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An ERP Study of Expectancy Violation in Face Perception

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Expectancies about face-structure can be induced by viewing parts of faces, which generates constraints due to two types of knowledge: feature-content and configuration. In a first experiment ERPs were recorded when parts of familiar faces were completed with incongruent features (from another face), as opposed to congruent features (from the same face). All features were in the correct configuration. An enhanced negativity was found for incongruent completions (N374) that was larger over the right side of the scalp. This replicates the results of Valdes-Sosa and Bobes (1990). In another two experiments, ERPs were recorded when parts of familiar faces were completed by congruent features, but sometimes placed in an incorrect position. In one experiment the features were jumbled; in the other, the features were slightly displaced. These configuration distortions were associated to late positive components, with a maxima at the centro-parietal region, of equal amplitude for both kinds of configuration anomalies. The N374 component seems to be a non-linguistic analog of the N400. The different ERP signatures for expectancy violations of configuration and feature-content suggest that these types of information are processed separately at some stages.

INTRODUCTION

During the perception of language different sources of information can contribute to the recognition of incoming signals. In addition to the sensory data provided by individual words (whether spoken or printed), other types of knowledge constrain what can be expected in a given context. While nobody disavows the possibility of this information interaction, "how early" and "how" is the subject of much debate. Research on face perception is beginning to address analogous questions, and this article is concerned with extending some of the Event-Related Potential (ERP) methods developed for the study of word recognition to the study of face recognition.

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For each information domain, conceptually distinct types of knowledge (sources of contextual constraint) can be identified. In language, syntactic and semantic expectancies are generated as words are stringed into sentences; orthography constrains transitions between letters in printed words. There is evidence that words that violate contextually induced constraints are processed less accurately or at a slower rate than words that are more probable for the context (Fischler & Bloom, 1979; Kleiman, 1980; Schuberth & Eimas, 1977). However, there is disagreement if the different sources of information are brought to bear on the same stages of recognition. In some models, different types of higher-order information can influence the earliest stages of recognition (Morton, 1969; Becker, 1980; Marslen-Wilson, 1987). In other models, different types of information are processed separately until the late stages (Fodor, 1983; Tanenhaus Carlson, & Seidenberg, 1984; Canseco-Gonzalez, 1991).

There is also disagreement if these conceptually distinct types of information, within each domain, are subserved by independent neural mechanisms (Fodor, 1983; Ellis & Young, 1988). The effects of expectancy violations on ERPs can, perhaps, contribute evidence to the debate. Are non-expected stimuli handled by common neural mechanisms in all domains? What happens if the expectancies are associated with different types of knowledge within the same domain? If information from different sources (say semantical and syntactical constraints) is integrated at a very early stage of word recognition, then the management of expectancy violations is probably resolved through a common mechanism. Different ERP effects, due to distinct types of expectancy violation, would suggest some degree of parallel processing and the involvement of different neural populations at some point.

Expectancy violations can be set up by presenting subjects with a context stimulus and then presenting a test stimulus which falls outside of constraints dictated by previous knowledge. Kutas and Hillyard (1980) employed this approach with verbal material, discovering a negative ERP component: the N400. This component is elicited when the last word in a sequentially presented sentence, is semantically incongruent with the preceding context (e.g., "I drink coffee and dogs"), or is a less probable sentence ending (Kutas & Hillyard, 1984). This effect has been related by some authors to semantic priming (Kutas & Hillyard, 1984; Kutas & Van Petten, 1988; Kutas & Hillyard, 1988; Bentin, 1989). In semantic priming a previously presented word facilitates the ulterior processing of related words. One interpretation of this effect is to consider that the "priming" (or context) stimulus pre-activates the memory representation of the subsequently presented test stimulus. This pre-activation facilitates the recognition of the test stimulus. Thus according to this view, N400 is an index of pre-activation of memory representation.

The results with semantic expectancy violations have spurred a search for ERP negativities associated with violations of contextual expectancies generated by other types of knowledge. Kutas and Hillyard (1980) found that unpredictable and infrequent variations in typeface at sentence endings do not elicit N400; instead, a late positivity is evoked. The authors concluded that not all deviations in sentences elicit N400. Unexpected changes based on the physical dimensions of the perceived message apparently lead to a P300 (Hillyard & Picton, 1987). Kutas and Van Petten (1988) list several possible classifications of the situations yielding N400 rather than P300.

