name Interference Task

Following the face/name interference task developed to assess spared familiar face recognition (Young, Ellis, Flude, et al., 1986), a test was constructed presenting faces of well-known French politicians or actors together with their names. The latter were presented orally through headphones because of AD's alexia. In a pretest, involving classifying faces as politicians or nonpoliticians, she performed below chance level (17/48). She could name only one celebrity (i.e., Mitterand). She was, however, able to perform at a 100% level in the second pretest, involving classifying names as politicians or nonpoliticians. The face photographs were presented on a computer screen and the patient was instructed to judge whether the name she heard simultaneously was either that of a politician or that of a figure from show business. The patient responded by pushing one of two response buttons. Table 2 shows the mean reaction times (RT) for the categorization of politicians' and nonpoliticians' faces in the face–name interference task.

TABLE 2
Mean Reaction Times (in Milliseconds) for Correct Classification of Politicians'and Nonpoliticians' Names Accompanied by Different Types of Distractor Faces

	Type of face distractor (person)		
	Same	Related	Unrelated
Politicians' names	1078	1123	1069
Nonpoliticians' names	1237	1245	1194
Overall	1157	1184	1131

Error rates were up to a maximum of 8% per cell [χ^2 (2) = 2.11, NS] and will not be taken into further consideration. RT's in the condition Related were higher than those in the other conditions. In order to determine this interference effect, a two-factor analysis of variance was carried out on Decision (politician vs nonpolitician) and Condition (same person, related, and unrelated). The effect of task Condition was not significant [$F(2,12) < 1$, NS]. As can be seen in Table 2, the RT's to politicians were faster than the RT's to nonpoliticians. This effect was significant [$F(1,6) = 7.06$, $p < .001$], but the interaction between decision and condition did not approach statistical difference [$F(2,12) < 1$, NS]. Thus the absence of the effect of task condition held equally for politicians' and nonpoliticians' names.

Relearning Names of Famous Faces

The goal of this task was to investigate whether there was evidence for covert recognition of famous faces in a name relearning task. Such evidence would be provided if learning the name of the face was more efficient for previously known faces of famous figures than for unknown faces. Given the severity of the prosopagnosia, only small sets of faces were used in this learning task. Two sets of stimuli were assembled and each set consisted of four photographs (two familiar and two unknown faces). Familiar faces were those of politicians well known to the patient but not recognized in previous tasks. The patient was informed about the task and the requirement to learn the name corresponding to each face. She was shown the photographs one by one and for each photograph the corresponding name was repeated five times by the experimenter. The patient was asked to study each photograph carefully, as long as was needed to be able to remember it subsequently. The four photographs were presented eight times in random order. After this learning phase each photograph was again presented and the patient was asked which of the four names corresponded to it. This testing procedure was repeated six times, yielding a total of 48 trials. Results were 54% correct (13/24) for famous [χ^2 (1) = .08, NS] and 50% correct (12/24) for unknown faces (at chance level). This result clearly shows that the patient could not take advantage of previous visual knowledge of the familiar faces.

In conclusion, we did not find any evidence for preserved covert identity processing in either study: these tasks did not provide evidence for faster relearning of familiar pairs and to interference in deciding the professional category for celebrities' spoken names. Our next question concerned spared covert processing of facial expressions.

PROCESSING OF EMOTIONS

In previous testing there was clear evidence for an impairment of expression recognition on the face, with still photographs as well as dynamic stimuli (i.e., short video clips). Results concerning the recognition of facial expressions are briefly summarized in this section. The performance of AD was next assessed in a finer experimental paradigm of single modality categorical perception task for both face and voice expressions.

Processing of Facial Expressions

We investigated the perception, visual knowledge, and mental imagery of facial expressions as well as the perception of emotions expressed in the voice.

