# Brain activity behind two modes of active vision

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Studies of active vision in naturalistic scenes show the existence of two classes of eye movements manifested in ambient and focal visual fixations (Ito et al., 2017; Pannasch & Velichkovsky, 2009), which have different functions in applied settings such as transportation research and eye-brain-computer interfaces (Velichkovsky et al., 2002; 2005). This finding corroborates with the anatomical separation of two "streams" of visual processing related to localization and action, i.e., dorsal system, or to identification of objects, i.e. ventral system (e.g. Goodale, Milner, 1992). A direct verification of this connection proved to be difficult due to an insufficient resolution of the conventional brain-imaging methods. Another hypothesis recently attributed the same observation to the lateralization of global and local attention in the right and left hemispheres, correspondingly (Mills et al., 2017). Therefore, there are two tentative explanations for the brain mechanisms of the same eye movement patterns in free image viewing. Our work was aimed at resolution of this controversy for a broader practical use of eye movement data.

In a previous experiment, we invited 13 healthy participants (age 21 to 31 years, right-handed, 8 females) as subjects (Velichkovsky et al., 2019). A combination of ultrafast multi-band fMRI scanning with the fixation-based event-related (FIBER) paradigm of data collection (Korosteleva et al., 2017; Marsman et al., 2012) allowed us to measure the brain functional activity in its relation to tasks, a semantic category of the inspected object (houses or faces), brain regions as well as ambient and focal visual fixations during free viewing at high temporal and spatial resolution. The results showed that both competing hypotheses can be in part confirmed. In line with our early proposal, ambient fixations were accompanied by activation of structures associated with the dorsal visual pathway, while focal fixations correlated with that of the ventral pathway. At the same time, the second hypothesis also proved to be correct: the activated structures of the dorsal pathway were localized in the right hemisphere and those of the ventral brain networks mainly —albeit not exclusively— in the left hemisphere.

In the present study, we attempted to extend these results with other subjects, new tasks and material, which was less redundant in terms of spatial localization and therefor promote the ambient mode of processing. Currently due to pandemic, we were able inviting 6 healthy participants (mean age 24 years, 5 right-handed and 1 left-handed persons, 3 females among them) who deliberately served as subjects. We used 120 artistically produced photo-collages of modern flat's interiors with a variable number of everyday objects in them as material. The subjects' task was to study these pictures for a further recognition. We used the same advanced fMRI instrumentation based on 3T Siemens Verio Tomography in the study. We registered eye movements by EyeLink2 (1000 Hz) eye tracker appropriate for application in high magnetic fields. Similar main results were obtained in this new study as previously — the dominance of occipital and parietal activation in the right hemisphere in the case of shorter (<270 ms) fixations considered as ambient, and the dominance of inferior temporal activity of the left hemisphere for longer fixations considered as focal. Figure 1 shows modeled BOLD responses in these contrasting neuroanatomical localizations for both classes of visual fixations. In a further step, we applied algorithms of Dynamic Causal Modeling (DCM, see Friston, Harrison, Penny, 2003; Parr et al., 2019) to the experimental data in order to elucidate cause-and-effect relations of these mechanisms of active vision and the main nodes of Default Mode Network (DMN) often related to the inner conscious processing at rest. As such nodes we selected Medial Prefrontal Cortex (mPFC) and Posterior Cingulate Cortex (PCC). The best of resulting DCM models is shown in Figure 2. It demonstrates a relative independence of both mechanisms of active vision of each other and their dependency on the activity within the DMN structures. The role of DMN seems to be substantial even in active tasks of visual exploration and recognition.

Thus, we found a double dissociation of brain mechanisms in charge of ambient and focal visual fixations in free processing of complex images. Together with the bulk of previous results, this conclusion has an obvious practical significance. It also poses a number of further questions about possible relations between two modes of active vision and other forms of asymmetries found at different levels of human brain organization.

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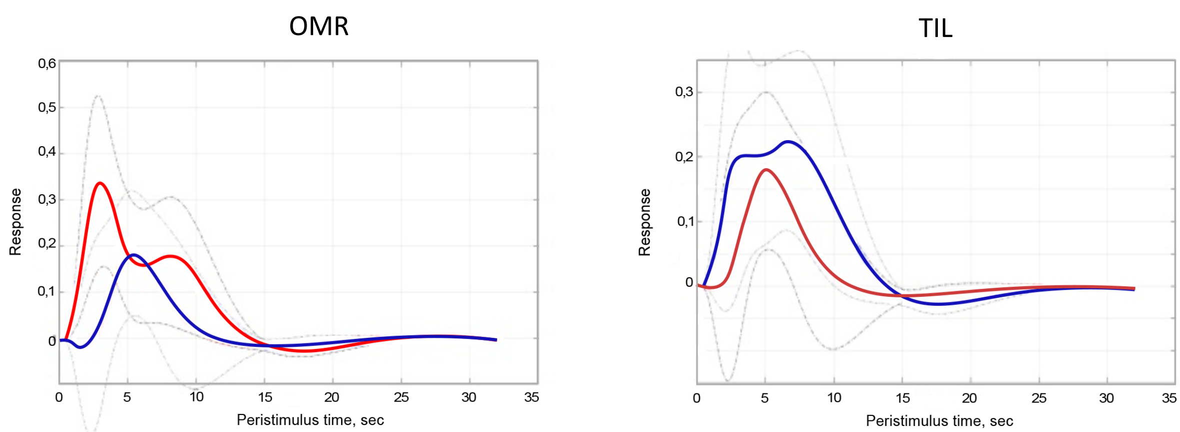


*Figure 1. Models of hemodynamic responses of two brain structures (OMR, Occipital_Middle_Right, and TIL, Temporal_Inferior_Left) for ambient (red) and focal (blue) classes of visual fixations, respectively. The modeling is based on basic information set of three components including Hemodynamic Response Function (HRF), its first derivate and dispersion.*

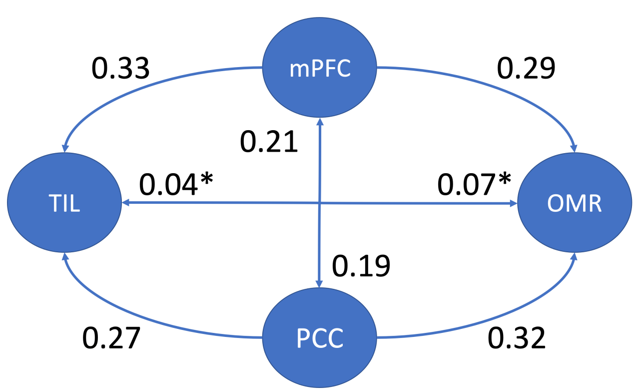


*Figure 2. Pattern of effective connectivity in the best of DCM models as based on the group BOLD data in four brain regions: TIL (Temporal_Inferior_Left), mPFC (Medial Prefrontal Cortex), OMR (Occipital_Middle_Right), PCC (Posterior Cingulate Cortex). *Non-significant connectivity after Bonferroni correction.*

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