

HEMISPHERIC DIFFERENCES IN EVOKED POTENTIALS TO FACES AND WORDS¹

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Abstract. Sixteen right-handed subjects (8 male and 8 female) were asked to compare two faces or two words successively presented at the centre of the visual field. The brain's electrical activity was recorded from the scalp at symmetrical points of the left and right occipital lobes (O_1 and O_2) and posterior temporal lobes (T_5 and T_6). The reference electrode was placed on the scalp vertex (C_z). A multi-factor analysis of variance revealed significant hemispheric differences of the N_{243} and P_{406} amplitudes. For the N_{243} the opposite asymmetry was found for faces and words. For the face matching the N_{243} amplitude was higher in the right hemisphere, whereas for word matching it was higher in the left hemisphere. For the P_{406} the asymmetry was in the same direction both for faces and words, with higher amplitude in the left hemisphere. In the case of face matching the hemispheric difference in the P_{406} was more pronounced, due to a negative shift of the potential in the left hemisphere in the latency range of 200-1,500 ms. Functional asymmetry of the brain in face perception thus appears to be reflected in the brain's electrical activity. We conclude that differentiation in hemispheric functions takes place while encoding information about stimulus in short term memory.

¹ Some of the results of the present study were presented in posters at the EBBS Annual General Meeting in Oxford in September 1985 and at the Second World Congress of Neuroscience (IBRO) in Budapest in August 1987.

INTRODUCTION

Clinical research on subjects with unilateral brain damage and on subjects with transected corpus callosum indicates superiority of the right hemisphere in memorizing and perceiving of human faces (6, 11, 18, 23, 45). Evidence to support the theory is also provided by numerous tachistoscopic studies with healthy subjects (3, 7, 9, 10, 12, 14, 16, 17, 19, 24, 25, 31, 37, 39, 42, 43, 47).

Although a great majority of studies of face perception on healthy subjects have shown superiority of the right hemisphere, there are reports of some experimental conditions and with some groups of subjects in which the researchers either did not establish hemispheric differences or even suggested the superiority of the left hemisphere. For example, Rizzolatti and Buchtel (38) did not find asymmetrical hemispheric functioning in women's perception of faces. Zocolatti and Oltman (48) and Rapczyński and Ehrlichman (34) obtained similar negative results with field dependent subjects, Phippard (29) with deaf subjects, Piazza (30) and Gilbert (8) with left-handed subjects. Moreover, Bradshaw et al. (1) did not discover asymmetrical brain functions when comparing faces in profile while Young and Bion (46) arrived at the same results with inverted faces. On the other hand, contrary data, indicating left hemisphere superiority, were obtained by Patterson and Bradshaw (28) in a study where the subjects' task was to compare two schematic faces which differed from each other in only one element. Marzi and Berlucchi (20) obtained similar results in a comparison of famous people's faces, Marzi et al. (21) in a comparison of faces of people known to the subject and Jones (13) in recognizing gender of faces presented.

Taking into consideration the inconsistencies between the results of tachistoscopic studies on hemispheric asymmetry in perceiving and memorizing faces, it seems that more unified data are obtainable through electrophysiological methods. Unlike the majority of behavioural experiments, in which only the ultimate results of the cognitive process are investigated, electrophysiological research also enables the researcher to study the dynamics of the process. This methodology permits the investigator to obtain data on regional scalp difference and on the phase of the process in which the differentiation of hemispheric functions occurs. Simultaneous recording of the electrical brain activity from symmetrical points on the scalp and the behaviour of the subjects seems particularly promising (41).

Until now the studies on electrical activity of the brain during perception and memorization of faces have been limited mostly to recording EEG activity from symmetrical points on the scalp (27, 35). The studies mostly reveal greater activation of the right hemisphere compared to

the left, i.e., lower amplitude of α activity, suggesting that the bioelectrical activity of the brain can be a sensitive indicator of the functional hemisphere asymmetry. Fewer researchers have studied the recording of visual evoked potentials (VEPs) to faces from symmetrical points on the right and left hemisphere. In one of the few studies where this method was applied, Small (40) found that the amplitude of the P_{300} component of VEPs to pictures of faces presented on a screen was higher in the right hemisphere than in the left. In Small's research the subjects were only to look passively at the screen on which pictures of familiar or unfamiliar faces were presented in the centre of the visual field. They were not assigned any task to perform. It is therefore uncertain whether the subjects were engaged in face perception.