Perception of facial expressions. The recognition of face expressions was first investigated with still faces. Three semiprofessional actors (one female, two males) were photographed expressing five different emotions (happy, sad, angry, afraid, and neutral). A trial consisted of one photograph at the top and two at the bottom. The patient was asked to indicate which of the two bottom pictures showed the same facial expression as the top one. There was a total of 46 trials. The patient performed well below the score of controls (58% of correct responses, at chance level), who performed at ceiling (97%) in this task.

Recognition of facial expressions was next tested using dynamic presentations (i.e., video clips). Materials consisted of a video film consisting of four blocks and constructed as follows. A semiprofessional actor was instructed by way of prototypical events to express different emotions (afraid, sad, happy, angry) which were repeated three times randomly per block. There were four blocks. In the first block, the facial expression was shown for a continuous 5 s. In the second block the face was initially shown in a neutral position and the face expression unfolded for 5 s. The third and fourth blocks presented control conditions and showed the beginning and the end frames of the previous block, but did not show the transition, which was hidden by a screen. The fourth block showed the same emotional expression in the beginning and at the end of the 5-s period, but in between the face was masked. The tape was shown twice. Normal controls perform at ceiling on this task. The performance of AD on the first block was below chance level (7/24), on the second block she performed better (15/24 or 0.63%), and on the last two blocks she was again very poor (0/12 for the third and 4/12 or 0.33% for the final block). Correct responses were always due to recognition of happy, with occasional recognition of sad adding to the score. The other expressions were all wrongly labeled.

Two sets of single modality categorical perception tasks were next administered to assess in more detail the performance of AD in the processing of faces and voices. The materials had been extensively used in previous research (de Gelder & Vroomen, 1995; 2000; de Gelder, Vroomen & Bertelson, 1998b) with normal subjects and are briefly described below. These tests allow for a more fine-grained assessment of the impaired skills. More importantly though, using these categorical perception tasks (as for example in de Gelder, Teunisse, & Benson, 1997a) involves not only a category assignment task or a forced choice between two explicitly mentioned alternatives but two other subtests, discrimination and goodness rating. Independently of the issue of categorical perception, the discrimination task is particulary relevant because it does not require conscious recognition ability and can be counted as a covert task. As we shall see, in the bimodal tasks which constitute the critical part of this study the same continua that were also presented unimodally were used. Again, this would provide us with a control on the secondary factors that might affect AD's performance in the bimodal tasks.

In this task we used visual stimuli that consisted of three 11-step facial expression continua (i.e., happy/sad, angry/afraid, angry/sad) used previously in categorical perception experiments with adults and children (de Gelder, Teunisse, & Benson, 1997a). For each continuum three tasks were administered, consisting of a 2 AFC discrimination task, an identification task, and a goodness rating task presented in that order. The identification and the goodness rating task required overt recognition of the facial expression. For the discrimination task no recognition of the expression was required since AD was instructed to answer which of the 2 bottom pictures showed the same facial expression as the top one. She commented on being unable to perform this recognition task, but was encouraged to venture a guess and reported repeatedly that she was just guessing. In the 2 AFC discrimination task, each trial began with an auditory signal, followed by simultaneous presentation of 3 photographs for 3 s. The first 2 bottom pictures, A and B, were always different. The third picture, X, was identical to either A or B. The patient was instructed to indicate which picture, A or B, was identical to the top one by pressing one of two buttons, labeled A and B, with a finger of either the left or the right hand. The warning signal of the next trial appeared 2 s after the patient's response. A and B were always two steps apart on the continuum, so nine comparisons were possible. For each comparison, the four possible orders of presentation (ABA, ABB, BAA, BAB) were each presented three times. The resulting 108 trials were presented in random order. The task began with 10 practice trials with faces showing several expressions. In the identification task, 11 photographs of the set were presented one-by one, and the patient identified each stimulus by pressing one of two buttons. A trial was announced by the same auditory warning signal and was followed after 800 ms by the face, which remained for 3 s. For the goodness rating task, each set of photographs was divided into two subsets, one containing the first six items and the other one the last six items. The pictures were presented manually under the same conditions as in the identification task. AD expressed her ratings verbally on a 10-point scale.