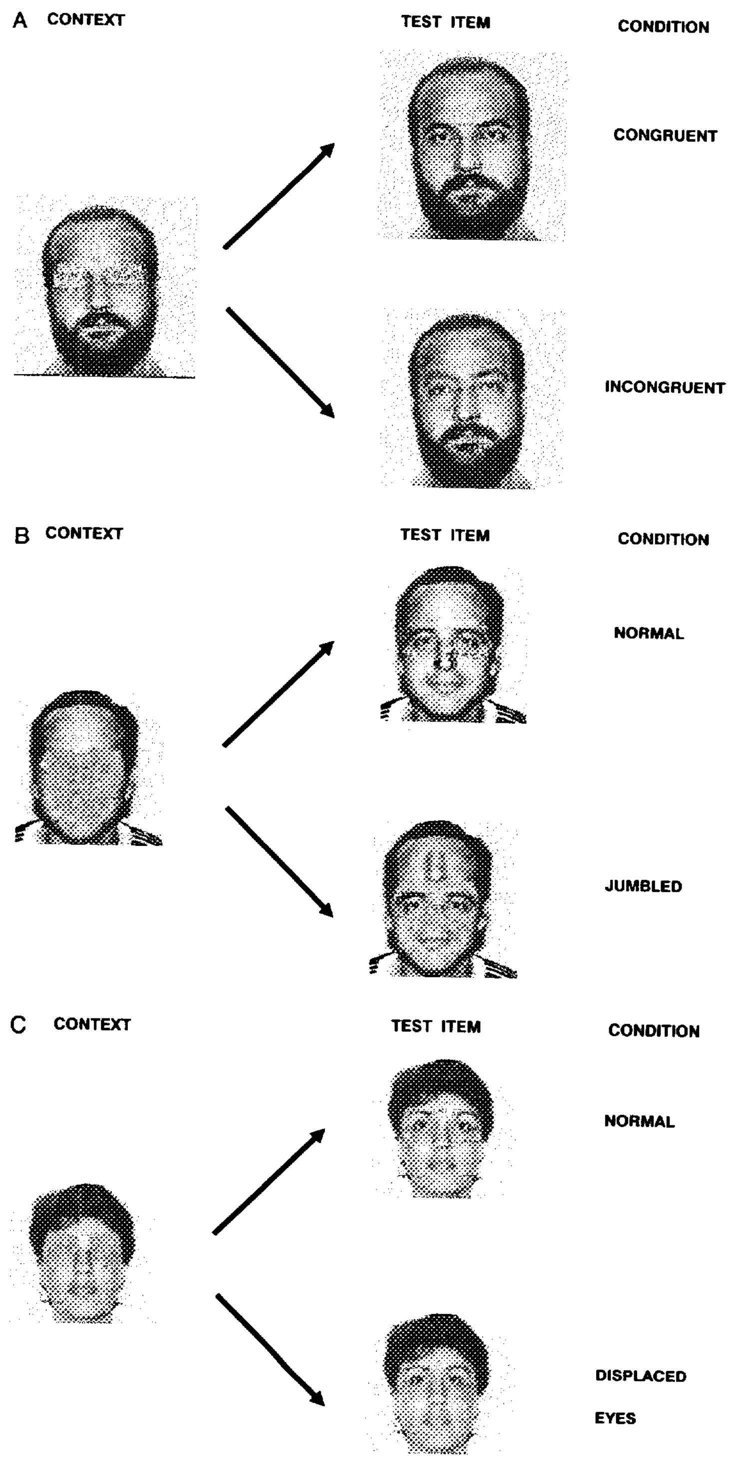
Syntactical deviations in sentences are of particular interest. In a study by Kutas and Hillyard (1983), only a small negative shift (restricted to frontal sites) was elicited by syntactical incongruities. These authors also noted a small late positivity to grammatical deviations that was evident at the very end of the epoch for the violation, spreading into the ERP for the next word. However, Herning, Jones, and Hunt (1987) and Munte, Heinze, and Prevedel (1990) found a larger N400, when words at sentence endings violated grammatical rules. Recently, Brown, Hagoort, and Groothusen (1992) found that a large positive shift was elicited at the point where a syntactical violation was introduced in a sentence. A problem with this type of study is the difficulty in producing syntactical deviations in isolation from semantic anomalies. Thus it is not clear if linguistic, but non-semantic, expectancy violations can create the conditions that elicit N400.

The initial search for components analogous to N400 generated negative results in non-linguistic domains. A changed note at the end of a well-known melody, or the interruption of a sequence of visual figures ordered on size, elicits a late positive component, similar to P300 (Besson & Macar, 1987).

A different situation has been found for face processing (Valdes-Sosa & Bobes, 1990). Face structure is clearly a non-verbal domain (Paivio, 1986; Kosslyn, 1988), for which specialized neural mechanisms have been posited (Grusser, 1984; Young, 1988; Benton, 1990). Thus the finding of an ERP signature for contextual violations within face structure has theoretical interest.

In face perception, viewing part of a face can create expectancies about the remainder. Aspects like the position, expression, and apparent age of the absent part can be predicted even for unfamiliar faces. Additionally, the structure (content) of the missing features is constrained in familiar faces (for an analysis of different codes derived from face structure, see Bruce & Young, 1986). There is evidence that parts of faces viewed in an anomalous pictorial context are processed less efficiently (Parks, Coss, & Coss, 1985; Haig, 1986; Young, Hellawell, & Hay, 1987; Brunas, Young, & Ellis, 1990).

Valdés-Sosa and Bobes (1990) presented evidence that a component



A CONTEXT
TEST ITEM
CONDITION
CONGRUENT
INCONGRUENT
B CONTEXT
TEST ITEM
CONDITION
NORMAL
JUMBLED
C CONTEXT
TEST ITEM
CONDITION
NORMAL
DISPLACED
EYES

similar to N400 can be elicited by incongruities within the structure of a known face. The paradigm used by Valdes-Sosa and Bobes (1990) probes expectancy effects within the structure of individual faces, in a manner which is formally similar to that used to produce the linguistic N400. A familiar, but incomplete face (with missing eyes/eyebrows), is viewed to create a context, and congruent or incongruent features are grafted on the image to complete the face. In this case, congruent is defined as belonging to the same face and incongruent as originating from another face (see Fig. 1A). The overall, correct, configuration of features is preserved in both cases, but the expected feature-content does not exist in the case of incongruent eye/eyebrows.

An enhanced ERP negativity, peaking around 374 msec, is associated with incongruent face completions only in subjects who were highly familiar with the faces used as stimuli. This component (N374) was enhanced for incongruent features even when the subjects had no knowledge of the corresponding face names. Valdes-Sosa and Bobes (1990) suggested that pre-activation of face descriptions in memory reduced N374 to subsequently correct completions, an hypothesis analogous to that discussed above for N400. A similar explanation for priming effects from incomplete faces on the speed of familiarity decisions of subsequently presented complete faces, was advanced by Brunas et al (1990), who suggest that a mechanism similar to pattern reinstatement (as present in PDP models, McClelland and Rumelhart, 1985, 1986) is the basis of this phenomenon.

The experiments just described explore the constraints imposed by descriptions of familiar faces: only the content of specified features are tampered with. Describing the structure of a face by breaking it down into parts (eyes, mouth etc.), whose content varies from one individual to another, is typical of early "feature list" models of visual recognition (Pinker, 1984) and underlies the development of forensic tools such as

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FIG. 1. Three experimental paradigms described in this article. (A) Face feature content violations (Exp. 1). On the left, the incomplete face "context;" on the top right, a congruent face completion, that is, the original eye/eyebrow fragment is put in place, thus, the original face is seen. On the bottom right, eye/eyebrows originating from another face image is grafted into the context, thus creating an incongruent face completion. Feature configuration is respected in both cases. For individuals familiar with the faces, incongruent completions like that of the bottom right, are clearly perceived as different from the original. (B) Severe face configuration distortion (Exp. 2). On the left an incomplete face, where all the internal features were removed, is presented as context. On the top right the absent features are added, placed in the correct position creating a normal face. On the bottom right the correct features are placed in an incorrect position creating a jumbled face. Feature content was preserved. (C) Mild face configuration distortion (Exp. 3). On the left an incomplete face is presented as context. On the top right the original eye/eyebrow fragment is put on the face in the correct position creating a normal face. On the lower right the eyes are slightly displaced from the correct position (notice that the inter-eye distance is shortened). Feature content was preserved.