Superiority of the right hemisphere was also revealed in our earlier tachistoscopic research in which we recorded simultaneously the errors committed and the VEPs from the left and right hemispheres during comparison of two faces shown successively in the left or right visual field (41). The subjects committed fewer errors when the faces appeared in the left visual field and greater electrical activation of the right hemisphere was observed merely 150 msec after the first face appeared on the screen.

In everyday life, to perceive the world one tries to direct ones eyes so that the image of the perceived object falls in the centre of the retina. Yet the majority of psychophysiological studies on perception of faces in healthy subjects have been conducted in artificial laboratory conditions with pictures of faces briefly presented either in the left or in the right visual field. Electrophysiological research, however, enables analysis of the naturally-occurring asymmetry of cerebral hemispheres with centrally presented stimuli.

The aim of the present research was to verify whether the visual evoked potentials in the right hemisphere are greater than those in the left hemisphere when the compared faces are presented in the centre of the visual field. In order to ensure that the possible hemispheric asymmetry is not connected with the task of comparing any two stimuli, we have utilized words as control material which presumably would involve the left hemisphere more than the right.

METHODS

Subjects

Sixteen right-handed persons (8 men and 8 women) ranging from 20 to 30 years of age, served as subjects. The subjects' acuity of vision was normal or corrected by optical lenses. Handedness was measured by

the Briggs and Nebes' Handedness Inventory (2). The scores of all subjects, familial right-handers, exceeded +19 on a scale on which +24 indicated maximal right-handedness.

MATERIAL

Seven pictures of faces and 16 three-letter words were used as stimuli. The pictures represented faces of 7 men (students) who tried to restrain emotions. They were without any peculiar features, without glasses or beards. Each of them wore a cap to conceal the hair. The faces on the screen were about 3° wide and 5° long. The words, three-letter concrete nouns, were typed horizontally or vertically. The length of the word presented horizontally was about 3° whereas the height of that presented vertically was about 5°.

Procedure

The subject was placed in an electrically and acoustically shielded room. In front of the subject at a distance of 180 cm there was a screen with a fixation point. The stimulus appeared for a period of 100 ms in the centre of the subject's visual field, above the fixation point. A 2.25 s pause followed. Then another stimulus, identical or different from the previous one, appeared in the same position for 100 ms. The subject was to decide whether the stimuli were the same or different and react by pressing one of two buttons. Half of the subjects had the button symbolizing different stimuli closer to them and the button indicating identical stimuli further from them. For the other half of the subjects the buttons were reversed. Moreover, half of the subjects pressed the buttons with the left hand and the other half with the right hand. The appearance of each new pair of stimuli was announced by the word „attention”².

Each subject participated in two experimental sessions. Sixty four pairs of stimuli were compared during each session, half of them identical and the other half different. During one session, the subjects compared pictures of faces, during the other session, words. In the face session, two pictures of faces appeared successively on the screen. The subject decided if the second face was the same as the first face or different. During the word session, 2 three-letter words were presented

² Pilot research showed that such verbal stimuli announcing the exposure does not produce a CNV. On the other hand, a click before the exposure evoked a large CNV which influenced the answer.

on the screen one by one. The letters of the first word were written horizontally and the second vertically³. The second word in the pair was either composed of the same letters as the first word or differed from the first word in one, two, or three letters. The subject decided whether the second word meant the same as the first word.

A Kodak Carousel slide projector with a Laffayette shutter was used to present the stimuli. The number of errors was recorded. The function played by each button, the hand which was used to press the buttons, the order of experimental sessions, and the sex of the subjects were balanced. Eye movements and the behaviour of the subjects were observed on a TV monitor.

The recording of evoked potentials

Visual evoked potentials were recorded from the scalp from symmetrical points on the left and right occipital cortex (points O_1 and O_2), as well as the posterior temporal cortex (T_5 and T_6). The reference electrode was placed in the vertex (C_z) and the ground electrode on the forehead. The resistance between each pair of electrodes did not exceed 5 k Ω . The electrical activity of the brain was amplified by four EEG amplifiers, bandpass 0.23-30 Hz. The VEPs were averaged by a digital computer, ANOPS 101. The sampling rate in each of the four channels was 106 samples per s. The analysis began 0.9 s prior to and ended 3.8 s after the first stimulus had appeared on the screen.

