Shared Mechanisms used in Visuo-Spatial Imagery and Perception

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The research outlined in this paper is concerned with the concept of shared representations. This concept suggests that – at least partly - the same mechanisms, which are involved in the processing of perceptual information are also used when people are engaged in higher cognitive tasks. Three research approaches are prominent to demonstrate the mechanisms shared by mental imagery and perception: A) Multisensory integration and dynamic behavior, B) Mental transformations and, C) Visual mental imagery. While this research takes place in widely different disciplines, common to the diverse approaches is the idea of shared mechanisms. The research areas defined below are not mutually exclusive. They can be combined to go beyond existing boundaries between disciplines.

A: Multisensory integration

Spatial orientation requires rapid processing of *ambiguous* cues from multiple sensory systems such as the visual or the vestibular system. Responses must have a short latency, since both reflexive (e.g., eye movements or postural adjustments) and perceptual responses are elicited. It has been often assumed that such sensory ambiguities are eliminated by bottom-up processing mechanisms (e.g., by frequency segregation). At the same time, however, humans can also use *anticipation* to resolve ambiguous or uncertain sensory information. In fact, there is empirical evidence that reflexive visuo-spatial processing mechanisms are *cognitively penetrable*. For example, it has been shown that the distance of an imagined target modifies the gain of the vestibulo-ocular reflex, which has been described as an automatic reflex. These top-down processing mechanisms also help to cope with transmission errors and noise inherent to the processing of sensory information. My own research has shown how top-down processing interferes with the mechanisms underlying the perception of self-motion.

In summary, evidence from psychophysical studies suggests that higher cognitive processes can penetrate the level of elementary visuo-spatial mechanisms.

B: Mental Transformations

Research in this field has focused primarily on mental rotation, which is the ability to rotate a mental image of a stimulus. The most common paradigm uses two objects presented at different orientations and the subject has to judge whether they are identical or mirror-reversed. In this type of task, the subjects have to mentally rotate a mental image of one object into congruence with another. This type of mental transformation has been

described as object-based, whereas another class of type of transformation has been described as egocentric perspective transformations. These transformations are imagined rotations or translations of one's point of view relative to that of the external *reference frame*. A perspective transformation requires a change of the viewer-centered reference frame relative to the environment-centered frame and the location of objects specified within that frame. Evidently, there are at least two (and probably more) types of mental transformations, which draw – at least to some extent - on different processing mechanisms. The approach of shared mechanisms allows for further separating the mechanisms that underlie these different cognitive abilities. Specifically, it has been shown that mental rotation can be influenced by concurrent motor or visual activity. Furthermore, I will report results from recent experiments showing that physical body rotations interfere with perspective transformations.

In summary, mental transformations draw on mechanisms, which are partly involved in the process of perception or motor control.

C: Visual Imagery

Most research supporting the concept of shared representations has been done in the domain of visual mental imagery, which is often referred to as the ability of seeing with the mind's eye. Studies using functional magnetic resonance imaging (fMRI) have shown activation in early visual areas (area 17 or area 18) when people generate high-resolution mental images. Activation revealed by neuroimaging technology leaves open the question whether a particular area is in fact functionally involved in a particular task. However, studies using transmagnetic stimulation over the occipital cortex have shown to disrupt task performance in visual mental imagery tasks. Further evidence for the funtional involvement of early visual cortex was provided by studies from clinical neuropsychology. The main reason why I introduce this area is of methodological nature. It demonstrates the use of neuroimaging technology to further resolve competing theoretical perspectives, which could not be critically tested by solely relying on behavioral measures.

In conclusion, this contribution will present evidence that cognitive and sensory-motor processes are nested and intertwined. The mutual interactions between cognitive and lower-level processes offer a way to better understand the mechanisms underlying spatial cognition.