Identikit and Photofit (Bruce, Doyle, Dench & Burton, 1991). Several studies with schematic faces (Bradshaw & Wallace, 1971; Tversky & Krantz, 1969) demonstrated, that the time to detect differences between faces decreased as the number of discrepant features increased. These results provide evidence that features are indeed important in face recognition. On the other hand, the configuration of features permits the identification of blurred faces, when the content of the individual features are very distorted (Harmon, 1973; Rhodes, 1986). Several recent studies have stressed the importance of configurational information (Sergent, 1984; Ellis 1986; Young, Hellawell & Hay, 1987; Haig, 1986; Bruce, Doyle, Dench & Burton, 1991). In fact configurational and feature knowledge are both likely to contribute to normal face processing (Sergent, 1984; Bruce & Young, 1986). Certain extreme types of models are possible, where configurational and feature clues are indistinguishable and interactive from the earliest stages of face processing (as in some computer models, see Bruce & Burton, 1989). It is thus interesting to compare the effects of expectancy violations associated with these two sources of face structure information.

Once a part of a face is viewed, the position and orientation of features in the rest of the face are constrained. This expected configuration can be altered, without affecting the content of most features (see Figs. 1B and 1C). As a caveat, it must be noted that it is very difficult to change each source of information (configuration or features) with complete independence from each other.

In this article we first replicate the results of Valdes-Sosa and Bobes (1990) with unexpected feature contents, and then go on to examine violations of expectancies about configuration. We hypothesized that different types of expectancy violation are associated with distinct ERP effects. If this were so, it would suggest that non-identical neural processes are elicited by content and configuration expectancy violations in face processing, and that, up to certain stages, both types of information can be processed independently.

METHODS

Subjects

Three groups of healthy, right-handed adults (as ascertained by personal report) with ages ranging from 25 to 42 years, participated as volunteers in the experiment. Each group was presented with a different experiment. All of the subjects had received higher education (university). Also, all of the subjects were highly familiar with the posers for the face photographs used as stimuli, since they had daily contact, working together at the same research center for at least 1 year. Twenty-four subjects (14 males and 10 females) participated in Experiment 1, 10 (6 males and 4 females) in Experiment 2, and 10 (4 males and 6 females) in Experiment 3. No subject took part in more than one experiment.

Face stimuli

Digitized black and white photographs of the faces of 70 members of the authors research department were used to generate the stimuli. The photographs consisted of frontal views, with neutral expressions, which were roughly equivalent for size and contrast (all original photographs were obtained under the same conditions). The photographs were digitized (EPSON EX/1000, Scanner Option Kit-8392) and stored in files on magnetic disk.

Face stimuli were presented on a EGA monitor and were approximately 9-cm high and 8-cm wide. Since subjects sat approximately 108 cm from the screen, the faces subtended a vertical visual angle of 4.8° and an horizontal visual angle of 4.2°.

In the three experiments, each trial consisted of the presentation of two stimuli (Fig. 1). First, an incomplete face image (i.e. with deleted features) was presented as context. Then the face was completed using either the original features (50% of the trials) or changed features (50% of the trials) grafted into the deleted areas. The incomplete faces (context) were created by replacing regions of the original image with visual "noise" (the regions deleted were not identical for all the experiments). The borders of the grafts were blended into the receiving image by smoothing with a sliding average.

In Experiment 1 the context image consisted of faces in which the eye/eyebrow region was digitally deleted. (Fig. 1A). The congruent completion consisted of placing the original features in place. The incongruent stimuli were prepared by grafting eye/eyebrow fragments, originating in other faces, into the deleted regions of the incomplete faces. For each face the incongruent fragment was selected from another face with similar physical characteristics such as skin and hair color, and size of the features. Incongruent fragments with obvious lack of fit, as judged by three observers (unfamiliar with the faces), were not used. The original configuration of the features was preserved. A group of 10 observers not familiar with the faces performed at near chance level when discriminating between congruent and incongruent completions (Valdés-Sosa and Bobes, 1990). Further examples of the images used can be found in Valdés-Sosa and Bobes (1990).

In experiment 2, all internal features (eyes, eyebrows, nose, and mouth) were substituted by visual noise (Fig. 1B) to create the stimuli used as context. These context stimuli were completed with features belonging to the original face image. The features could be placed in the correct positions (normal face) or in wrong positions (jumbled face) (Fig. 1B). Five different kinds of jumbled faces, according to all possible combinations for the re-arrangement of the features were included, each in the same proportion. The following sequences (from top to down) were used: (1) eyes/eyebrows–mouth–nose; (2) nose–eyes/eyebrows–mouth; (3) nose–mouth–eyes/eyebrows; (4) mouth–eyes/eyebrows–nose; and (5) mouth–nose–eyes/eyebrows. While the content of the features was preserved, the configuration of the features was altered.

The configuration distortions used in Experiment 3 were milder than those used in Experiment 2. Only the eyes/eyebrow region was deleted in the context stimuli, in the same way as described for Experiment 1 (Fig. 1C). The completion of the face always was obtained by using features from the same face (as in Experiment 2). Again, the missing features could be added at the correct position (normal face) or displaced from their original position (displaced eyes) (Fig. 1C). Four different kind of displacements were used in equivalent proportions: upward displacements, downward displacements, shortening of the inter-eye distance, and lengthening of the inter-eye distance.

The displacements were generated interactively with the image displayed on a CRT monitor, using a custom-made program. The amount of displacement was selected by a judge to be sufficient to produce a recognizable difference from the original face image, but not so large as to destroy the normal face structure. In other words, the result had to produce a plausible face. The amount of displacement was always smaller than approximately 10% of the original measures (either elevation of the eyes in the face or the inter-eye distance).

Procedure

During each experiment the subjects sat in a comfortable chair in front of the CRT monitor, observing the stimuli displayed in the center of the screen. The subjects were instructed to minimize body and eye movements.