Sixty four responses were averaged in each experimental session and the averaged potential thus obtained was registered on paper by an XY recorder. In the middle of each session, the two amplifying systems were changed around to eliminate the effect of possible amplification differences.

RESULTS

The analysis of VEPs

Every evoked potential recorded from the occipital or from the posterior temporal scalp region contained the following four waves: P_1 , N_1 , P_2 , N_2 . The average latencies of these peak waves were 156 ms, 243 ms, 406 ms and 750 ms, respectively.

The waves were separately identified by two persons, both experienced in the analysis of VEPs. They were unanimous in the identification

³ Using this procedure the subject cannot compare the stimuli merely on the basis of graphic representation of words but is obliged to analyze them semantically (5).

of waves resulting from the first stimulus as well as waves P_1 and N_1 from the second stimulus. However, peaks P_2 and N_2 from the second stimulus were sometimes difficult to identify. This was due to the fact that the VEPs to the second stimulus overlapped with the contingent negative variation (CNV) and with the potentials connected with the preparation for and accomplishment of the motor reaction. This reaction varied in latency with different experimental situations. Therefore, the analysis of VEPs was limited only to components from the first stimulus.

The baseline was determined on the basis of the average value of the EEG in the period of 500 ms prior to the appearance on the screen of the first stimulus.

Two methods were applied for the statistical analysis of VEPs.

Method 1

In each of the recorded VEPs the amplitudes and latencies of successive wave peaks were measured. Figure 1 shows the average latencies and amplitudes of the respective wave peaks as well as their standard

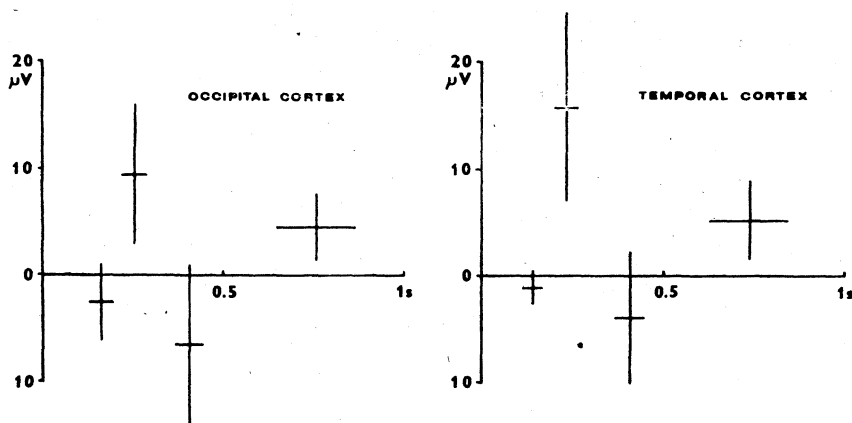


Fig. 1. Amplitudes and latencies of wave peaks P_1 , N_1 , P_2 and N_2 in VEPs recorded from the occipital and temporal scalp regions. The centres of the crosses designate the average amplitudes and latencies of the wave peaks. The vertical and horizontal lines represent double values of standard deviation between the subjects. Positive potentials of the active electrode referred to C_2 were recorded below the zero line.

deviations resulting from between subject variability. Multifactor analyses of variance were then applied separately to the amplitudes and latencies of each wave. The factors were: hemisphere (left or right), stimulus type (faces or words), scalp region (occipital or temporal) and the sex of the subjects (male or female).

The analyses revealed a significant hemisphere factor for the amplitude of wave P_2 ($P < 0.01$). Across both faces and words, the amplitude of this wave was considerably higher in the left hemisphere than in the right (Fig. 2). The interaction between the hemisphere and stimulus type was statistically insignificant, $F = 1.80$, $df = 1/14$, $P < 0.05$.

The analyses also show a statistically significant interaction between the hemisphere and the type of material for the amplitude of wave N_1 ($P < 0.01$). In response to face the amplitude of wave N_1 was higher in the right hemisphere than in the left hemisphere (Fig. 2).

