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Insight and stress

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Abstract. The development of neurotechnology in recent years and the creation of self-contained artificial systems that provide purposeful activity and decision-making under stress has substantiated the necessity to develop neurophysiological research of insight (Wechsler 2014). The purpose of our study was to develop an insight modelling technology and to verify it empirically in the course of experimental research on the neurophysiological mechanisms of visual insight using objective measurement methods. Insight has 3 stages: the indeterminacy stage, the stage of insight, and the post insight period. The classical Selye model of stress can also be decomposed into the following 3 time periods: pre-stress, stress, post-stress. Although an insight period and a stress period may have similar or different time scales, what is important is common periodicity, involving the same cortical and subcortical parts. The neurophysiological mechanisms of insight in solving problems of visual recognition of contour objects were studied using psychophysical testing methods and objective measurements (Hess, Field 1999; Kounios, Beeman 2014). In our study we identify the instant of insight occurrence with the image recognition threshold under conditions of indeterminacy. A computerised version of the Gollin figure test determining the recognition threshold for incomplete fragmentary images was chosen as a model of insight. In order to analyse the distribution of activity in the human brain and the state of neural networks during the perception of the gradual increase in the contour of the image and in the process of insight development, we applied the method of functional magnetic resonance imaging (fMRI).

Keywords: insight, heuristic type of thinking, stress, functional magnetic resonance imaging (fMRI), neural networks.

Introduction

Insight, which may also be defined as the heuristic type of thinking, is a sudden, unexpected, and surprising appearance of a solution in the problem solver's consciousness, which is accompanied by positive emotions. Insight possesses special attributes: the effect of uncertainty, the stage of preliminary (unconscious) accumulation of information, and an emotional reaction to the recognition.

Methods and results

Our study consisted of 2 stages, and in the first stage we used psycho-physiological and psychological markers.

As a model of insight we chose the determination of the recognition threshold for incomplete fragmentary images — the computerised Gollin figure test (Foreman, Hemmings 1987). The test is a psychophysical method which can be used for measuring recognition thresholds of incomplete fragmented figures. We found that on average the recognition threshold coincides with the first presentation of 20% of the contour.

Eye tracking was used to objectively control the subject's attention in the direction of the subject's gaze in the process of figure recognition during the test.

Insight should contain an emotional component. During the Gollin test 92% of respondents informed us about their emotional reaction.

In the second stage of our study we used the fMRI method to measure the state of the brain at the time of insight occurrence. It is one of the leading methods used in mapping the functional areas of the brain, and with its help it becomes possible to see the neural networks of the brain functioning during rest, as well as when performing certain tasks.

The fMRI stage was carried out in 2 phases. During phase 1 the volunteers lying in the tomograph were shown a screen with a white fixation point against a black background, and their task was to look at the point. This step enabled us to assess the subjects' resting state. During phase 2 the subjects were shown pictures with a gradual extension of the outline and instructed to determine what was pictured on the screen as quickly as possible.

The activation was averaged over all the stimuli in phase 2. The data were divided into three periods: 1 — sub-threshold, before the occurrence of the recognition threshold, from 0 to 10% of the increase in the image contour; 2 — threshold, the threshold of insight occurrence — between 10 and 25%; 3 — above-threshold, after the recognition threshold — from 25 to 60%.

Each of the studied periods in phase 2 (subthreshold, threshold, and above-threshold) was compared with phase 1 (the subjects looking at the fixation point).

The analysis of brain activity was carried out based on the change in the BOLD signal in time in response to stimulation developed in time, consistent with the inertia of changes in blood flow (fig. 1).

The activity of the cytoarchitectonic fields (zones) of the brain according to Brodmann was investigated, including prefrontal cortex (BA9, BA10, BA11), temporal and parietal cortex (BA7, BA39, BA40, BA22), limbic cortex (BA23, BA24, BA29, BA30, BA31), post-temporal (BA37), occipital cortex (BA17, BA18, BA19), insula (BA13, BA14, BA16, BA44, BA55), and subcortical nuclei, such as amygdala. The state of these structures was investigated, guided by modern ideas about the activity of large-scale neural networks connecting these structures.