Each trial was initiated by the subject and consisted on the following events. First the letter string "XXXXXXX" was placed in the center of the screen as a fixation point and as a warning that the trial was about to begin. When the subject was ready, he pressed a key and the warning stimulus was replaced by the context presentation. When the subject pressed the key again, the test-image was presented and was displayed for 1 sec. Thus the time the context was on the screen was under control by the subjects, while the test-image presentation time was constant. The EEG recording was synchronized with the test-image onset. After the test-image offset, the word "RESPOND" was shown for another second, to indicate that the subject should verbalize his response. Then the screen was black for 8 sec. The task of the subject consisted of discriminating between correct (original face) and incorrect (changed face) completions. Classification efficiency was measured using Signal Detection Theory (Swets, 1964), by calculating discrimination sensitivity (d') and response criterion (β) with the formulas described in Meyer *et al.* (1988).

An experiment comprised a total of 140 trials, presented in two blocks. In each block every face was used once as context, in a pseudo-random order (each face presented twice in an experiment). If a face was completed correctly (congruently or normally) in one block, then the completion was incorrect (incongruent or distorted) in the other. The order of presentation of the two blocks were counterbalanced over subjects. A previous study, similar to experiment 1, demonstrated that this type of repetition had no effect on the ERPs (see Valdés-Sosa and Bobes, 1990) or on behavioral measures (Bobes, 1989).

Electrophysiological Recording

Electrophysiological data acquisition was carried out using disk electrodes (Ag/AgCl) placed on six derivations of the 10/20 international system (F7, F8, Cz, Pz, O1, and O2). All electrodes were referred to linked earlobes. Inter-electrode impedance was always below 5 kOhms. Additional bipolar derivations were used to record the vertical and horizontal EOG. The signals were amplified by a factor of 10000 and filtered between .05–30 Hz (3 dB down). Additionally, a notch filter with peak at 60 Hz was used. In each trial 256 points of digitized EEG were recorded at a sampling rate of 4 msec, totaling 1.02 sec and stored on magnetic disk for off-line analysis. The EEG recording was synchronized with the onset of the test item (completion of the context image). A pre-stimulus baseline of 150 msec was obtained in each trial and data acquisition continued 874 msec after stimulus onset. Each EEG segment was visually inspected and those with artifacts in any channel, or eye-movement artifacts in the corresponding EOG, were eliminated. Trials with incorrect responses were also eliminated.

For each subject, averaged evoked responses for each recording site were recorded for each stimulus condition, and were subjected to low-pass filtering under 5.5 Hz. The baseline was corrected by subtracting the average pre-stimulus amplitude value. Difference waveforms were obtained by subtracting the ERPs obtained in different conditions for each derivation in each individual. For the statistical tests the average amplitude of waveform was measured for each individual in the same time windows for all derivations. After inspection of grand average ERP waveforms, the windows were positioned to be centered on the effects of interest (see results section). These measures were submitted to repeated measure ANOVAs. The Greenhouse-Geisser procedure to control Type I error in repeated-measures designs was used when appropriate (Keselman & Rogan, 1980).

RESULTS

Experiment 1

On debriefing after the recording session, all subjects reported that they had identified almost all of the incomplete face context before completion. The mean discrimination sensitivity (d'), between congruent and incongruent faces, for the sample of subjects was 3.5 (SD = 1.6), which is significantly different from zero (t = 9.6, df = 23, $p < .0001$). The mean percent of hits was 91% (SD = 6). The mean measure of response bias (log β) was −.59, which is not significantly different from zero.

The averaged ERPs elicited by the face completions exhibited a similar morphology to that described by Valdés-Sosa and Bobes (1990). The sequence of the most prominent peaks (Fig. 2) was in the posterior sites P70, N166, P590, and in the central and frontal sites P202, and P590. In the latter sites either a negative peak or a plateau was present between P202 and P590.

The type of face completion (congruent or incongruent) produced little effect on the earliest components (before 250 msec), although it did produce evident modulations of the later components. This can be observed in the overlays of congruent and incongruent-ERPs (Fig. 2). Enhanced late negativities, associated with the incongruent completions, were

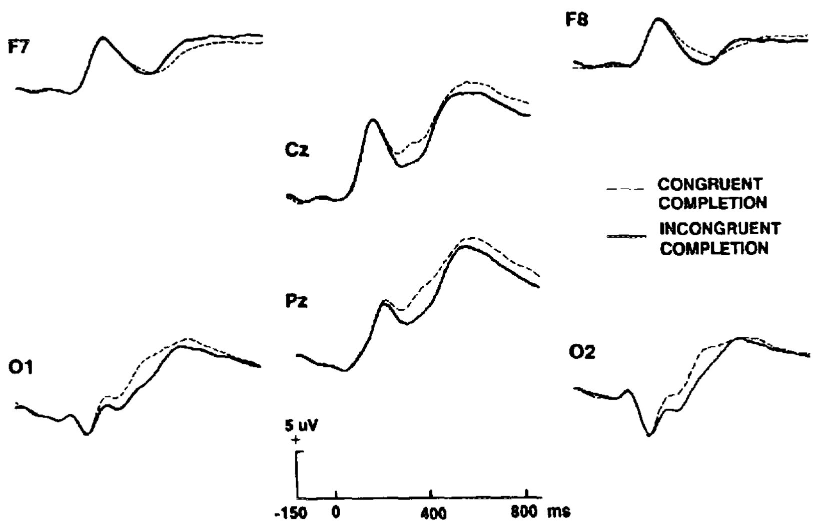

FIG. 2. Grand average ERPs obtained for congruent and incongruent stimuli in Experiment 1. In this, and subsequent figures, the grand average ERP over all subjects is plotted with positive deflections pointing up. The six derivations used are indicated on the far left. The ERPs associated with congruent face completions (thin interrupted line) are overlaid on the ERPs associated with incongruent face completions (thick line).

found in most derivations (most clearly in Cz, Pz, O1, and O2). The negativity presented a well defined peak, near 374 ms at Cz in the difference waveforms. Also, the onset latency of the negativity appeared earlier at O2. On visual inspection the negativity appeared larger over the posterior sites, and over the right side of the scalp, although this last asymmetry was more evident at frontal sites. The negativity presented a maxima at O2.

