PSYCHOPHYSIOLOGY

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Representation of visual and auditory unputs relative efficiency in parameters of bimodal evoked potentials

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A phenomenon of a mismatch of the bimodal ERP and the sum of unimodal ERPs was used in our research. The aim was to determine how efficiency of bimodal integration correlates with amplitude of mismatch in groups of observers preferring giving priority to visual or auditory information. It was discovered that the revealed dependences are of opposite character in the compared groups. It is concluded that amplitude of mismatch correlates with efficiency of integration, and efficiency of integration is higher, the priority of visual input is more expressed that the auditory one.

Key words: *intersensory integration, evoked related potentials, mismatch amplitude, lead analyzer.*

When a man sees an object or hears sounds produced by it, an image appears in brain, which is not purely visual or auditory, but combines descriptions of this object in all possible modalities. It is actually possible to say: all images that retain in memory are multisensory. However knowledge about mechanisms of these multisensory images formation is extremely insufficient. We are not informed about mechanisms of sensory interaction, brain areas participating in integration and keeping of the heterosensory information.

Attempts to identify the cortical location of the area responsible for intersensory integration have given contradictory results. Microelectrode investigations in monkeys revealed maximum concentrations of multimodal cells in the prefrontal cortex [3, 8, 10]. Furthermore, the ablation of the monkey left prefrontal cortex affected the visual-auditory association most of all. At the same time, magnetoencephalography studies provided evidence of the location of the visual-auditory interaction, some results showing this are located in the projection visual cortex [4], others in the right parietaltemporal area [9]. Results obtained using MRI scans pointed to the boundary between the temporal and parietal areas of the cortex, the inferior frontal gyrus, the insula, the left cingulate and accessory motor zones of the right hemisphere [6]. There were attempts to answer this question with the help of evoked potentials [7].

It should be noted that all these attempts were based on identification of areas in which values for this parameter were maximal. We took the view that there are grounds for identifying the areas in which measures reflecting integrative processes are not simply maximal, because magnitude maximally correlates with the effectiveness of intersensory integration.

In our previous research [1] we used a mismatch phenomenon of bimodal ERPs and a sum of unimodal responses. We investigated dependence of mismatch amplitude on the efficiency of visual and auditory integration. The obtained results show that efficiency of heterosensory integration correlates with the amplitude of the mismatch. Thus the greater the effectiveness of integration, the greater the focus of mismatch shifted from the occipital to the frontal areas of the cortex.

At the same time the analysis of results that we have received before has shown that different observers solving a task of bimodal images identification used visual and auditory inputs differently. Experiment has been organized in such manner that parameters of unimodal stimuli and the masks provided approximately equal level of identification of visual and auditory stimuli (at level of 35-40 % of correct answers) were selected preliminary. However later, during the experiment when visual, auditory and bimodal stimuli followed randomly, observers improved the performance on one of sensor systems and reduced on another one. So they showed preference in using of a certain sensor input (visual or auditory). This, according to D. Kaneman [2], is connected with the necessity to distribute processing resources between modalities. Such distribution often happens unequal.

In this work we have aimed to define how bimodal integration efficiency is connected with the mismatch amplitude of the ERPs in groups of observers giving a priority either visual or the auditory information.

METHODS

Apparatus. The experimental apparatus was based on a personal computer with a Celeron 350 MHz processor and a 15″ monitor (1024 x 768 pixels, 85 Hz), a Dimond A200 video card, and a Creative Live 5.5 sound card. Sound signals were presented via Philips SBC HP800 headphones (Holland). EEG recordings were made using an eight-channel bioamplifier with an intrinsic noise level of 1 μV and bandpass of 0.3-30 Hz.

Stimulation. We developed an alphabet of images consisting of five real objects: a train, a car, an airplane, a cat, and a dog. Each image was represented by a visual and a sound stimulus.

Visual stimuli consisted of dark outline drawings on a white background. All were of the same size and fitted in a circle of diameter 1.5. Images were presented on the computer screen and were synchronized with the frame raster. The contrast (0.15-0.30) and duration (35-60 msec) of visual stimuli were selected individually for each subject such that the recognition probability in this alphabet of images was 0.3-0.4.