The normal pattern of discrimination is reflected in better in between than within category differences but this is not found for AD (see Fig. 1).

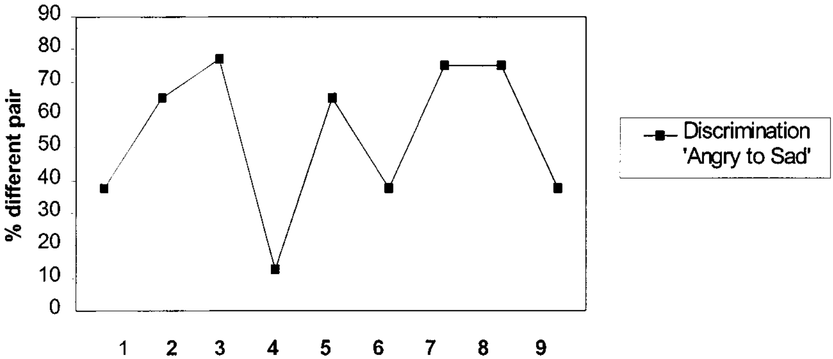

FIG. 1. The figure shows AD's discriminations of facial expressions. On the horizontal axis, the continuum starts from angry (on the left) and continues to sad (on the right). Each step of this continuum represents the presentation of two faces which are 2 steps apart on the 11-step facial continuum ''angry–sad.'' On the horizontal axis, step 1 is for the presentation of the 1–3 pair AD had to discriminate: in this pair, 1 is the first face of the 11-step continuum angry–sad and 3 the third face of the same continuum; 2 is for the 2–4 pair, 3 for the 3–5 pair, 4 for the 4–6 pair, 5 for the 5–7 pair, 6 for the 6–8 pair, 7 for the 7–9 pair, 8 for the 8–10 pair, and 9 for the 9–11 pair. The different pair judgments are presented on the vertical axis.

For the identification task, AD does not show the normal S-shaped identification pattern (see Fig. 2).

Her performance at the extremes was poor and there was no clear category boundary. In the goodness rating task, she was not able to distinguish the extreme expressions (supposed to be more expressive) from the other ones

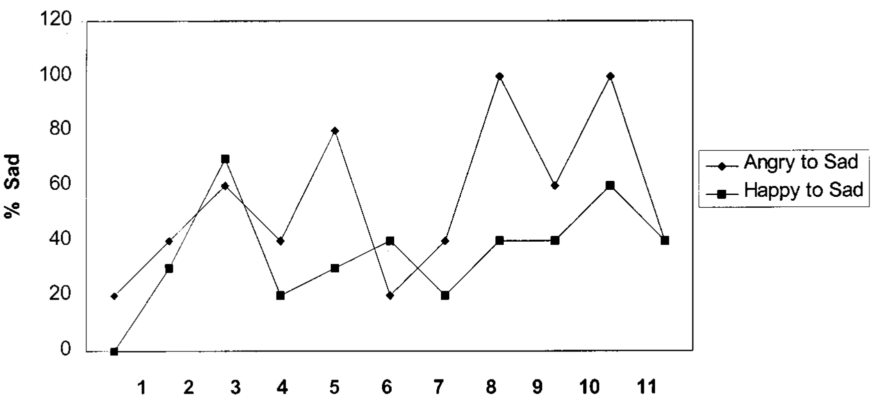

FIG. 2. The figure shows AD's identifications of facial expressions. Two continua are proposed (angry–sad and happy–sad). The horizontal axis represents the 11-step continua (on the left, the continuum starts from angry or from happy; on the right, the continuum represents the sad face). On the vertical axis, the percentage of sad responses is presented.

inside the continua. Only for the happy–sad continuum did she show a difference for the two subsets (i.e., an advantage for the six items of the happy subtest which were judged as more expressive by AD). In conclusion, identification, discrimination, and goodness rating did not yield evidence for recognition of facial expressions.