The mean latency of the late positive peak, measured at Cz, was 590 msec for congruent trials and 586 msec for incongruent trials, values which were not significantly different ($t = 0.7$, $df = 21$, $p < .5$).

A two-way, repeated-measures, ANOVA was performed on the mean amplitude for three time windows (from 100 to 250 msec; from 250 to 450 msec; from 450 to 650 msec) including all recording sites. The first window was positioned to include the early components; the second window was symmetrical around the peak of the negative modulation of the ERPs, and the third window included the late positive peak. The factors were congruity (congruent vs incongruent completions) and recording site (one level for each site). The congruity effect was not significant in the early and late time windows. The mean amplitudes for the middle time window (from 250 to 450 msec) are depicted in Fig. 5, and the results of the ANOVA are now described. The main effects of congruity ($F(1, 22) = 9.36$, $p < .006$) and recording site ($F(2.4, 52.1) = 9.56$, $p < .0001$) were significant in this time window. Also, the interaction between congruity and recording site was significant ($F(2.2, 49.1) = 4.89$, $p < .009$). The congruity effect reflects the more negative values associated with incongruent-ERPs. The interaction reflects the fact that the congruity effect was of larger amplitude at some sites. To analyze this interaction, another ANOVA was performed as described below.

A three-way, repeated-measures, ANOVA was performed on the time window from 250 to 450 msec, excluding the mid-line sites. The factors were congruity (congruent vs incongruent completions), position (frontal vs occipital), and hemisphere (left vs right). The main effect of congruity was significant, ($F(1, 22) = 9.52$, $p < .005$). This reflected the more negative values for incongruent-ERPs. Position was not significant. Hemisphere was significant, ($F(1, 22) = 7.2$, $p < .013$), reflecting more negative values over the right hemisphere. The interactions between congruity and position were significant, ($F(1, 22) = 6.34$, $p < .02$), reflecting the larger negativity associated with incongruent-ERPs at occipital sites. Planned comparisons showed that this interaction was significant over the left hemisphere ($F(1, 22) = 8.28$, $p < .009$), but only marginally significant over the right hemisphere ($F(1, 22) = 4.00$, $p < .06$). Also the interaction between congruity and hemisphere was significant, ($F(1, 22) = 7.54$, $p < .01$), reflecting the larger negativity associated with incongruent ERPs over the right side of the scalp. Planned comparisons demonstrated that this interaction was significant at frontal sites ($F(1, 22) = 7.75, p < .011$), but not at occipital sites. The interaction between position and hemisphere was not significant. The three way interaction between congruity, position and hemisphere was also not significant. The congruity effect did not differ significantly between O1 and O2.

These results can be summarized as follows: In the time window from 250 to 450 msec, incongruent trials elicited a widespread negativity that was larger over occipital sites and over the right hemisphere (although the left–right asymmetry was greater at frontal sites; see Fig. 5).

Experiment 2

The mean discrimination sensitivity ($d' = 8.9$, $SD = 1.6$) score for discriminating between normal and jumbled face was higher ($t = 7.43$, $df = 32$, $p < .0001$) than in the incongruent feature detection task (see Experiment 1 and Valdés-Sosa & Bobes, 1990). The mean percentage of hits was 99% ($SD = 2$).

The general morphology of the ERPs obtained in this paradigm, as determined by visual inspection, is similar to that described in experiment 1, except for a larger amplitude of N166 at the occipital regions (Fig. 3). The earlier components are similar in the ERPs elicited by normal and jumbled faces. In the later time region a positive component is enhanced in the ERPs evoked by jumbled faces, relative to the ERPs evoked by

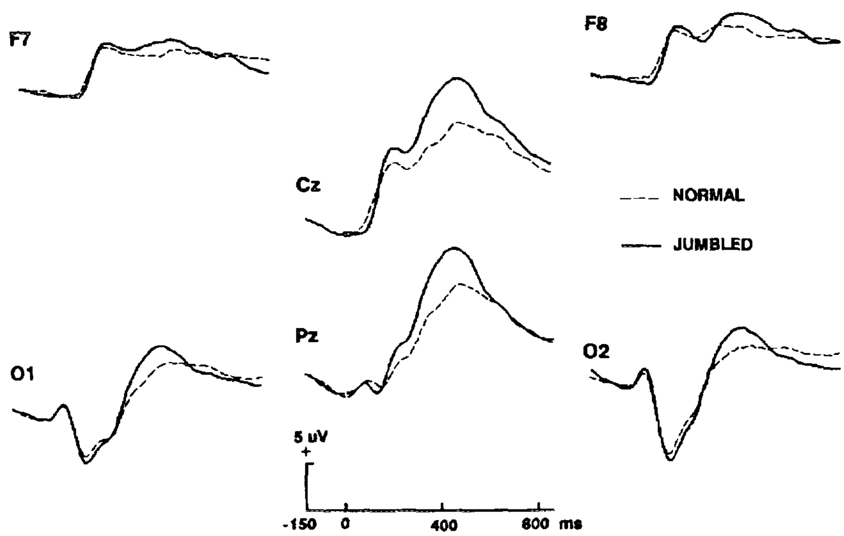

FIG. 3. Grand average ERPs obtained in Experiment 2. The ERPs associated with normal face completions (thin interrupted line) are overlaid on the ERPs associated with jumbled face completions (thick line).

normal faces. This positivity presented a well defined peak near 435 ms at Pz and is larger over centro-parietal region (Cz and Pz; Fig. 5). There is a small early negativity in O2 derivation associated with jumbled completions, which begins at approximately 142 ms and lasts until 278 ms.

A two-way repeated measures ANOVA was performed on the mean amplitude values for the time windows which include the small early negativity (from 142 to 278 msec) and the P470 peak (from 370 to 566 msec). The factors of distortion (normal faces vs jumbled faces) and recording site were used. No effect was significant for the first time window. In the window from 370 to 566 msec the main effect of distortion ($F(1, 9) = 19.83$, $p < .0016$) was significant, which reflects the more positive values associated with jumbled faces. The effect of site ($F(1.5, 13.9) = 14.54$, $p < .0007$) was also significant, which is related to the larger positive values at Cz and Pz as demonstrated by Planned Comparisons ($F(1, 9) = 20.95$, $p < .002$). The interaction between these two factors ($F(2, 18.3) = 9.39$, $p < .0015$) was also significant. Planned Comparisons demonstrated that this interaction was of larger magnitude at the two central sites than at the others ($F(1, 9) = 50.6$, $p < .0002$). No laterality effects were found.