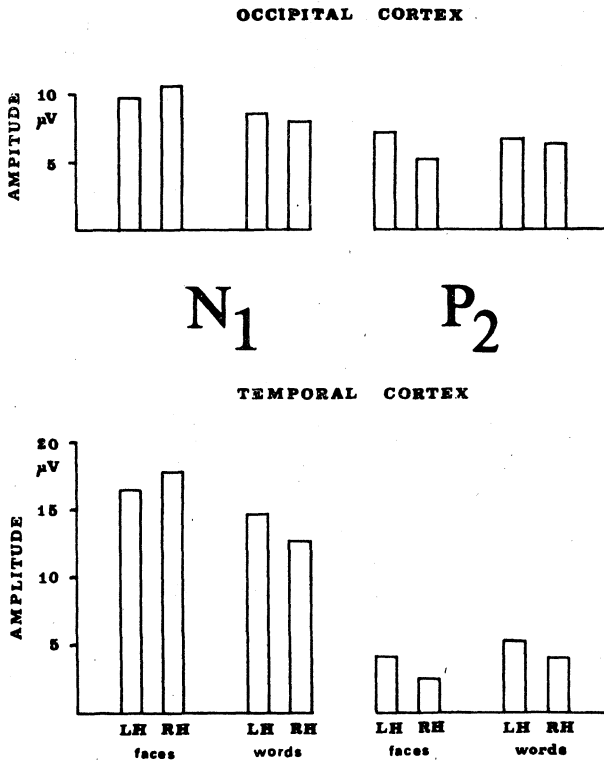


Fig. 2. Mean amplitudes of waves N_1 and P_2 in VEPs to faces and words recorded from symmetrical points on the left and right occipital and posterior temporal cortex.

Figure 3 presents the above relations on the basis of results obtained from individual subjects.

Moreover, the analyses reveal considerable differences between the amplitudes and latencies of the early waves P_1 and N_1 in the comparison

of faces and words. In response to faces the amplitude of wave P_1 was higher ($P < 0.05$) and the latency of wave N_1 was shorter ($P < 0.01$) than in response to words.

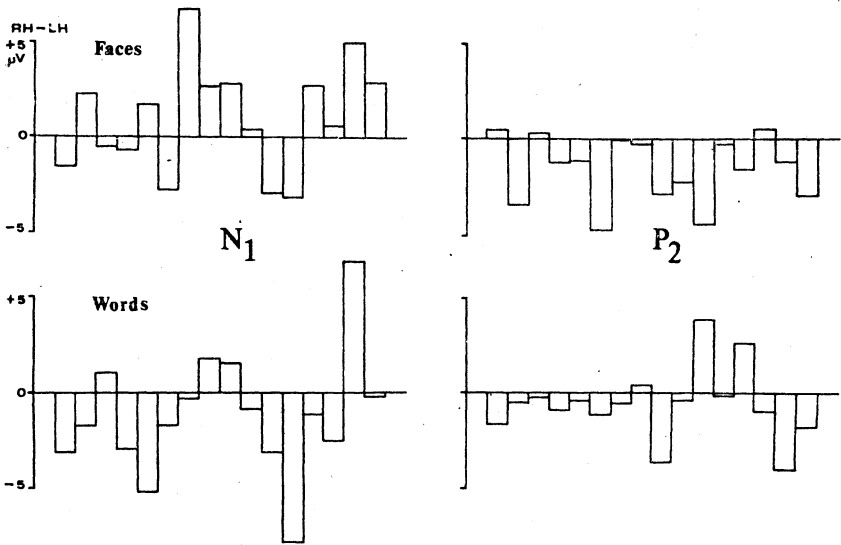


Fig. 3. Differences between the amplitudes of waves N_1 and P_2 in VEPs in the left and right cerebral hemispheres of individual subjects. The data presented are averaged differences in the occipital and posterior temporal cortex.

Analysis of variance, where an additional factor was the hand with which the subjects pressed the buttons, proved that this factor was of no importance either to the amplitudes or to the latencies of any of the VEP waves. Moreover, this factor did not interact with any of the remaining factors.

Method 2

For further computer analysis, each averaged VEP was approximated with a curve determined by characteristic points such as the coordinates of the successive wave peaks P_1 , N_1 , P_2 , N_2 and by the initial and final points (note also 41). The approximation curve was made up of third order polynomials, each of which interpolated two subsequent characteristic points of the VEP. Derivatives of these points were equal to zero. The procedure was applied to obtain approximation curves of the average VEPs for each subject in each experimental situation (16 subjects \times 2 regions \times 2 hemispheres).

All curves, approximating individual VEPs, were sampled at 100 time points and the data obtained were computerized. A comparison of the curves approximating VEPs from the left and right cerebral hemispheres, was then carried out. A Student's test for dependent pairs was applied to test the differences between the VEPs in subsequent time points.