In conclusion, AD's results are entirely compatible with evidence reported in the previous sections (e.g., an impaired face processing, both with identity and facial expressions) and confirm the single modality dissociation between intact affective voice processing (i.e., AD exhibited the classical pattern of categorical perception, see below) and an impaired affective face processing.

Mental imagery for facial expressions. In a previous paper (Bartolomeo et al., 1998), we reported that AD had intact mental imagery for the visual appearance of familiar faces. Does this ability for mental imagery also extend to facial expressions? We first tested whether AD can draw a convincing picture of a happy, sad, or angry face. She can copy facial expressions as well as drawing these from memory. Examples of her drawing of facial expressions (whole faces and parts) are given (Fig. 3). She does not, however, recognize the expressios on the faces she has drawn.

In a later testing session we studied mental imagery for facial expressions. AD could answer questions perfectly about the shape of the mouth, the position of the eyebrows, and the characteristics of the eyes in different facial expressions. Finally, production was examined. She could easily mimic different expressions in the face (as well as in the voice). In conclusion, these observations support our previous results that visual perception and visual mental imagery are functionally independent and extends this observation to facial expressions.

Processing of Voice Expressions

Before presenting the cross-modal tasks we wanted to establish that AD had no problem with recognizing expressions of emotion in the voice. For this purpose an audio recording was made of three semiprofessional actors pronouncing a short neutral sentences six times each time with a different tone of voice (neutral, happy, sad, angry, disgusted, afraid) as instructed by examples of appropriate circumstances in which such sentences were uttered. These were each repeated three times (making a total of 54 trials). A test tape was then made with the order of presentation of the different emotions semirandomized such that no two same emotions were heard consecutively. The tape was presented to AD with the instructions to judge the affective content of the voice by selecting one of the six response alternatives. AD performed 88% (48/54), which is a performance in the normal range. Errors were mostly due to confusions between happy and sad, a pattern that is no different from that of normal subjects. We can conclude from this that AD has entirely normal recognition of affective prosody. Like for the case of

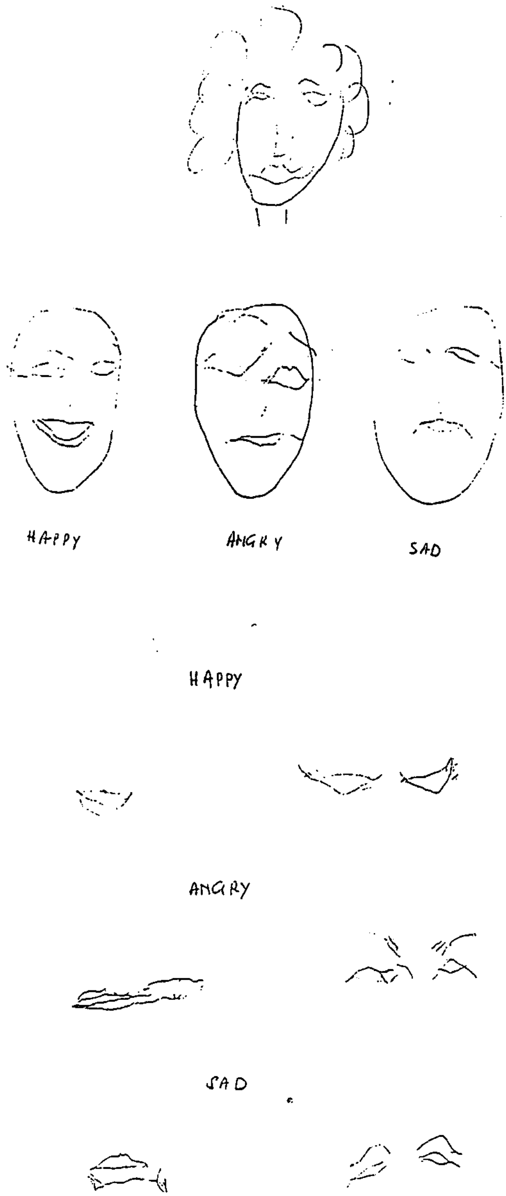

FIG. 3. Several drawings of AD: (1) Her drawing of a normal face (top), (2) her drawings of happy, angry, and sad faces (middle), and (3) her drawings of three mouths and eyes (happy, angry, and sad) and the correponding eyes and eyebrows (bottom).

face expressions we then use a more fine-grained task, which again had the advantage of consisting not only of an explicit identification task but also a discrimination task presented first and not requiring overt labeling of the emotions.

