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**Symposium:**
# Depth: The forgotten dimension in multisensory research

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Given the abundant multisensory information that is presented to us from various distances in both front and rear space, it is surprising to realize how few of the studies of multisensory interactions/integration have incorporated the distance from the observer at which this information was presented into the design of their studies. Taking depth into account is particularly important given that the strength of multisensory interactions depends on the inputs from the different senses involved, which, in turn, vary as a function of the sensitivity of peripheral receptors in the depth dimension (e.g., touch is limited to skin contact, vision and audition extend to far stimuli). Investigating how multisensory stimuli interact in depth is also particularly important to understand how space is represented, as the brain forms multiple representations of space, varying in their extension from the body of the perceiver. This symposium will highlight the latest behavioral, neuroimaging, and neuropsychological research on how the relative depth from which sensory cues are presented affects the interactions taking place between the senses. The goal of the symposium will be to highlight the relevance of knowledge about multisensory interactions in depth both for understanding the basic mechanisms of multisensory integration and space representation.

## Abstracts:

### Looking beyond the horizon of audiovisual simultaneity.

Massimiliano Di Luca & Sarah Warnes

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It is often assumed that the effect of distance on audiovisual simultaneity perception is primarily attributable to the lower speed of sound. As the source of an audiovisual event moves farther away from an observer, the latency of sounds should increase. At intermediate distances, the latency of sounds should compensate the relatively higher neural latency required to process visual signals. At roughly 16 m there should be a horizon of simultaneity: auditory and visual events generated in synchrony at this distance should arrive in sync at the sensory cortices. This reasoning does not consider that light source distance causes decreased retinal size and lower stimulus energy at the retina, which might increase the neural latency of vision. This study tested whether light distance affected perceived simultaneity in an audiovisual temporal order task for audiovisual stimuli presented at arm's length or at 16 m distance. The light source distance affected the perception of simultaneity. This effect was greatest when the distance from which the lights were presented was randomized across trials, causing participants to pay attention to several locations in depth and to view the stimuli peripherally. As a result visual latency increased even further. Furthermore, the perceived simultaneity did not change as a function of visual distance by maintaining foveation of visual stimuli with equal retinal size and perceived luminosity. The results indicate that both visual and auditory source distance can affect perceived simultaneity. Therefore, the horizon of simultaneity is only attainable with visual stimuli of identical retinal size and energy, whereas in a real-world situation the horizon of simultaneity might be farther than previously thought, or might not exist at all (when using small visual stimuli).

### Multisensory interactions in peripersonal space.

Andrea Serino

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The space immediately surrounding the body, i.e., peripersonal space (PPS), is represented by a dedicated neural system of fronto-parietal areas, which integrate tactile, auditory, and visual stimuli presented on, or close to, the body.
In this talk, I will present the first complete mapping of peripersonal space representations around different body parts – namely, the face, the hand and the trunk - in humans. Our latest findings show that these body-part centered PPS representations, although differing in extension and response properties, are not fully independent from each other, but are referenced to the more common reference frame of the trunk. In this talk, I want to argue that different PPS representations have different functions. The peri-hand space is mainly involved in hand-objects interactions: it is represented by premotor and parietal areas, which not only integrate multisensory stimuli around the hand, but also project to the motor system in order to trigger appropriate responses. The peri-hand

space also dynamically shapes as a function of changes in upper limb function or structure, such as after after tool-use, amputation, prosthesis implantation and immobilization. The peri-face space is more involved in social interactions, as its boundaries are sensitive to the presence of, and interaction with, other people. Finally, the peri-trunk space serves as a global representation of the whole-body in space, as it includes the other body-parts centered PPSs and shapes during whole body movements (e.g., walking). I will conclude by proposing that the whole-body PPS represents a primary interface between the self and the environment.

**Multisensory interactions in the depth plane in front and rear space.**

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Over the last couple of decades, much has been learned about the nature of multisensory interactions. Among other things, it has been shown that multisensory processing is (un)affected by, for example, the particular spatial and/or temporal alignment of stimuli, stimulus intensity, attention, semantic congruency, and so on. However, one factor that has often been ignored in multisensory research is the distance, or depth, from which stimuli are presented (with the exception of several studies of multisensory temporal processing in depth; see earlier talk by di Luca). In this talk, I will discuss several recent studies of crossmodal spatial attention and multisensory integration in healthy subjects and stroke patients in which the stimuli were presented from different depths in front and/or rear space. The results of these studies indicate that the distance from which information is presented can modulate multisensory interactions. Critically, this modulation depends on the particular sensory modalities involved. Whereas multisensory interactions involving touch are generally more pronounced closer to the body, no such asymmetry in terms of a depth-dependent enhancement is observed for audiovisual interactions. The potential role for multisensory experience in depth in the development of distance-dependent multisensory interactions will be highlighted. Understanding the constraints on multisensory interactions in depth is highly relevant for more applied situations such as the rehabilitation of sensory deficits and multisensory warning signals during driving.

**Driving hand-objects interactions in depth by anticipated weighting of visuo-tactile processing.**

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Voluntary actions require preparation of the upcoming movements. Such motor planning is typically accompanied by suppression of peripheral sensation. Here we report that preparing an action to grasp an object instead enhances multisensory processing in depth, as indicated by a remapping of the target closer to the hand well before the hand moves. In a first experiment, we assessed both unisensory tactile perception on the hand and multisensory perception of the same touches in combination with irrelevant visual distractors on the target object during the execution of grasping movements. Visual distractors affected perception of touches more strongly during the planning phase than during a similar, static, object vision condition. Crucially, visuo-tactile (VT) interaction was enhanced in proximity to the onset of the action in the absence of any overt movement, showing both interference and facilitation with respect to previously occurring VT stimulation. Thus, dynamic VT processes lead, rather than follow movement execution. A second experiment tested whether anticipated modulation of VT processing depends upon the final goal of the action, or its sub-goals. We probed VT processing during planning and execution of two-step sequential actions, namely during reach-to-grasp movements and when bringing an object to the mouth. The results supported the hypothesis that VT weighting processes anticipate the final aim of a complex action. These findings reveal that planning to grasp an object entails a multisensory link between signals from the environment and the body that is functionally related to the action goal. Such multisensory planning may thus reflect early sensorimotor transformations aimed at guiding voluntary actions.