Hand-Position Space

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Our ability to interact with the external environment critically depends on the brain’s computing of relative spatial locations of objects with respect to the hands, each thought to be coded in a separate set of reference frames. How does the brain achieve the complex interactions between vision, haptics & proprioception? What happens to this multisensory integration when the hand is amputated?

Where are my hands?

This seems like a trivial question but in fact following brain damage, some people lose this ability and no longer recognize their own body! The brain is able to generate a coherent percept of our limb position (as well as the rest of the body) using sensory information arising from vision, proprioception, and touch. Indeed, we know of multiple representations of the hand in various brain areas, which encode the hand position based on information from separate or multiple modalities.

Damage to the parietal cortex can cause various impairments in perceiving and recognizing individual body parts in general, and in recognizing one’s own body parts in particular (resulting in various disorders called asomatognosia, autotopagnosia, neglect, and somatoparaphrenia). For example, in one report, when an examiner brought the left arm of a brain damaged patient into her visual field, asking whose it was, she answered: “It isn't mine. I found it in the bathroom, when I fell. It's not mine because it is too heavy. It must be yours.” (Rode et al., 1992, p. 204)

Another unusual neurological disorder, in which one of the sufferer's hands seems to take on a mind of its own, is the alien hand syndrome (also called anarchic hand or Dr. Strangelove syndrome). The hand, while...
still being a part of the patient's body, behaves in a manner that is totally distinct from the sufferer's normal behavior, so that the hand has the capability of acting autonomously.

In the lab we are interested in how multisensory integration of the hand representation is achieved in the normal brain. We are using different approaches and experimental methods to learn more about the representation of the hands in the brain:

Multisensory Illusions

A particular example for mismatch between sensory inputs about the hand position is the rubber hand illusion. In order to elicit the illusion, a subject views a dummy hand (usually prosthetic hand) being stroked by a paintbrush in synchrony while simultaneously feeling strokes applied to her corresponding real, but occluded hand (using a second, unseen paintbrush).

Typically, this procedure will create an illusion that the touch occurs where the rubber hand is being stroked, (i.e. that there is a displacement of the felt location of the touch from the hidden real hand to the visible dummy hand). The subject in this illusion experiences just one unified multisensory event (the brush seen and felt touching the dummy hand), rather than two separate unimodal events (seeing one brush and feeling the other brush). In addition there is a change in the position sense of the real hand so that the subject experiences that her hand is closer to the dummy hand or even "inside" it. Amazingly, most subjects also report that they feel as if the dummy hand is their own hand. This set of phenomena is abolished when the two paintbrushes stroke the real and the dummy hands asynchronously.

Another interesting bodily illusion occurs when the tendon of the biceps muscle (which flexes the elbow) is vibrated, one gets the vivid illusion that the arm stretches (the elbow extends), despite the arm being absolutely immobile. This kinesthetic illusion is elicited because the vibration of the tendon excites the muscle spindles and tendon organs in a manner similar to when the muscle actually stretches. That is, perception of limb movements does not necessarily require the actual movement of the limbs! We currently study the effects of visual feedback on this proprioceptively induced illusion.

Hand-centred coding of space

The illusions described above examine how visual and proprioceptive information about our hand position is integrated in order to elicit a single and coherent percept of position sense. This information, which arrives directly from the hand, provides us with absolute cues of the hand position. In everyday life, other multisensory information about hand position might also be derived from the (potential) interaction of our body with the environment. These cues, such as the blow of air caused by rapidly approaching objects, the bumping sounds when we place dishes in a high cabinet, or the sight of a bottle moving as we pick it up,
of such cues in everyday life, it might therefore be worthwhile to characterize the neural processing of hand position information with respect to multisensory cues in the space around the hands (peripersonal space).

Indeed, it has been known for some time that there are multimodal neurons in the non-human primate's brain that encode both tactile and visual information that arises from the same location in space – i.e., integrating visuotactile information, which is centered on body parts (see figure, adapted from Graziano, 1999).

Such neuronal properties are ideally suited for the planning of hand movements for interactions with external objects, and might play an important role during reaching and avoidance movements. In the lab we have been investigating the human homologues of such hand-centred mechanisms for coding external objects, and its potential functional consequences. The study of hand-centred representations of space is tightly linked to the study of the representation of the body in the brain (sometimes referred to as the body schema?).

Using fMRI, we were able to identify cortical areas in the human brain that respond selectively to 3D real objects only when they approach near the hand. Some of these areas were similarly activated when a 3D object was approaching a dummy hand, placed in a realistic position, while the subject's hand was retracted away from the approaching stimulus. For these areas, illusory visual information of the hand position overrides the veridical proprioceptive hand position (see panel C in the figure below). We are currently studying the effect of arm amputation on the representation of visual space.
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