To examine categorical perception (CP) of expressions conveyed in the voice, a discrimination task and an identification task were used with a single continuum (anxious/happy). A seven-step voice expression categorical perception continuum between two natural tokens of semantically neutral utterances (‘‘Zijn vriendin kwam met het vliegtuig’’ meaning ‘‘His girlfriend came by plane’’) was used (de Gelder, Vroomen, & Bertelson, 1998b). The semantically neutral utterances were spoken once in a ‘‘happy’’ and once in an ‘‘anxious’’ tone of voice, and five intermediate expressions were synthesized in a manner comparable to the morphing procedure used for faces. Further acoustic details and analysis of the intonation of the sentences are given in Vroomen, Collier, and Mozziconacci (1993). Normal subjects show CP for these voice expressions. In the discrimination task, there were 18 different pairs and each block of 18 pairs was presented four times in different random orders. There were 7 identity pairs (1-1, 2-2, . . ., 7-7), 6 one-step-pairs with the lowest stimulus first (1-2, 2-3, . . ., 6-7), and 6 one-step pairs with the highest stimulus first (2-1, 3-2, . . ., 7-6). The interstimulus interval was 1.5 s within a pair and 4.5 s between pairs. The patient judged verbally by responding either ‘‘same’’ or ‘‘different.’’ To acquaint her with the range of the stimuli, the two extremes were presented four times before the identification task began. Then the formal identification test started. There were 35 trials, and each stimulus of the continuum was presented five times in random order. The patient decided whether an utterance expressed happiness or fear by judging the production verbally.

In contrast with the results for categorical perception of face expressions, AD shows a normal pattern on the voice continuum (Fig. 4). Discrimination as well as identification results show the same pattern as obtained with normal adults and suggest categorical perception of these emotions in the voice.

Covert Recognition with Cross-Modal Bias

Two cross-modal tasks examined whether the perception of the face expression can nevertheless have an impact when presented simultaneously with a voice. In this task a voice expression must be recognized in the presence of a face with a congruent or incongruent expression. If some face expression is preserved it will affect the judgement of the expression in the voice. This task follows up the suggestion of covert recognition of the face expression and examines whether there is an impact of recognizing the emotion displayed in the face on the categorization of affective prosody in speech. de Gelder and Vroomen (1996) found that normal subjects who are given concurrent information from the face and the voice and told to ignore

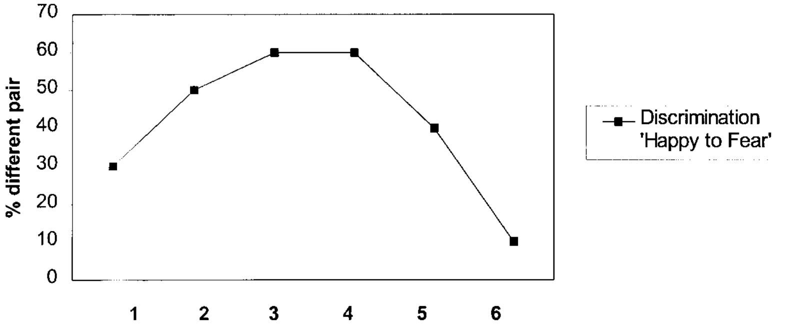

FIG. 4. The figure shows AD's discriminations of vocal expressions. On the horizontal axis, the continuum starts from happy (on the left) and continues to fear (on the right). Each step of this continuum represents the presentation of two voices which are one step apart on the seven-step vocal continuum happy–fear. On the horizontal axis, step 1 is for the presentation of the 1–2 pair AD had to discriminate : in this pair, 1 is the first voice of the seven-step continuum happy–fear and 2 the second voice of the same continuum; 2 is for the 2–3 pair, 3 for the 3–4 pair, 4 for the 4–5 pair, 5 for the 5–6 pair and 6 for the 6–7 pair. The different-pair judgments are presented on the vertical axis.

