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Editorial: Unraveling the complexity of sensory space perception

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Editorial on the Research Topic

Unraveling the complexity of sensory space perception

Environmental sensing refers to the process by which organisms extract information from their surroundings to construct representations that guide behavior (Swanson, 2011). Sensory recognition and the perceptual construction of such information are inherently complex, given the multiplicity of mechanisms involved in each sensory system (Kaas, 1989). Spatial perception is fundamental to survival, as it enables the identification of food, the location of shelters, and the detection of predators, allowing organisms to rapidly adjust their actions to avoid risks.

At the functional level, spatial perception supports navigation through the environment (Loomis et al., 1992; Yamamoto and Philbeck, 2025), distance estimation (Santillán and Barraza, 2019), balance control (Corrêa et al., 2023), emotional expression (Cardoso et al., 2021), and the coordination of complex movements (Angelaki et al., 2025). Whether it is a bat in flight, a fish swimming against the current, or a human walking across uneven terrain, all rely on spatial integration to efficiently and safely explore their surroundings. On a broader scale, spatial recognition underpins social and cognitive life (Proulx et al., 2016). In social animals, spatial signals can help distinguish among different social contexts (Dorfman and Eilam, 2021). In humans, this ability is closely linked to abstract reasoning (Harris, 2023).

Human spatial perception arises from the integration of multiple sensory systems (Bremmer, 2011). No single sense, in isolation, can provide all the information required for an individual to determine their position in the environment, orient themselves relative to objects, and plan appropriate motor or cognitive actions. It is the dynamic combination of sensory inputs that enables the construction of a coherent representation of space. Although this strategy may introduce redundancy, since sensory modalities can convey overlapping information, the engagement of multiple senses in building perceptual representations reduces the likelihood of processing errors (Ernst and Bühlhoff, 2004). The relative weight of each modality varies according to context and the reliability of the available information (Burns and Blohm, 2010). This flexibility ensures the robustness

of spatial perception across a wide range of contexts, from everyday life to extreme conditions, such as virtual environments and microgravity (Bogon et al., 2024; Glasauer and Mittelstaedt, 1998).

The present Research Topic, entitled *Unraveling the Complexity of Sensory Space Perception*, was designed to gather contributions that expand our understanding of how sensory systems process spatial information and how novel methods can facilitate the investigation of these processes. Six articles were accepted, addressing different sensory modalities: the vestibular system (Zhang et al., 2025; Gerb et al., 2024), vision (Takeichi et al., 2025), proprioception (Almeida et al., 2025), audition (Metcalf and Harris, 2025), and visuo-haptic integration (Fischer et al., 2025).

Gerb et al. (2024) investigated the relationship between subjective discomfort in spatial orientation and performance on objective real-world navigation tasks, along with its association with cognitive function in individuals with normal vestibular function. Their findings suggest that the subjective sensation of spatial discomfort may serve as a valuable clinical marker, correlating with both behavioral performance and cognitive decline. The study emphasizes that spatial orientation assessment should integrate subjective and objective measures.

Zhang et al. (2025) examined the optimal rotational speed for the unilateral centrifugation subjective visual vertical (UC-SVV) test, in which participants adjust a luminous line to what they perceive as the true vertical in the absence of external references. This test specifically targets otolithic vestibular function. The study provides practical parameters for standardizing the UC-SVV test in clinical contexts, indicating that rotational speeds of 180°/s (or 240°/s, if tolerated) enhance the test's sensitivity and reliability in detecting vestibular dysfunctions.

Takeichi et al. (2025) tested whether the human visual system can extract information about physical properties of fluids, such as viscosity, from non-rigid motion. Using the pseudo-flow technique, based on tracking image gradient vectors, they demonstrated that vision can infer the physical properties of non-rigid structures from local motion, advancing our understanding of how the visual system encodes motion and structure in the environment.

Almeida et al. (2025) compared joint position sense measures obtained with inertial sensors embedded in devices of different masses: a heavier smartphone and an ultralight sensor. In elbow repositioning tasks, they observed a systematic bias associated with the smartphone, which also showed moderate-to-good test-retest reliability. By contrast, the ultralight sensor exhibited poor-to-moderate reliability. The study concludes that, while both devices are suitable for assessing proprioception, device mass systematically affects outcomes and must be considered in clinical and experimental applications.

Metcalf and Harris (2025) examined how prior knowledge influences the perception of vocal elements in MIDI stimuli, even in the absence of an actual voice. The authors found that a vague illusion of vocal presence can occur without prior learning, but that only previous familiarity with the music enables the precise perception of words. These findings underscore the fact that auditory perception is not passive but rather emerges from the interplay between bottom-up sensory cues and top-down cognitive expectations.

Fischer et al. (2025) characterized precision and accuracy in target localization tasks performed under visual, haptic, and combined visuo-haptic conditions. Their results reveal that integration does not always follow ideal models of sensory combination and that structural differences between visual and haptic maps shape spatial perception. These findings hold important implications for the design of human-machine interfaces with haptic feedback and for applications in virtual reality and robotics.

In conclusion, the original objective of this Research Topic was successfully achieved. The studies presented here reveal new aspects of the complexity of sensory processing and its relationship with the spatial domain. As emphasized in the call for this Research Topic, we remain confident that advances from diverse fields, including psychology, neuroscience, and computer science, will continue to elucidate environmental information processing, with implications not only for the clinical assessment of the nervous system but also for the development and application of current and future technologies in the service of humanity.

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