Experiment 3

In this case the difference between normal and distorted faces was not as easy to detect as in the jumbled face experiment. The mean discrimination sensitivity score ($d' = 4.56$, $SD = 1.9$) for displaced eyes faces was smaller than for jumbled faces ($t = 4.41$, $df = 18$, $p < .0003$). The mean score was not different from that obtained in experiment 1 ($t = 1.38$, $df = 32$, $p = .18$). The mean percent of hits was 92% ($SD = 2$).

Despite the differences in discrimination behavior, the ERP obtained in this experiment were very similar, as determined by visual inspection, to those obtained in the experiment with jumbled faces (Experiment 2). Again the ERPs in the early time regions are similar for the two stimulus conditions (Fig. 4). A late positive component was enhanced in the ERPs associated with displaced eyes, relative to the ERPs associated with normal completions. This positivity begins at 300 ms and peaks near 486 ms at Pz. The latency of this positive peak is significantly longer than the latency of the corresponding peak in Experiment 2 ($t = 2.33$, $df = 18$, $p < .02$). This component is larger over the centro-parietal region (Cz and Pz; see Fig. 5) and was symmetric over both sides of the head. The small early negativity between 142 and 278 msec is also present, but only at O2 derivation.

A two-way repeated-measures ANOVA was performed on the mean amplitude values for the time windows from 142 to 278 msec (which includes the early negative effect), and from 414 to 598 msec (which

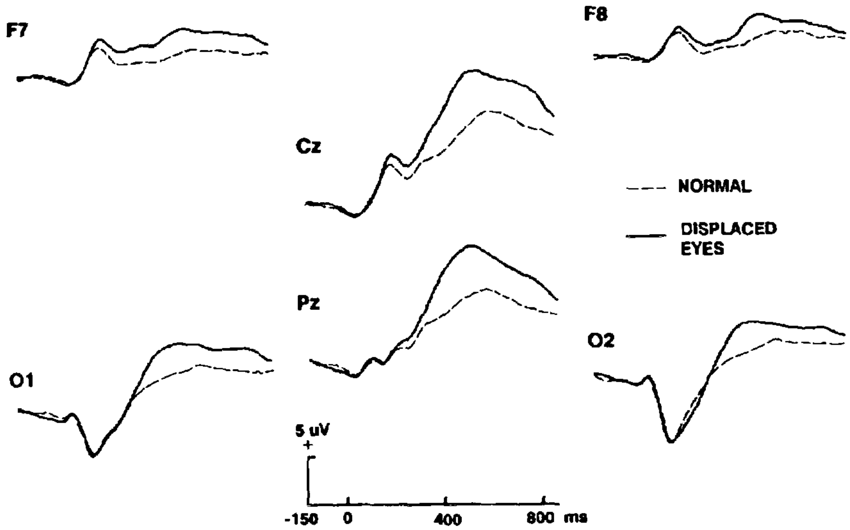

FIG. 4. Grand average ERPs obtained in experiment 3. The ERPs associated with normal face completions (thin interrupted line) are overlaid on the ERPs associated with displaced eyes completions (thick line).

includes the late positive component, P512). The factors of distortion (normal vs. displaced eyes) and recording site were used. No effect was significant for the first time window. For the second time-window, the main effects of distortion ($F(1, 9) = 37.74$, $p < .0002$), was significant, which reflects the more positive values associated with displaced eyes faces. The effect of site ($F(2.7, 24.3) = 25.81$, $p < .0001$) was also significant, which is related to the larger positive values at Cz and Pz as demonstrated by Planned comparisons ($F(1, 9) = 74.9$, $p < .00001$). The interaction between these two factors ($F(3.1, 28.2) = 12.42$, $p < .0001$) was also significant. Planned comparisons demonstrated that this interaction was of larger magnitude at the two central sites than at the others ($F(1, 9) = 72.71$, $p < .00001$). No laterality effects were found.

DISCUSSION

The results of this study describe different ERP effects of expectancy violation in face perception, depending on the type of knowledge that generates the rules that are disregarded. When an unexpected feature-content (in the correct position) is perceived, a negativity is enhanced in the ERPs. When the correct features are placed in incorrect configurations, a positivity is enhanced in the ERP. The exogenous components in all experiments were very similar.