The mask for the visual stimuli was obtained by superimposing all the images used. It was presented 250 msec immediately after the end of stimulus exposure. Mask contrast decreased linearly to zero over the last 100 msec.

Stimulation was performed binocularly from a distance of 115 cm. Background screen brightness was 60 cd/m2. Background illumination in the experimental chamber was at a level of 20 Lx.

Sound stimuli consisted of fragments of recordings of real sounds emitted by the corresponding objects. Fragments had similar spectral characteristics and were of uniform intensity (30 dB above threshold) and duration (500 msec).

The mask for sound signals consisted of all the sounds superimposed. This was presented simultaneously with the stimulus. Sound signal intensity decreased linearly to zero over the last 250 msec.

Sound stimulation was performed binaurally. The probability of auditory stimulus recognition was also 0.3–0.4. This was ensured by individual selection of the necessary mask intensity.

Recordings. EEG recordings were made from the surface of the head using eight monopolar leads (F3, F4, C3, C4, P3, P4, O1, and O2) in accord with the standard 10/20 system. The reference consisted of combined ear lobe electrodes. Signals were digitized using a 16-channel analog-to-digital converter with a sampling frequency of 200 Hz; data were recorded on the computer hard disk.

Procedure. Visual, auditory, and bimodal stimuli were presented at intervals of 4–6 sec in random order. The subject's task was to recognize the images presented. The subject named the image in response to the experimenter's signal. Each subject was initially familiarized with the set of visual and auditory stimuli. The stimulation parameters giving the recognition probabilities indicated above for unimodal stimuli were then individually selected.

Processing. After recordings were made, visual control was used to select artifact-free fragments of EEG traces (100 msec before the stimulus and 500 msec after the stimulus). Visual, auditory, and bimodal ERP were obtained by averaging 100 artifact-free EEG fragments. Averaging was performed independently of recognition correctness. The null line for all ERP was determined as the mean level of the prestimulus EEG segment.

ERP obtained in response to sound and auditory unimodal stimulation were then summed. Summed curves were subtracted from the ERP in response to bimodal stimuli. This yielded mismatch curves for each lead. Individual mismatch curves were averaged by subject group with simultaneous calculation of significant intervals at the 5% significance level. The results of each experiment yielded probabilities that subjects would recognize the visual (pv), auditory (pa), and bimodal (pva) stimuli. These values were used to calculate the parameters of the "ideal observer" (pio): the probability of recognition of bimodal stimuli which could potentially be achieved on integration of decisions taken independently by the visual and auditory analyzers. This measure was calculated using the equation used for calculation of the probability of independent events:

$p_{io} = p_v + p_a - p_{v*}p_a$

The effectiveness of visual-auditory integration (E) was assessed as

$E = 1 - (p_{io} - p_{va})/(p_{io} - p_r)$,

where p_r is the probability of random guessing (in our experiments, $p_r = 0.2$).

The difference $p_{io} - p_r$ yields a corridor of values in which the experimentally obtained probability p_{va} can be located. The difference $p_{io} - p_{va}$ identifies the position of p_{va} within this corridor. Effectiveness tends to unity when the difference between the theoretical and experimental probabilities decreases and reaches it when p_{va} becomes equal to p_{io}. If the subject's results for each sensory input are at the level of random guessing, then the effectiveness of integration is zero. The relationship between the amplitude of mismatch in each lead with the effectiveness of integration was assessed by group of subjects by correlation analysis.

Subjects. Experiments involved 25 subjects of both genders, aged 19–21 years, without visual or auditory pathology. Based on psychophysical results of the experiments two observer groups were formed consisting of 10 persons according to its performance of the unimodal stimuli recognition. The first group was formed from observers for which the probability of visual stimuli recognition was greater in comparison with auditory stimuli. The second group included observers for which the probability of auditory stimuli recognition was greater. Future processing and analyzing were realized within formed groups. All subjects were informed of the experimental procedure and were assured that the experiments were safe; they gave consent to take part in the studies. Investigations were performed in accord with ethical standards.

RESULTS

ERPs to randomly following visual, auditory and bimodal stimuli were registered by means of 8 electrodes during each of 25 experiments. The individual mismatch curves for each area of each observer have been received after subtraction from bimodal ERP the sum of unimodal responses. Then they have been averaged on the general group of observers (fig. 1).