In the BOLD-signal dynamics, some fields of the temporal, lower-tempered, occipital, posterior-dark and frontal lobes of the cortex clearly indicated two responses: the first — in the prethreshold presentation of the image contour, the second — at the moment corresponding to the recognition threshold (at the time of insight). The data show that the maximum response is observed in the area BA37 which coincides with the moment of recognition — the presentation of 20% of the image contour.

In addition, the multidirectional responses of brain neurons were revealed in the fields BA37 and BA7, which can be characterised as contrasting response. It was observed that in the right hemisphere the opposing responses of the zones BA37 and BA7 are significantly more pronounced than in the left hemisphere. The peak of the discrepancy coincided with the recognition threshold and the subject's positive emotional reaction (the moment of insight occurrence). At the moment of insight, activation of the frontal lobe zones, namely, BA44, BA45, and BA46, was observed. On the left, these areas correspond to Broca's area — the speech zone. A change in the BOLD signal

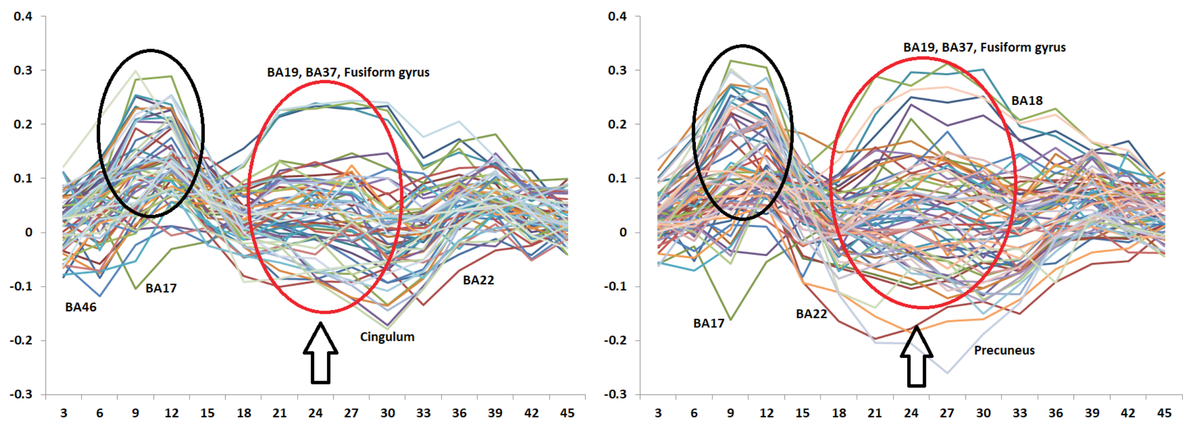

Fig. 1. The change in time of the BOLD signal of some brain fields according to Brodmann, selected as areas of interest. X-axis: time and percentage of filling the contour of the test image, numerically equal to the moment of presentation. Y-axis: change in blood flow in relative units Z-estimates. In the dynamics of the BOLD-signal two responses were clearly traced: the response to the "incubation" pre-threshold period is outlined by a black oval. The response to the moment of insight is outlined by a red oval

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in time in the right and left hemispheres of the brain was revealed; statistically significant differences between the responses of BA45 and BA46 in the right and left hemispheres were shown. Thus, in the right hemisphere in zones BA45 and BA46 distinct reactions associated with the threshold of recognising an object in a fragmented contour stimulus were clearly observed. In the left hemisphere (BA44) in the dorsal part of Broca's area, there was no response registered either at the introduction of visual stimulation, or at the time of recognition of the object (Ardila, Bertolucci, Braga et al. 2010).

