Attention and Eye-Movement Preparation: A Relationship between the Two Processes

Attention as one of the central phenomena of consciousness has been extensively investigated, primarily within visual neuroscience. When inspecting a visual scene, humans and other primates make eye-movements in order to foveate[1] objects of interest. These, so called saccadic eye-movements or shortly saccades, are landmarks of overt attention and each one is preceded by saccade preparation - neural processing that determines precise timing and spatial goal of the movement (when and where to saccade). On the other hand, visual attention can be allocated to a specific object while the current gaze is directed elsewhere – so called covert attention. A long standing issue in neuroscience is whether every shift of visual attention is necessarily accompanied by saccade preparation or those two processes are independent. This has been mainly investigated using neurophysiology techniques in awake, behaving monkeys.

Here we outline two important studies that support the two different proposals. Kustov and Robinson suggested that every attentional shift is necessarily accompanied by preparing a saccade to the attended location (Kustov and Robinson, 1996). Authors employed microstimulation of the Superior Colliculus while monkeys attended to a specific location. Microstimulation-evoked saccades deviated towards the attended location, showing that attention is accompanied with saccade preparation to the attended location. Conversely, Juan et al propose that attention can be allocated to a specific location without preparing a saccade to that location (Juan et al, 2004). They use an antisaccade task whereby monkeys are presented with a visual search array (four small bars around the location where monkey fixates, three of which are green and one is red) and have to make a saccade to the opposite location of the singleton. At various times after the array presentation, microstimulation is applied to the frontal eye field (FEF) and microstimulation-evoked saccades always deviate towards the endpoint of an upcoming saccade and never towards the location of the singleton. Authors state this is the evidence that attention can be allocated to the one location (the location of the singleton) without having saccade preparation to that location.

Our task appears to be the first one that spatially controls allocation of visual attention and saccadic intention. The task is outlined below followed by a description of human functional brain imaging study.

Task Description

There is a fixation point on the screen and two target locations. One target location is precued (briefly highlighted before the presentation of targets). Then, the two targets appear and start to flicker, one green, another red. A subject has to fixate until the target at the precued location undergoes a subtle change - flicker briefly changes its frequency. This is a ‘go’ signal - upon this change, the subject has to react and look at the green target. Therefore, the precued location is attended. Let us mark one location with A. If location A is precued and flickers red, *attention* is allocated there. If location A is precued and flickers green, *intention* (motor intention to make an eye movement) + *attention* are allocated there. If another location is precued and the location A flickers green, *intention* is allocated at the location A. If

[1] Bringing an image onto the fovea enables detailed visual examination since the fovea contains the highest density of photoreceptors and has associated a big part of the visual cortex that processes images falling onto it.

another location is precued and the location A flickers red, *none* is allocated at the location A.

Human Study

A functional magnetic resonance imaging study aims to reveal the nature of the Superior Colliculus (SC) function in allocating spatial attention. For this study, one visual target is placed in the right and another in the left visual hemifield, thus activating contralateral colliculi. Activity in one SC can be compared between following conditions: attention is allocated to its response zone (contralateral target is precued, contralateral target flickers red), intention + attention are allocated to its response zone (contralateral target is precued, contralateral target flickers green), intention is allocated to its response zone (ipsilateral target is precued, contralateral target flickers green), or none is allocated to its response zone (ipsilateral target is precued, contralateral target flickers red). This comparison should reveal whether SC is predominantly attentional or motor structure. If one SC is activated maximally when attention is directed to its response zone that would suggest the SC is predominantly attentional structure. If activation is maximal for intention allocated to its response zone while having attention allocated elsewhere, that would recognize its predominant motor processing. In the case of maximal activation during trials with simultaneously allocated intention and attention at its response zone, the comparison between the two previous conditions would resolve the question.

Importantly, our study may show the relationship between the two processes on the level of different brain structures. Specifically, it may show that in the FEF intention and attention are separated but in the SC they are merged, consistent with the both key studies in rhesus monkeys (Juan et al, 2004; Kustov and Robinson, 1996).

In addition to the SC and FEF, functional imaging can highlight involvement of other structures. We speculate that the lateral intraparietal sulcus, substantia nigra pars reticulata, caudate nucleus, and dorsolateral prefrontal cortex would actively participate in spatial allocation of saccadic intention and visual attention.