As shown in Fig. 1, mismatch was seen at all recording points; they appeared quite quickly, but were most expressed after 150 milliseconds. The beginning of the first mismatch component coincides with the onset of bimodal ERP, i.e. it has the latency approximately 60-70 ms and all its extent has no more than 10-15 ms. Its appearance is caused by decrease of first bimodal ERP wave amplitude in comparison with the sum curve. All subsequent mismatch components arising in period of 130-300 ms reflect increase of the later bimodal ERP waves amplitude. Thus we can speak about two oppositely directed processes. The first, short, is localized in the limited area (F4, C3, C4). The second, long, is disclosed in all electrodes and is expressed better. This result is received on the general group of observers.

Then all observers were ranked according to their individual performances of unimodal visual and auditory stimuli. On one row end there are observers with the greatest difference between p_a and p_v, on other end – with the greatest difference between p_v and p_a. Ten observers from both sides on the row were pooled into two groups: those who give priority to auditory information and those who prefer visual signals**.** Further the analysis of the received results was spent for each group separately.

In the previous research we discovered the direct correlation between the mismatch amplitude and efficiency of visual-auditory integration. Now we defined how these functions are shown in two groups.

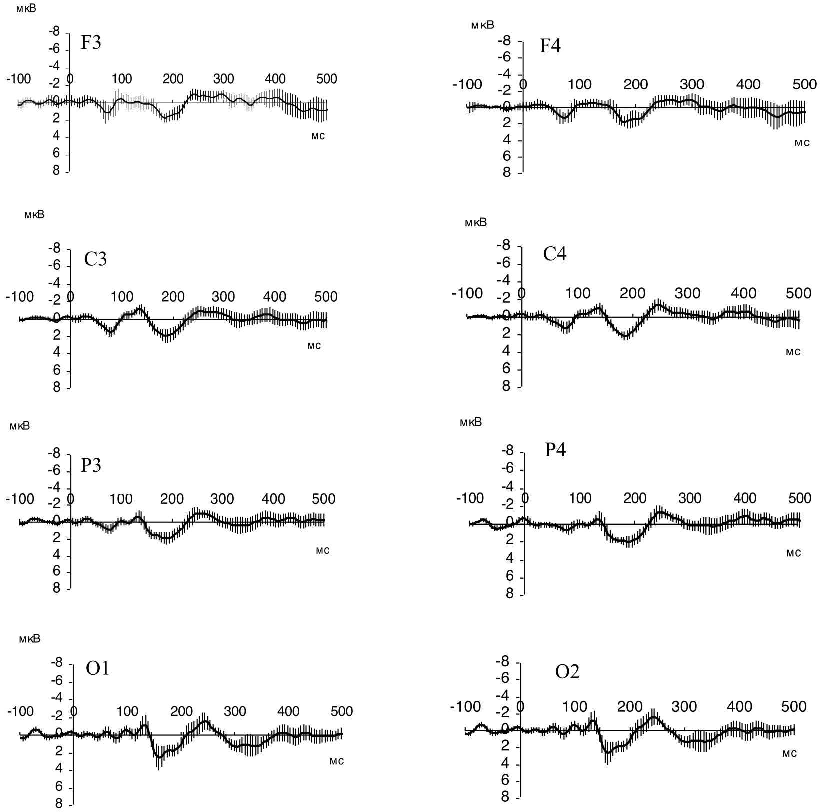

Fig. 1. Difference in bimodal ELP and summed curves averaged for the whole group of subjects. The vertical lines on the curves show significant intervals at the 5% significance level

At first we have established how the mismatch amplitude in each derivation correlates with efficiency of visually-auditory integration. The received results are presented in table 1.

Table 1

Correlation between efficiency of bimodal integration and the mismatch amplitude

Cortex areas	Dominance of the visual input		Dominance of auditory input	
	left	right	left	right
Frontal cortex	0,81*	0,58	-0,62	-0,44
Temporal cortex	0,82*	0,54	-0,15	-0,11
Pariental cortex	0,53	0,44	-0,28	-0,74*
Occipital cortex	0,13	0,35	-0,45	-0,11

The asterisk notes statistically reliable values (p ≤ 0,05).