the face still showed an impact from the face expression. Symmetrically to the previous effect of the face on the voice with those subjects, here we observed with our patient that the expression of the face affected the way the voice was judged. Since our patient has no problems with judging affective prosody but is well aware of her difficulties with facial expressions, this task involving an indirect testing method seems particularly appropriate for her. If her voice judgments were affected by the face expressions this would present evidence for covert recognition of facial expressions.

Impact of voice expression on judging the face. In this first cross-modal condition, we tested whether the emotion conveyed in the voice had an impact on the categorization of face expressions. For the auditory materials, we used two natural tokens of the same sentence spoken in a happy or a sad tone. For the visual materials we used the facial continuum happy/sad described above. The 11 visual stimuli along the happy–sad continuum were factorially combined with the two utterances. These 22 bimodal trials were presented five times and trials were randomized. The pictures occupied a 9.5 × 6.5 cm rectangle on the computer screen, which at the mean viewing distance of 60 cm corresponds to a visual angle of 10.0 × 6.8°. The photograph was presented at the onset of the word ''vliegtuig'' and remained on the screen till the end of the sentence. The patient was encouraged to respond as fast as possible after the offset of the sentence and instructed to ignore the auditory information, to judge whether the face was ''happy'' or ''sad.'' The task was administered two times with a 3-week interval.

The results (see Fig. 5) clearly show that there is no differential impact

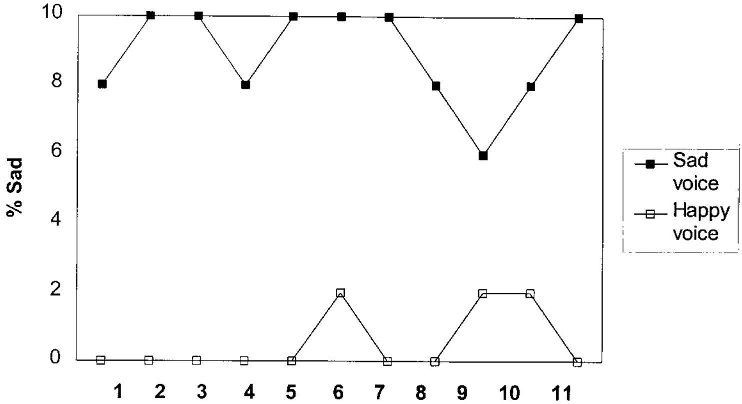

FIG. 5. The figure shows the impact of voice expressions on face judgments. The horizontal axis represents the 11-step facial continuum happy–sad (happy on the left and sad on the right). The percentages of sad reponses are given for the sad voice condition and for the happy voice condition.

of the different auditory tones on the face affects [χ^2 (1) = 154.35, $p <$ .001]. This pattern of results is different from the one obtained with normal subjects (see de Gelder & Vroomen, 1995; de Gelder et al., 1998c, for more details). Although she was explicitly instructed to ignore the voice, her pattern of results seems to show that she judged the faces entirely from the information provided by the voice. Therefore, her impairment in overt recognition of facial expression seems too important to even allow the demonstration in this paradigm of a covert impact of voice affects on face affects.

Impact of the face expression on voice judgments. In this second cross-modal task, we studied the impact of recognizing the emotion displayed in the face on the categorization of prosody in speech. The auditory materials were the same as those described above in the categorical single modality voice expression task. For the visual materials we used two faces of the same actor posing once with a happy and once with an afraid facial expression. Again, the seven auditory stimuli from the voice continuum were factorially combined with a happy or with an afraid face (de Gelder & Vroomen, 1995). There were 14 trial types each presented five times in random order. The task was administered two times with a 3-week interval. The pictures occupied a 9.5 × 6.5 cm rectangle on the computer screen, which at the mean viewing distance of 60 cm corresponds to a visual angle of 10.0 × 6.8°. AD was asked to judge the affect in the voice. She was told that each time a voice fragment was heard a face expression also appeared on the screen. She was aware of the fact that she was unable to recognize face expressions and was told just to ignore them.