Figure 4 presents the left and right occipital and posterior temporal VEPs to faces averaged for all the subjects whereas Figure 5 the VEPs to words. Below, there are curves presenting the values of Student's

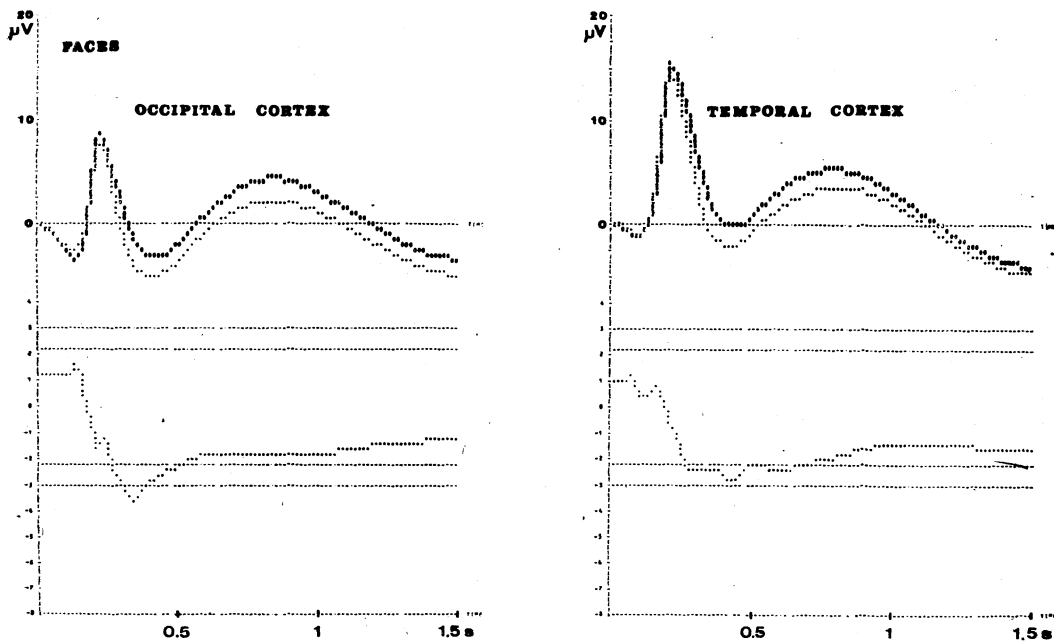


Fig. 4. The comparison of averaged VEPs to faces for 16 subjects recorded from the left (O_1, T_5) and right (O_2, T_6) cerebral hemispheres referred to C_z . The values of Student's statistics for differences between VEPs in 100 subsequent sampling points are presented below two superimposed VEPs. The values of statistics were determined for a two-tailed test for dependent pairs. Horizontal lines represent levels of significance: $t = \pm 2.1$ for $P = 0.05$, $t = \pm 2.9$, for $P = 0.01$ with 15 degrees freedom. When several points are marked for a particular abscissa to make the diagram continuous, the statistical value t is determined by the point with biggest deflection. Dots represent potentials from the left hemisphere and circles those from the right hemisphere. Places where they overlap are marked with the letter z .

statistics and marking the points where the differences between VEP amplitudes from the left and right hemispheres are at the significance levels 0.05 and 0.01.

The figures show that in the face task, in both the occipital and the posterior temporal scalp regions, the amplitudes of waves N_1 and N_2 are higher and the amplitude of wave P_2 lower in the right hemisphere than