Summary

In our study we proposed to use the recognition threshold of incomplete images as the model of insight with all its attributes — the stage of information accumulation, the sudden occurrence of the solution under the conditions of uncertainty accompanied by a pronounced emotional reaction, and a post-insight "relaxation". The outcomes of the study show the neuronal activity of insight as a result of the balance of neuronal nets working in opponent interactions (Saaty 2008). For example, the peak of activity in BA37 is accompanied by a maximum decrease in BA7 activity including the precuneus of parietal cortex. We have established that there are also opposing relationships between the activity of the neural network of the cingulate cortex and that of the prefrontal cortex at the moment of reaching the threshold (Kraft, Grimsen, Kehrer et al. 2006). In addition, an increased right-lateral activity of the frontal cortex BA9, BA13 (anterior right insula, amygdala) was identified (fig. 2).

In phylogenesis, insight appeared much earlier than the analytical way of solving problems, which involves inner speech. Our study suggests that it is not a separate area of the brain that ensures decision-making under insight conditions, but a complex network of mutual connections mainly in the parietal temporal and occipital cortex and the opponent interactions of the prefrontal cortex with the anterior sections of the cingulate gyrus. We applied our new version of slow incomplete image presentation fitted to the slow (bad temporal resolution) fMRI method to measure the response of the brain to dynamically changing signals in time. This was facilitated by the fact that it is possible to control the time interval of the computerised Gollin figure test. The development of modern psychology requires mandatory control of the hormonal status and human genetic differences of the study participants (Shelepin, Pronin, Shelepin 2015; Shelepin, Shelepin 2015; Shelepin, Trufanov, Fokin et al. 2018).

The study was reviewed and approved by the Ethics Committee of Saint Petersburg State University (12.06.2017, no. 02-124).

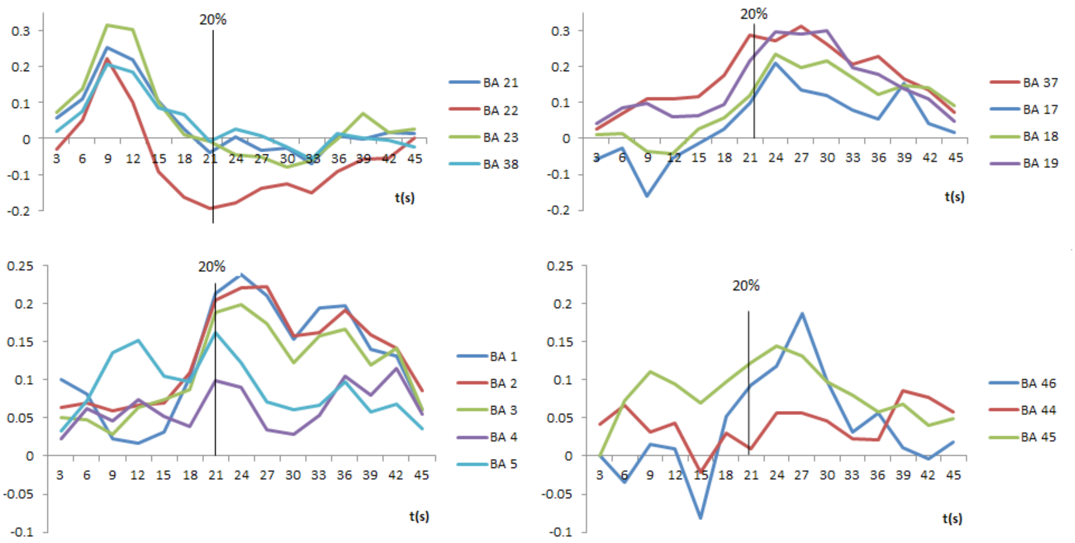

Fig. 2. A generalised demonstration of the whole brain response to a dynamic visual stimulus showing the responses of selected areas of the frontal, parietal, temporal and occipital cortex

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