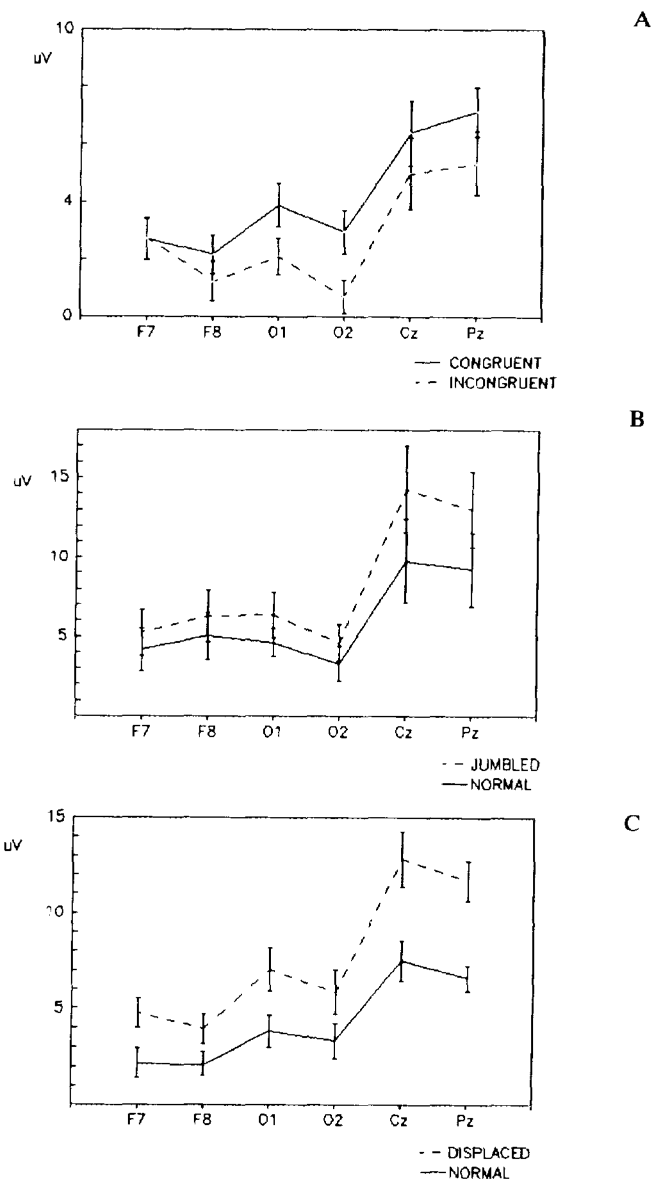

FIG. 5. Mean amplitude (and standard errors) at each recording site for the indicated time windows. (A) For Experiment 1 values for congruent and incongruent trials are plotted separately. The time window used was 250–450 msec. Observe that the congruity effect is larger for right homotopic sites, and also larger at occipital sites. (B) For Experiment 2 values for normal and jumbled trials are plotted separately. The time window used 370–566 msec. Observe that the effect of distortion is symmetric over left and right sites, and is larger at Cz and Pz. (C) For Experiment 3 values for normal and displaced-features trials are plotted separately. The time window used was 414-598 msec. Observe that the effect of distortion is symmetric over left and right sites, and is larger at Cz and Pz.

The Effects of Content Violations

The subjects were able to identify all of the incomplete faces used as context stimuli, a result related to their high degree of familiarity with the posers. This is important since in a study using incomplete face primes by Brunas *et al.* (1990), facilitation of subsequent whole-face familiarity decisions was significant only when the primes had been identified. This result would seem to imply that expectancies (or the correct pre-activations in memory) are generated only when the context stimulus is recognized, a condition that seems to be satisfied in this paper.

In experiment 1, the ERPs elicited by incongruent completions, when compared to the ERPs elicited by congruent completions, present an enhanced negativity, which grows in size over the scalp in both front to back and left to right directions (although this last asymmetry is stronger at frontal sites). This result replicates the findings of Valdés-Sosa and Bobes (1990) who refer to the effect as N374. The possibility exists that N374 originates either as the enhancement of a negative component or from the modulation of the late positive complex. The data presented in this article suggest that the relative negativity of the incongruent ERPs does not appear to arise from a modulation of the late positive component. The peak amplitude of this positive wave is the same in congruent and incongruent ERPs. Also the mean latency of the late positive peak is actually somewhat shorter in incongruent trials than in congruent trials (although this difference is not significant). Thus N374 could not arise from a delay in the late positive complex.

It has been suggested that N374 (Valdés-Sosa & Bobes, 1990) is related to associative pre-activation of face feature descriptions in long-term memory. The activation of other types of code (visuo-semantic, expression, person-semantics etc; Bruce & Young, 1986) would not be necessary. In other words, the negativity will be large to the degree that the structural representation (containing the description of the missing features) has not been activated. This interpretation is supported by the following facts (Valdés-Sosa & Bobes, 1990): (1) When the faces are unfamiliar (no face descriptions exist), then N374 is not elicited by incongruent face-completions; (2) the amplitude of N374 is significantly correlated (across subjects) with success in the task of discriminating congruent from incongruent completions (a task presumably depending on the ability to use face-descriptions); and (3) knowledge of names corresponding to the faces is not necessary to evoke N374. Additional evidence that N374 is specific to the face-structure domain was found in a study using familiar artificial faces (Olivares, Aubert, Bobes, & Valdés-Sosa, 1992). Since the artificial faces were studied under conditions that did not permit associated semantics to be acquired, the production of N374 would seem to depend exclusively on face structural codes.

Other authors (Smith & Halgren, 1987; Barrett, Rugg, & Perrett, 1988) have described negativities that are modulated during face recognition, using repetition priming paradigms. Repeated faces are recognized faster than non-repeated faces in this type of paradigm (Bruce & Valentine, 1985; Ellis, Young, Flude & Hay, 1987). The ERPs evoked by non-repeated faces presented enhanced negatives with peaks near 400 msec. It is not possible at this point to establish the equivalence of N374 to these previously described negativities. Repetition priming may arise through mechanisms different from the associative processes that seem to be involved in Experiment 1.

The Effects of Configuration Violations

In contrast to the results of Experiment 1, the incorrect completions of Experiment 2 (jumbled faces) and Experiment 3 (displaced eyes) were associated with an enhanced late positivities (P435 and P486 respectively). The scalp topography of these positivities is similar in both experiments, with a centro-parietal maxima and symmetric over both sides of the head. In addition to an opposite polarity, these changes have a different scalp topography and latency than N374 (see Fig. 5). In this task the same face features were preserved, but their positions within the face were altered.

Discrimination between jumbled and normal faces is easier than detecting incongruent completions (as reflected in the high d' scores for Experiment 2). The subjects task consists of discriminating faces from non-faces. This type of distortion can be detected even in unfamiliar faces, since it requires no knowledge of the individual faces involved. Only knowledge of (abstract) feature configuration rules is necessary. This could suggest that deviance in easier tasks will elicit a positivity.

However, the results of Experiment 3 do not agree with this explanation. Detecting slight eye displacements was just as difficult as detecting incongruent features in Experiment 1, as measured by d'. The fact that the latency of the positivity elicited in Experiment 3 is longer than that of Experiment 2 supports this contention. It is possible that familiarity with the faces helps to perform the task. Faces with displaced eyes are not easily rejected as "non-faces" (Haig, 1984; Bruce, Doyle, Dench & Burton, 1991). It seems that the appearance of a negativity or a positivity is more dependent on the nature of the constraints that are violated, than on the difficulty of the task by itself. In both tasks it is the relational properties of the stimuli that are altered.

Several authors (Goldstein & Chance, 1980; Valentine & Bruce, 1986a, b) have suggested that faces may be encoded by reference to a generalized prototype, or schema of a face. Evidence for specialized mechanisms for encoding face structure has emerged from studies of jumbled faces similar to those used in Experiment 2. Distinguishing objects, or highly scrambled face features, from faces is equally fast when the stimuli are presented to both hemispheres (Young, Hay, & McWeeny, 1985). However, moderately jumbled faces (like in experiment 2) are distinguished faster from faces when presented to the right hemisphere (left visual hemifield). Perhaps the positivities elicited in Experiments 2 and 3 are associated with specialized mechanisms for using a general prototype in analyzing relational properties of face stimuli.