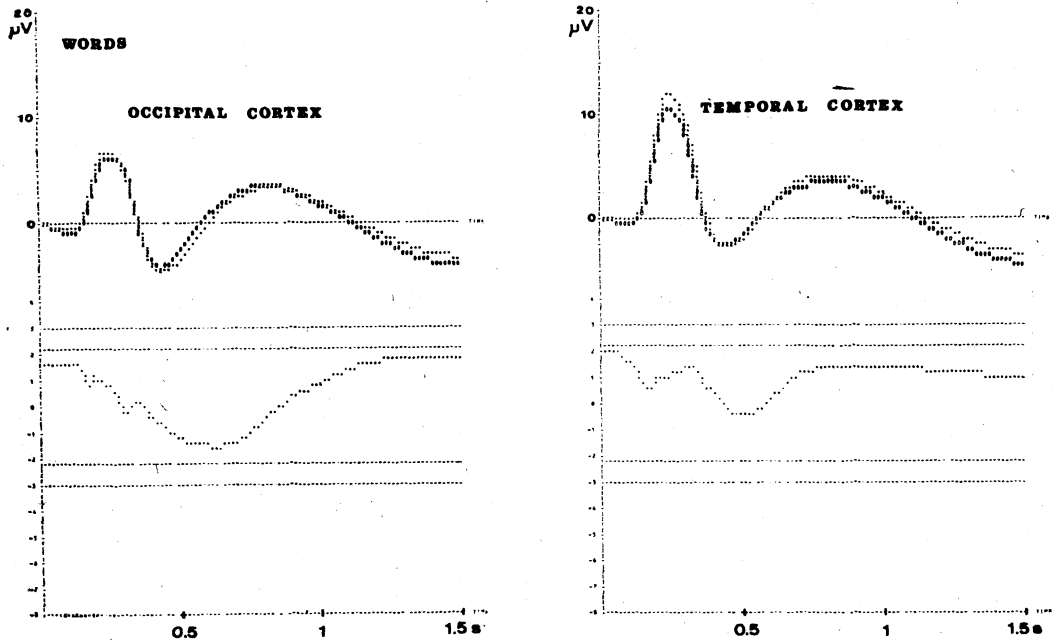


Fig. 5. The comparison of averaged VEPs to words for 16 subjects recorded from the left and right hemispheres (referred to C_2). Further information is provided in the description of Fig. 4.

in the left. These differences are statistically significant in case of the occipital scalp region for latencies ranging from 267 to 526 ms (in 18 points at the significance level 0.05, six of them at the significance level 0.01). In the case of the posterior temporal scalp region, the statistically significant differences occur for latencies ranging from 267 to 733 ms (in 31 points at the significance level 0.05).

In the word task, both from the occipital and the posterior temporal scalp regions, the averaged amplitude of wave N_1 is slightly lower in the right hemisphere than in the left. The differences between the amplitudes of VEPs recorded from the left and right hemispheres were, however, at no point statistically significant.

Error analysis

The analysis revealed that the number of errors depended on the comparison type ($F = 11.27$, $df = 1/14$, $P < 0.005$). The subjects committed more errors when the compared stimuli were identical than when they

were different (Fig. 6). The interaction between the type of material and sex of the subjects ($F = 7.95$, $df = 1/14$, $P < 0.025$) also proved to be relevant. While men committed an equal number of errors in the face as in word task, women made more errors when faces were compared ($F = 8.16$, $df = 1/6$, $P < 0.025$).

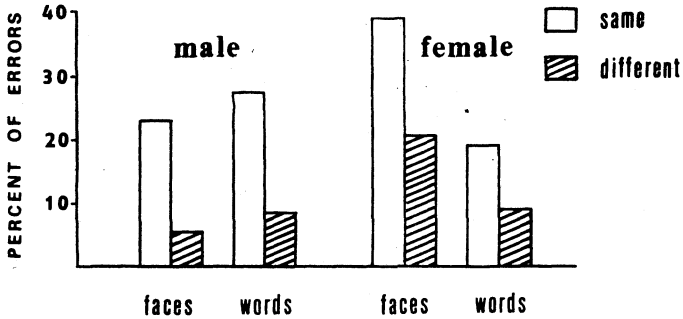


Fig. 6. Averaged percentage of errors committed by the subjects when comparing two faces or words subsequently presented in the centre of the visual field.

Additional analyses of variance showed that the hand with which the subject pressed the button in answer to the question had no influence upon the results (the hand factor as well as any interactions between this factor and other factors appeared to be statistically insignificant).

DISCUSSION

According to the results of the experiments presented above, the process of comparing two faces or words presented centrally in the visual field is accompanied by asymmetrical electrical brain activity. Moreover, there is a considerable difference in asymmetry when faces are compared and when words are compared. In the comparison of two faces, the amplitude of wave N_1 was higher in the right hemisphere than in the left, while the amplitude of wave P_2 was higher in the left hemisphere. On the other hand, in the comparison of two words, the amplitude of both waves was higher in the left hemisphere than in the right.

