Functional properties of the posterior cingulate cortex and the posterior insula: Characterization using basic types of coherent and incoherent motion stimuli

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Introduction

The perception of motion and its processing is critical for our actions within a dynamic environment. Although many neuroimaging studies have investigated visual motion processing in the cerebral cortex of humans, gaps remain in our understanding of which cortical areas are involved in which type of basic visual motion processing. Two brain areas demonstrating the problem of a poor characterization of response properties are the posterior cingulate gyrus and the posterior insula. Both regions seem to be involved in the later stage of motion processing. As a side product of respective studies, they have been found to be activated by various visual motion stimuli [e.g. 1-3]. However, none of those reports focused on these two regions specifically and addressed the question of the response characteristics to simple visual motion stimuli.

Therefore, in the present study we used basic types of visual motion patterns of different complexity to identify and describe the properties of motion sensitive areas of the human brain using fMRI with special emphasis on the characteristics of the posterior portion of the cingulate gyrus and the posterior insula.

Methods

Nine human adults participated in the study which was approved by the local ethical committee. To identify motion responsive cortical areas BOLD fMRI was performed at 3 Tesla (Siemens TRIO, whole-brain-EPI, 2x2x4mm³, TR 2000ms) contrasting different moving dot stimuli (HORIZONTAL, VERTICAL, ROTATION, RADIAL, and RANDOM motion) against a static dot pattern. All stimuli were centrally masked (7°) and presented in a block-design (12s moving and 18s static stimuli, 10 repetitions). Analysis was performed using BrainVoyager QX, including motion correction, spatial smoothing (Gaussian kernel 4mm FWHM), Talairach normalization, and subsequent group-analysis applying the general linear model approach.

Results

All stimuli activated a distributed cortical network including well-known regions such as V1 and extrastriate visual areas, as well as several occipito-temporal, parietal, and frontal regions. Regarding the posterior cingulate gyrus and the posterior insula, every single subject revealed bilateral activation in response to each of the motion stimuli. However, the degree of the corresponding activations was quite variable. A region-of-interest analysis of the posterior cingulate gyrus revealed that, in line with the global effects, the RADIAL stimulus resulted in the largest activation cluster. Corresponding activation sizes evoked by the other motion stimuli accounted for only 23-74% of the volume activated by the RADIAL stimulus. In the posterior insula, RADIAL and HORIZONTAL motion resulted in the largest activations, followed by VERTICAL motion. Interestingly, ROTATION yielded an activation size comparable to RANDOM motion accounting for only 33% and 22% of the RADIAL activation, respectively. As for the posterior cingulate gyrus, most of the different motion stimuli activations overlapped with the activation area of the RADIAL stimulus.

Contrasting coherent versus incoherent motion resulted in discrete bilateral activations in the posterior cingulate gyrus and posterior insula (**Figure**). The corresponding time-locked averaged signal intensity time-courses reveal the prominent signal increases in response to the respective coherent motion stimuli, which is lacking for the random motion.

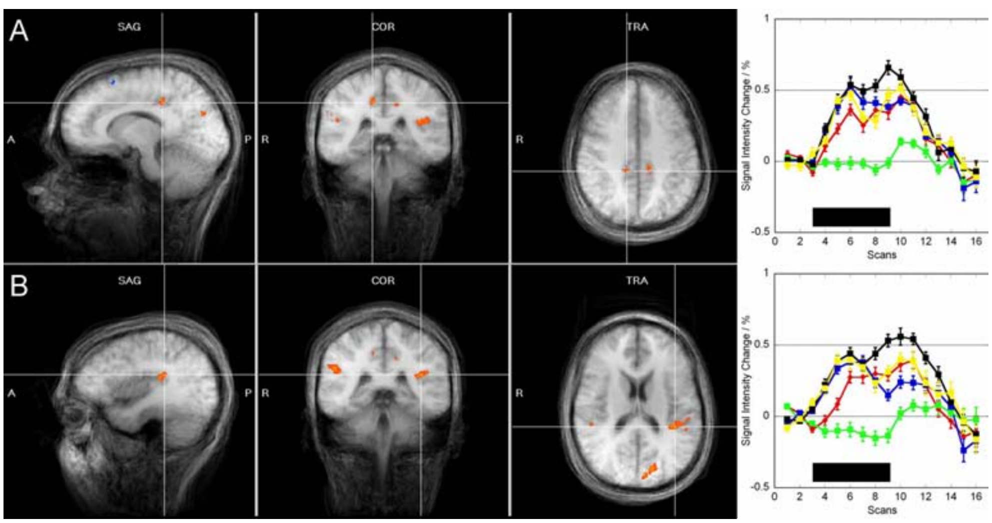

Figure: Differential activations resulting from the contrast coherent (red – HORIZONTAL, yellow – VERTICAL, blue – ROTATION, black – RADIAL) versus incoherent (green – RANDOM) motion in the posterior cingulate gyrus (A) and the posterior insula (B) and respective time-locked averaged signal intensity time-courses.

Discussion

In this study, next to other well-known motion-sensitive areas, we describe a region in the posterior cingulate gyrus which reveals a high sensitivity to coherent motion. Regarding the posterior portion of the cingulate gyrus, only a few studies report activation of this area and tentatively explain this by sustained attention [e.g. 1,4,5]. However, in our study the attention level was expected to be the same during the whole experimental session and therefore could not account for the differences for coherent and incoherent motion stimuli. This suggests that the posterior portion of the cingulate gyrus, as well as the posterior portion of the insula, serves multiple functions, one of which is the processing of basic visual motion information.

In the present study, unlike in earlier reports [3], we were able to detect activation of the posterior portions of the cingulate gyrus and the insula in every single subject. It is noteworthy, that neither in the posterior cingulate gyrus nor in the posterior insula the detected responsiveness to the different motion stimuli follows their grade of complexity. We grouped the five stimuli employed in coherent and incoherent motion, expecting that motion coherence yields stronger activations, which was indeed observed. However, regarding the different coherent patterns, we considered radial and rotational motion to be more complex than simple translational movements. In line with the grade of complexity, the two brain regions we focused on responded best to radial motion. However, in terms of activation size, the simple horizontal translation was a more effective stimulus as were vertical translation and even rotational motion. This suggests that not the grade of complexity, but the relevance of the stimulus for the subject's everyday life is critical. On the one hand, we perceive radial (in-depth) motion as we move back or forth in our environment and horizontal translation as we turn left or right, and on the other hand we experience these motions as objects come closer or depart and cross our visual field in horizontal direction, respectively. In comparison to that, rotational movements and vertical translations usually happen more infrequently, giving a plausible explanation for the current findings.

References

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Supported by the VolkswagenStiftung.