At once the obvious fact attracts attention. The correlation between the mismatch amplitude and the efficiency of the bimodal integration is positive in the observers who prefer the visual information. On the contrary, in those observers who prefer the auditory information the correlation has negative character.

In the first group the correlation is higher in the left hemisphere, in the second one is in the right. In those who prefer visual information the correlation is most expressed in frontal and temporal cortex. In those who are guided by an auditory input the correlation is maximal in parietal cortex. The received results are well illustrated by the diagrams on fig. 2.

The generalized results show that in two compared groups the revealed dependences have opposite character. At the same time the correlation between the mismatch amplitude and the integration efficiency is essentially higher in group of those who prefer visual information.

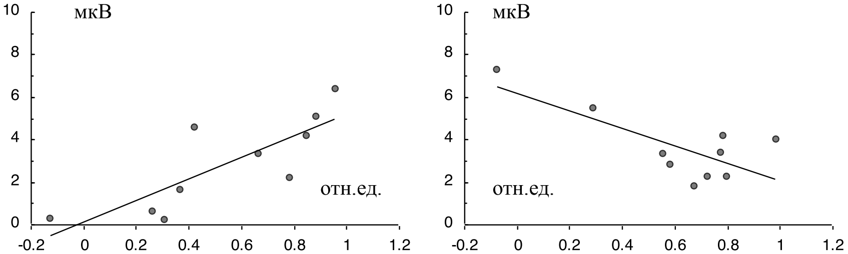

Fig. 2. The efficiency of bimodal integration (an abscissa axis) and the mismatch amplitude (an ordinate axis). This function which is in left frontal cortex at the priority of a visual input is shown at the left graph. At the right graph is shown the function in the right parietal cortex during priority auditory input. The functions of linear regression are shown

DISCUSSION

The received data suggest that the mismatch between bimodal ERP and a curve received as a result of summation of unimodal responses to visual and auditory stimuli is appeared in all derivations. This fact can testify the generalized character of the processes providing intersensory integration. Besides, in the previous research we have discovered that the efficiency of visually-auditory integration is higher, the amplitude of discovered mismatches is bigger. This dependence is more expressed in anterior cortex areas of the left hemisphere [1]. We will remind that these data have been received without taking into account of visual and auditory input efficiency.

In present research we have studied these questions subject to this problem. The received results have demonstrated that the revealed functions have an opposite character in comparing groups. In group preferring visual information the mismatch amplitude correlates with the intersensory integration efficiency and such corellation reaches the highest values in frontal and temporal cortex of a left hemisphere. For the observers preferring auditory information this dependence has negative character and is more expressed in a parietal cortex of the right hemisphere. The integrated results are presented on the three-dimensional diagram in which the data of both groups are approximated by the least- squares method (fig. 3). The left frontal cortex is taken here as an example.

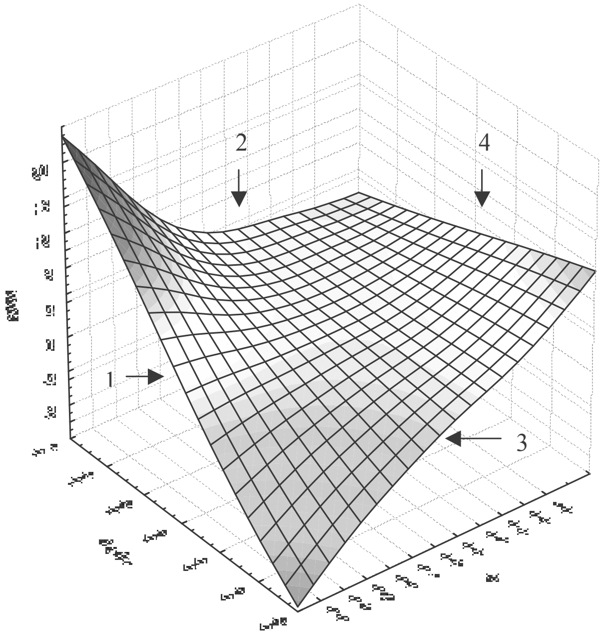

Fig. 3. The relationship between intersensory integration efficiency, relative efficiency of sensory inputs and the mismatch amplitude in left frontal cortex. Symbols for axes: E – efficiency of integration (relative units), Pav – a difference between probability of an identification of visual and acoustical stimuli (rel. un.), LFC – amplitude of a mismatch in the left frontal cortex (μV)