The existence of the opposite pattern of hemisphere asymmetry in the comparison of words and faces has been proved by clinical research on subjects with unilateral brain damage, with a transected corpus callosum, as well as by numerous experiments on healthy subjects in which the method of lateral presentation of stimuli was used. The studies indicate that the right hemisphere is involved in spatio-gnostic analysis while the left hemisphere analyzes semantic and linguistic information. According to most of the electrophysiological studies, higher amplitudes

of evoked potentials occurred in the hemisphere which was more involved in the analysis of the stimulus. Thus, in the experiment presented above, higher amplitudes were expected in right hemisphere in face comparison and in the left hemisphere in words comparison. The relation was indeed obtained for wave N_1 . A different hemispheric asymmetry, however, was achieved for wave P_2 . The amplitude of this wave was higher in the left hemisphere than in the right, both in the faces and words. The data obtained appear inconsistent with the results of Small's research (40). Small's studies on VEPs to centrally presented faces indicated a higher amplitude of wave P_{300} in the right hemisphere than in the left.

Recent studies of Potter et al. (32) support our results. These authors recorded VEPs to picture of faces from frontal, temporal and parietal scalp regions. The task of the subjects was to decide whether two sequentially presented faces were the same or different. Potter et al. found that at all recorded sites the potentials to the first face in the range of 600-1,100 ms were more negative over the right hemisphere than over the left. In parietal scalp region the hemispheric asymmetry was particularly strong, and started about 400 ms after stimulus. In our opinion, incompatibility of our results with Small's is due to a different degree of involvement of the subjects in face perception and to differences in the ways in which the subjects analyzed the presented stimuli. In Small's research, the subjects had no task to accomplish. They merely looked at the screen on which pictures of faces appeared, whereas in our experiment, the subjects were actively involved in the memorizing and comparison of pairs of faces appearing on the screen. The fact that we obtained a higher amplitude of wave P_2 in the left hemisphere both in the comparison of faces and words leads to the conclusion that the asymmetry was connected with the very task of comparing two stimuli and not with the applied material. A somewhat greater difference in case of comparing faces than words was probably due to the overlapping on wave P_2 of the preceding wave N_1 which differed in case of faces and words.

Our study also indicates the phase of visual information analysis in which the differentiation of electrical activity of the cerebral hemispheres takes place. The differences in the electrical activities of the hemispheres, appearing already in response to the presentation of the first of two faces, leads to the conclusion that the differentiation of brain functions occurs even before the subjects retrieve the picture of first face from memory, before they compare it with the image of the second face and decide whether the faces are the same or not. On the basis of the data obtained in this study as well as the results of earlier psychological re-

search (4, 22, 25) and studies recording potentials evoked by face presentation (40, 41) we have made an assumption that the differentiation of hemispheric functions takes place while encoding information in short term memory.

It is also important to note that the hemispheric asymmetry is equally large in the occipital and temporal scalp regions. This result seems to be particularly interesting when we take into account research on hemispheric asymmetry with the use of material other than faces. Studies on the perception of such stimuli as chess-boards, different sloping lines, or spatial configurations of points, conducted with the VEP method, indicate greater hemispheric differences in the potentials recorded from the temporal and parietal scalp regions than from the occipital scalp region (15, 26, 33, 36, 44). Vella et al. (44) even claim that the slight supremacy of the right hemisphere they noticed in the occipital scalp region is merely a reflection of the large hemispheric asymmetry in the temporal region. A different result was obtained by Small (40) who studied the VEPs to faces. The greater differences occurred in the occipital cortex. It seems justified to think that the results were inconsistent probably because the information about faces was analyzed in different ways from those used with the information concerning other stimuli.

The data obtained in our experiment, encourage us to discuss the relationship between the hemispheric differences and the sex of the subjects. In 1977 Rizzolatti and Buchtel (38) discovered a greater asymmetry in face perception in men than in women. Other studies, however, do not confirm those results (12, 16, 37, 40, 43, 47). Neither did our experiment indicate differences in hemispheric asymmetry in men and women.

Another relationship revealed in the course of our study should be discussed here. The subjects committed decidedly more errors when comparing the same stimuli than when the stimuli compared were different. We believe that this was caused by the procedure applied in the experiment. In half of the comparisons included in the experiment, the compared stimuli were the same while in the other half the stimuli were different. The subjects were not informed about this beforehand. Since each stimulus could be compared with only one similar stimulus and a number of different stimuli, the subject could expect a large number of comparisons with different stimuli. When the subject was not certain about the answer, the answer chosen more frequently was probably that the stimuli were different. This was perhaps also the cause of errors in the comparison of the same stimuli.

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