Different Types of Face Knowledge: Different ERP Effects

Disregard for constraint elicited different ERPs, depending on the type of face knowledge (feature-content and configuration) involved. This eliminates unintentional configuration distortion as a factor in the feature content substitution experiments (Experiment 1 and Valdés-Sosa & Bobes, 1990). It also controls for low-level pictorial cues at the border of grafted incongruent completions.

As mentioned in the Introduction, the interaction of feature and configurational information could occur at different levels of the processing stream. One extreme position could be that features and configuration are non-separable dimensions, and that the two kinds of information are combined even at the level of initial encoding. The stimuli eliciting the ERPs (fragments of faces) were physically equivalent in the three experiments. However, the ERP effects of expectancy violation are different in the first and other experiments. This indicates that at some point in the processing of stimuli out of context, different neural populations were recruited according to the type of violation. This result is inconsistent with an extreme (early) interactionist point of view. If feature and configurational information are integrated from a very early stage of processing, then similar effects would be elicited by violations of either type of knowledge. In other words, featural and configurational information of faces must be processed independently up to some degree in order to elicit the pattern of ERP effects described in this paper. Otherwise it would not be possible to tamper with one sort of information, without affecting the coding of the other.

Non-identical neural mechanisms for analyzing content and configuration is also suggested by neuropsychological studies. The recognition of faces as members of an superordinate class (in the taxonomic scheme of Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976) is not affected in prosopagnosics (Damasio, Tranel, & Damasio, 1990). However, the recognition of faces as unique entities (assigning individual identity to different exemplars) fails. This dissociation of face recognition at superordinate and subordinate levels suggests that the type of processing required in Experiment 1 is not necessary for Experiments 2 and 3.

Studies of split-brain subjects (Levy, Trevarthen, & Sperry, 1972; Sergent, 1982, 1984) have been interpreted as indicating that, although both disconnected hemispheres are capable of recognizing faces, different strategies were employed. The right hemisphere apparently relied more on configuration and the left hemisphere more on feature analysis. It is improbable that the normal brain segregates these two types of knowledge by hemisphere. In fact alternative models of the brain lateralization of face processing have been proposed (Rhodes, 1985). What is important is that in some patients a relative dissociation of configurational and feature processing obtains. These neuropsychological studies converge with the ERP results presented in this paper in suggesting non-identical processing modules for the two types of knowledge.

Inter-domain Comparisons

Theoretical considerations of face processing have developed by searching for analogies with models originally developed for printed word recognition (Bruce & Young, 1986; Young, Hellawell, & Hay, 1987; Young, 1988; Brunas, Young, & Ellis, 1990). It is thus interesting to compare our results to those obtained with verbal material. We believe that semantic incongruities in the verbal domain are in a certain sense, analogous to content violations in the face structure domain. To be detected, they require that the observer identify the stimuli as individual entities: identification as members of a general category (faces or words) is insufficient. This analogy could be related to the fact that negative components are enhanced by both semantic incongruities (N400, Kutas & Hillyard, 1980) and face-structural incongruities (N374). This hypothesis is similar to that proposed by Stuss, Picton, and Cerri (1986) who suggested that N400 is an index of the amount of search in long-term memory for individual items.

The scalp topography of N374 is not the same as that of N400 elicited by word stimuli (Kutas, Van Petten, & Besson, 1988). The N400 is largest at centro-parietal sites and slightly larger over the right side of the scalp. The scalp topography of N374 is larger at occipital sites, and the right–left asymmetry is perhaps larger than for N400. Even when N400 is elicited by faces (Barrett & Rugg, 1989), in a semantic (occupation) matching task, the scalp topography is more anterior than N374. This agrees with Valdés-Sosa and Bobes (1990) and points to a possible difference in the underlying generators of N374 and N400. Thus the two components should be considered analogous, but not identical with the evidence available.

On the other hand it is more difficult to establish an analogy between the configurational violations used in this paper, and corresponding linguistic incongruities. The anomalies in jumbled faces are easier to detect than feature-content changes. It is possible to consider jumbled faces as analogous to typeface size changes (Kutas & Hillyard, 1980). Both types of violations are detected at more "superficial" levels of processing (Craik & Lockhart, 1972; Sporer, 1991). This means that both types of change can be detected by relatively simple algorithms, without resorting to extended search in long term memory. Additionally both are followed by augmented late positive waves. Perhaps expectancy violations at a shallow depth of processing (also typical of many oddball-P300 tasks; Hillyard and Picton, 1987) lead to positive waves. However, typeface changes in the Kutas and Hillyard experiment were infrequent, as in the oddball paradigm. Jumbled faces constituted half the stimuli in Experiment 2. Also, the slight feature displacements used in Experiment 3 elicit a late positivity. Detecting slight feature displacements was found to be equivalent in difficulty to perceiving incongruent features. The level of processing necessary to solve this task is not clear. These considerations argue against a simple "depth of processing" explanation.

Another view of this problem would be to consider syntactical rules as somewhat analogous to face configuration rules. Words have to be recognized belonging to grammatical classes (nouns, verbs, etc.), and the order in which they can appear is specified. In the same way, face parts must be recognized as belonging to feature classes (eyes, noses, etc.) and the permissible relative positions are specified. Valid content entities are exchangeable (within limits) at specified sentence/face positions. This analogy could be supported if we accept the position of Brown, Hagoort, and Groothusen (1992) who contend that syntax violations are associated with a late positivity, a result also found with face configuration violations. This issue will have to await further studies with grammatical incongruities for clarification.

A basic, perhaps unsurmountable difficulty is uncertainty on which entities are to be compared in the facial and linguistic domain. Is a face analogous to a word or a sentence? Another is the scalp topographic differences found in different domains. Despite the problems mentioned above, the results suggest that ERP changes associated with different types of constraint violations can contribute to a comparison of different types of knowledge within each information domain. Further studies are necessary to determine if the dichotomy between content and configuration, suggested by our data, holds for other information domains (like music or object perception), or if it breaks down in the light of new results.

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