It is noticeably that when efficiency of visually-auditory integration is low the mismatch amplitude of the ERPs is essentially higher at those observers who prefer auditory information, in comparison with those who is guided by a visual input (on the diagram the dependence is designated by number 1**).** However during the increase of integration efficiency in the auditory-observers the mismatch amplitude decreases (dependence 2), and in visual-observers it increases (dependence 3). As a result when values of efficiency are high the mismatch amplitude becomes higher in those who prefer the visual information (dependence 4).

What do the received data specify? Conclusion we can make is suitable to illustrate with the diagram, shown on fig. 4.

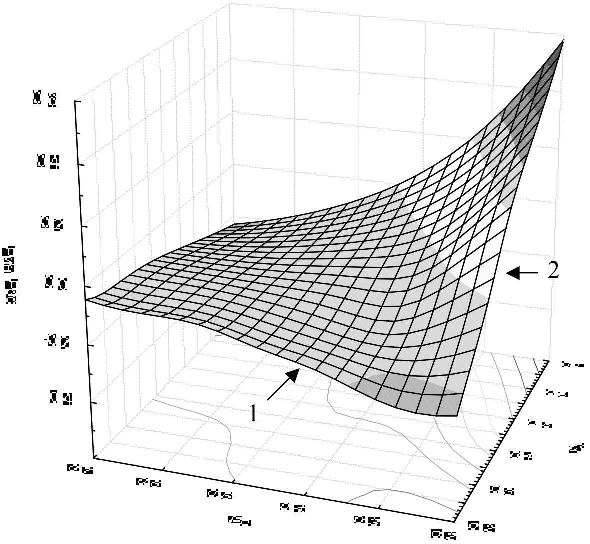

Fig. 4. Relation of the visual-auditory integration efficiency with probability of the unimodal stimuli identification. Symbols for axes: Pv – probability of visual stimuli identification (rel. un.), Pa – probability of auditory stimuli identification (rel. un.), P_{io}-P_{va} – approximation degree to performance of «the ideal observer».

There is the integrated data for the whole group of subjects on this diagram too. Apparently if the visual input is poorly used the increase of the auditory channel significance is accompanied by the modest rise of intersensory integration efficiency (dependence 1). If the auditory input is weakly used the increase of the visual channel significance is accompanied by the considerable rise of intersensory integration efficiency (dependence 2). Thus, the efficiency of intersensory integration the higher, the efficiency of auditory input the lower and the efficiency of visual input the higher (a diagonal between left and right surface corners). On the contrary, equal distribution of resources between modalities is less effective for intersensory integration (a diagonal between near and far plane corners).

How can we interpret such conclusion? It was shown by Colavita [5] in 1971 that it is peculiar to man to use visual information first of all. The signals of other modalities have standby importance in a way, but at the same time the integration of mechanisms are realized in brain and they beneficate the visual images by information of other modalities. The received results suggest that this intersensory integration is rather effective. However when we have to rely on unvisual signals (e.g. auditory) to solve task their interaction with the visual information becomes essentially less effective as appeared. It seems the information transfer through intersensory communications has unidirectional character. So, the auditory information can expand visual, but opposite process is inefficient. The auditory system has to solve recognition tasks on one's own.

If it is considered that the integration efficiency correlates with the mismatch amplitude [1] it becomes clear why this relationship decreases at first and then gets the inverse sign as the auditory input priority increases. But how did we find certain law for whole sample [1] if the results in two comparing groups are opposite? The answer is clear: the dependence is more expressed for subjects having visual input priority. As a result the total dependence coincides with one which is specific for subjects having visual input priority.

CONCLUSION

The received results allow one to make the following conclusion: the mismatch amplitude of bimodal ERP and the sum of unimodal responses correlates with the visual-auditory integration efficiency; in turn the integration efficiency depends on relative efficiency of visual and auditory inputs; the integration is more effective when the relative efficiency of a visual input is higher.

This result can also present a certain interest for solving the problems of person-operator activity optimization.

The Literature

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