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Integrative sensorimotor coding and the neurophysiology of intent: Comment on "Kinematic coding: Measuring information in naturalistic behaviour" by Becchio, Pullar, Scaliti, and Panzeri

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Becchio et al. introduce a compelling framework conceptualizing movement patterns as cognitive information carriers ('*kinematic codes'*) read-out by observers as a form of non-verbal communication. This kinematic coding approach has broad implications for cognitive and behavioural neuroscience, providing a computational link between action and perception in social settings. Specifically, it carves out a path for principled investigation into agent-environment interactions, which we aim to employ to link together the neural mechanism of action, perception and decision-making [1,2]. Here, we outline this research endeavor aiming to characterise the role of perceptual and motor neural processes in sensorimotor decision-making and, by extension, in communicating cognitive intention to others.

Motor patterns, whether they emerge from muscle activations, motor unit spike trains, brain oscillations or kinematic trajectories, are conventionally seen to reflect decision-making outcomes. Recent work promotes a more integrated viewpoint where perceptual and decision-formation processes operate along an action continuum [3]. From this continuous and parallel perspective, humans dynamically interact with their environment, sampling sensory information, forming perceptual decisions and executing actions. Hence, motor patterns encode information about a variety of cognitive processes. Supporting this claim, in an active-sensing experiment where participants judged object heaviness, perceptual variance was accounted for by lifting arm muscle activation patterns [4,5]. Crucially, diverse types of functional muscle interactions were found to encode distinct forms of decision-related information in this task [6]. Similarly, during object-wielding, body-wide postural fluctuations were shown to correlate with perceptual judgments [7], and during multisensory decision-making, active exploration of visuo-haptic information was shown to enhance perceptual accuracy [1].

However, to mechanistically understand the structure-function relationships of motor patterns in naturalistic behaviors, embedding the agent in their environment is a necessary additional research step. Becchio et al. propose this conceptual shift, moving from interacting neural subsystems encoding and decoding decisions to the behavioural encoding of decisions that are read-out by an observer. This reframing is directly pertinent to understanding neural mechanisms geared towards communication. For instance, neurophysiological evidence suggests speech processing entails neural encoding of articulatory kinematics (i.e. tongue and lip movements), even when these are not visually available [8]. Hence, representing others' bodily movements is central to effective information transmission. Importantly, other motor behaviours not overtly intended for communication may also be disambiguated. For instance, pixel covariations in video recordings of psychiatric patients' bodily movements in dyadic interaction were associated with treatment outcomes and affective states [9,10]. This nonverbal synchrony exemplifies the subtle behavioural manifestations of cognitive states that may not be consciously visible to observers but may still impact the quality of their social interactions. We suggest that the kinematic coding framework represents a principled approach with enhanced specificity to address meaningful questions across these research streams.

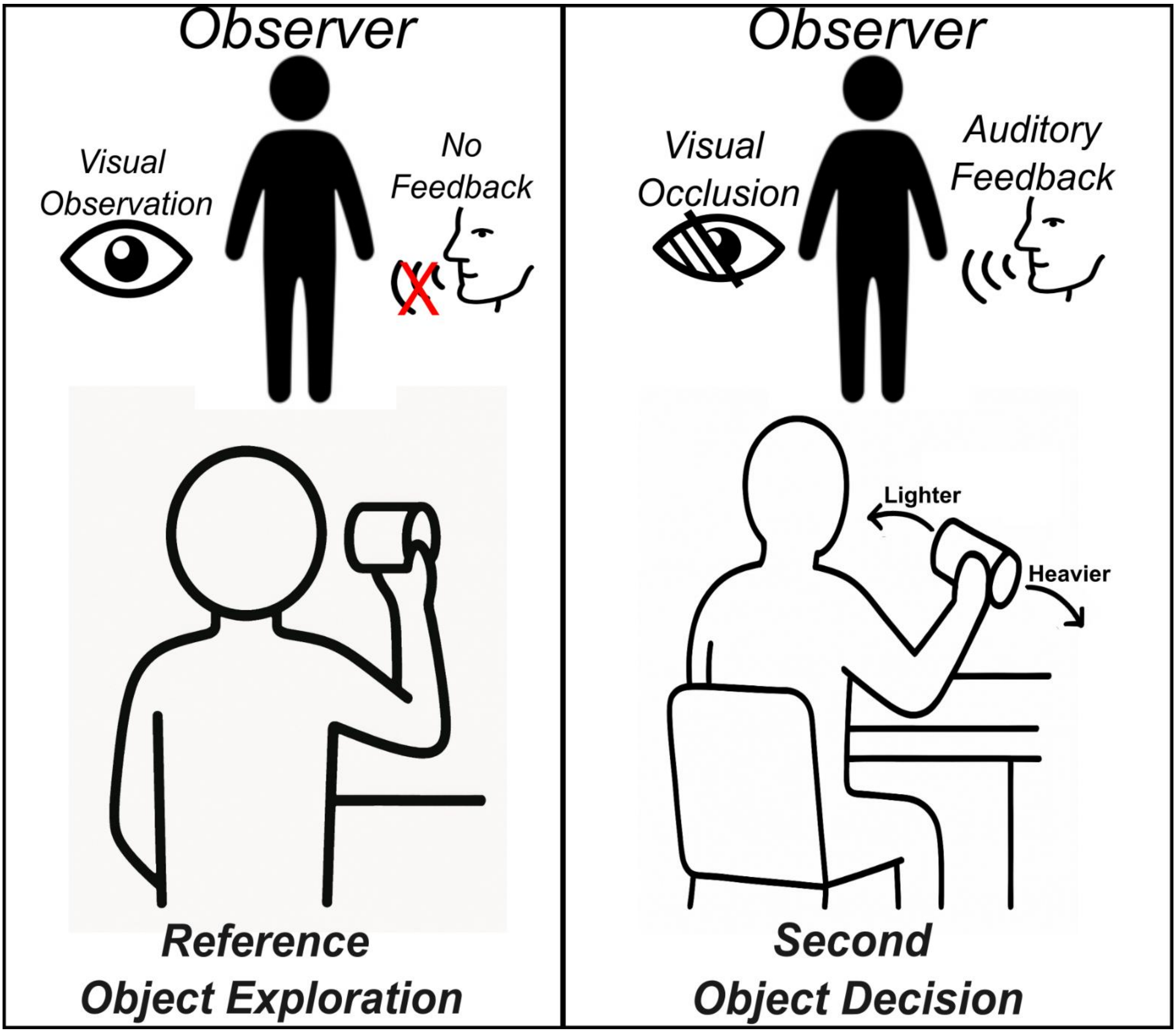

Figure1: The active-sensing experimental paradigm *[4]*. Including an observer and incorporating visual occlusion combined with observer feedback enables kinematic coding concepts to be readily accessed.

In future work, we aim to capitalize on our newly developed computational methodologies combined with neurophysiological measurements to characterize the neural mechanisms underlying this new "*decision-during-action*" view [3,11,12]. By mapping cortical, spinal and corticospinal neural interactions during active-sensing tasks, we wish to offer an in-depth characterization of the neural codes of sensorimotor decision-making and learning. As Becchio et al. suggest, including observers in the active-sensing paradigm with visual occlusions or as an active part of decision outcomes (e.g. feedback) will uncover what information is available (or not) to others and how sensorimotor decisions are shaped in social settings (Fig.1), ultimately bringing to bear a more comprehensive understanding of agent-environment interactions.

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