In contrast with the first cross-modal condition in which there was no bias effect from the voice tones on the judgments of the facial affects, in this

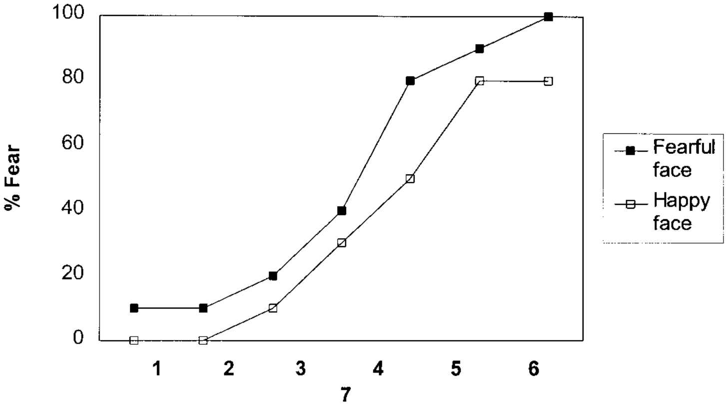

FIG. 6. The figure shows the impact of face expressions on voice judgments. The horizontal axis represents the seven-step vocal continuum happy–fear (happy on the left and fear on the right). The percentages of fear reponses are given for the fearful face condition and for the happy face condition.

second cross-modal condition in which the experimental situation was reversed, AD's judgments of the voice exhibit a cross-modal bias effect [χ^2 (1) $= 29.16$, $p < .001$]: indeed, we can observe in Fig. 6 that the different voice judgments tend to be categorized more as fearful when a fearful face was presented than when a happy face was presented. AD does seem to process to some extent the specific expressive information on the face since the face expression has a clear and systematic impact on her judgement of the expression in the voice (Fig. 6). Therefore, we can conclude from that second cross-modal condition that the information from the face (i.e., facial expressions) has a clear impact on the categorization of the different voice tones. The pattern of her results is entirely similar to that of normals.

Some weeks later, AD was tested again in this second cross-modal condition (see Fig. 7) and her pattern of results seemed to confirm this latter conclusion: AD's judgments of the voice exhibit a cross-modal bias effect [χ^2 (1) $= 10.4$, $p < .01$]. Indeed, the different voice judgments tended to be categorized more as fearful when a fearful face was presented than when a happy or inverted face was presented.

DISCUSSION

Prosopagnosic patient AD has completely lost recognition of personal identity and facial expressions but shows evidence for covert processing of the latter. Facial expressions that can no longer be recognized in isolation are still processed such as to combine with the input from the voice. In other words, these explicitly unrecognized facial expressions do exert a cross-modal bias effect on identification of expression in the voice. This report is

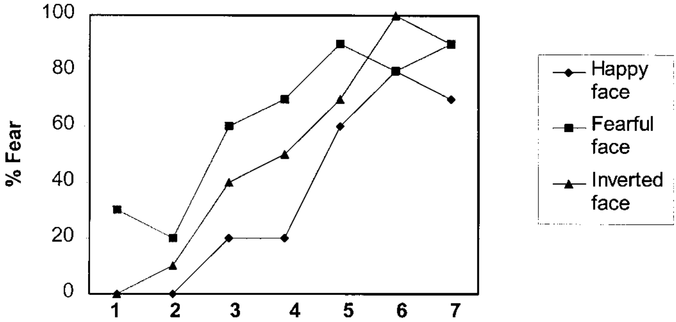

FIG. 7. The figure shows the impact of face expressions on voice judgments. The horizontal axis represents the seven-step vocal continuum happy–fear (happy on the left and fear on the right). The percentages of fear reponses are given for the fearful face condition, for the happy face condition, and for the inverted face condition.

the first to explore bimodal emotion recognition in a brain-damaged patient and to provide evidence for covert perception of face expressions in a prosopagnosic patient. The cross-modal bias paradigm appears thus like a new research paradigm that is well suited for studying spared facial expression recognition. Not only does it not require any overt recognition of facial expressions but it takes advantage of the unimpaired auditory input channel. This residual ability appears to be specific for facial expressions and does not seem to generalize to other aspects of face processing such as recognition of personal identity or speech reading (de Gelder, Vroomen, & Bertelson, 1998b).

The paradigm we used allows one to disregard the possibility that the bias effect reflects only the fact that addition of a second input modality generates arousal or distraction and confuses the perceiver. Rather than merely showing a distraction effect of vision on audition, we show clearly that the direction of the effect reflects the content of the second input modality.

As we argued in establishing this phenomenon with normal individuals (de Gelder & Vroomen, 1995; de Gelder, 2000), the effect has a perceptual basis and is mandatory. It has a perceptual basis in the sense that it does not result from a postperceptual judgment reached after the two input sources have been processed separately and evaluated independently (Massaro & Egan, 1996; de Gelder & Vroomen, 2000). Needless to say, in the case of our patient, a postperceptual bias explanation is clearly unlikely given her inability to process facial expressions overtly or even to match faces for sameness of expression.

We noted in the Introduction that covert expression of faces has not previously been reported in the literature. As a consequence, the present models of covert face processing and the available explanations are tailored to the case of loss of overt identity recognition and the sparing of covert identity processes.

A first explanation appeals to impoverished representations (Farah, O'Reilley, & Vecera, 1993). The possibility of impoverished but still somewhat preserved representations is certainly worth considering. We have raised the possibility of impoverished representations when discussing the impact of visual speech representations (de Gelder et al., 1998b). AD had some spared visual speech recognition ability when dynamic stimuli were used. Yet she showed very little audiovisual bias. We considered the possibility that this reduced audiovisual effect might be due to impoverished visual speech representations. But note that the evidence of some spared visual speech was obtained in explicit speech reading tests.

A second approach was defended by Bauer (1984) and is based on a distinction between dorsal and ventral processing streams implicated in face recognition. The notion is that dorsal routes are preserved and could account for automatic processing of aspects of faces in cases where ventral routes for overt recognition and verbal report are impaired. Recently de Haan, Bauer, and Greve (1992) offered an account that intends to combine a special systems account with Bauer's dual processing view. The application of this model to covert expression processing has not yet been considerded. Farah (1996) notes that Bauer's dual systems approach is similar to the approach of blindsight defended by Weiskrantz. As a matter of fact such an extension is envisaged in Weiskrantz (1997).

It must be noted that some structural face (de Gelder, Bachoud-Levi, & Degos, 1998c) and object (Peterson & de Gelder, 1998) recognition is preserved nothwitstanding the lesion. Our patient's lesions affect the occipitotemporal or ventral stream but do preserve the dorsal stream. This means that a face structurally encoded even if all further processing in those occipitotemporal areas is made impossible by the lesion. Such an elementary structural representation is too underdeveloped to support any recognition, but it could still be the basis for generating a cross-modal effect.

A third explanation of covert processing is that of two qualitatively different systems corresponding to covert and overt expression processing. On this picture, the covert processing system would be intact in this patient but it is a system that does not support overt recognition and is generally not involved in recognition processes properly speaking. In other words, the output of processing would never reach awareness but could nevertheless combine with information from the affective expression in the voice. Recent studies of facial expression processing have provided evidence for nonconscious processing of facial expression (Morris, Ohman, & Dolan, 1998; Whalen, Rauch, Etcoff, McInerney, Lee, & Jenike 1998). More generally, current theories of affective processing grant that substantial aspects of affective information processing do not involve consciousness (Ledoux, 1996). Further research needs to address the question which of these explanations best fit this novel case of covert processing of facial expressions.

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