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Comment

Measuring how typical and atypical minds read other's intentions Comment on "Seeing mental states: An experimental strategy for measuring the observability of other minds" by Cristina Becchio et al.

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Becchio et al. [1] propose a model to render other's minds observable against the *Unobservability Principle*. Such model develops over four, distinct steps. First, it provides experimental evidence indicating that mental states (i.e., intentions) can be encoded in behavioral patterns (e.g., movement kinematics). Second, it provides strategies to test the efficiency of the quantification of such intention-related behavioral manifestations (i.e., resolution of the uncertainty between two intentions based on different patterns of accumulation of kinematic parameters). Third, it indicates specific features of the observed behavior that viewers use to detect different intentions (i.e., a series of decision rules based on kinematic features through which intention categorization occurs). Fourth, it proposes a manner to manipulate such specific behavioral features so that an observer can detect different intentions, based on how informative such behavioral features are. We see in this operational/experimental approach a significant contribution to the theoretical debate on the possibility to observe mental states, allowing the direct testing of the *unobservability principle* and therefore providing falsifiable hypotheses. Besides this already central aspect, we believe this approach holds promise to the elucidation of clinical open questions, such as those posed by autism spectrum disorders (ASD). Indeed, experimentally evaluating the ability to observe and manipulate other's intentions allow us to quantify with high accuracy the deficits in the representation of other people's minds that so chiefly characterize ASD as well as the outcomes of treatment options focusing on this aspect. Here we suggest a few clarifications and extensions of the proposed model which will make it possibly tailored for clinical applications.

When considering the first step of the model, Becchio and colleagues argue that mentalistic information is *perceptually available* in the observed action. However, it is unclear whether the degree of conscious availability is being considered. In other words, must mentalistic information be *consciously available* for it to be perceived? This aspect becomes particularly relevant when considering the Theory of Mind (ToM) deficits evident in ASD. Indeed, it has

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been argued that only the spontaneous mentalizing skills may be at the core of the ASD difficulties with reading other people's minds [12], since learning scripts that explicitly reveal the other's intentions can help reducing the negative outcomes of mentalizing deficits to the level of typical performance. Following the evidence provided by Sartori et al. [10], conscious availability of motor information is not required in order to observe other minds. When participants were asked to observe actions performed using slightly different kinematic patterns, which were not consciously noticeable, corticospinal activations reflected such differences. These effects appear to be elicited by very subtle aspects of observed actions, pointing to a finely tuned mechanism that specifically encodes body parts *beyond awareness*. Considering this aspect, investigating motor intentions not only via kinematic patterns but also corticospinal excitability profiles (for a further example, see [11], below) will represent a useful strategy to quantify and monitor the mentalizing skills of individuals with ASD. Furthermore, the implicit nature of these observations and the low compliance required to collect the data facilitate the implementation of these strategies also to young children and individuals with ASD with limited verbal skills. Are individuals with ASD incapable of mind reading or such ability remains under threshold and cannot be operationalized?

Moving along the model's steps, once the determination of the perceptually available information – whether overtly or covertly – occurs, then it is necessary to understand which are the boundaries within which perceptual experience can efficiently convey the intention-related information. We contend that also neurophysiological data can provide an indirect measure of perceptive efficiency. For instance, when we observe sequences of movements representing a request driven by a social intention (e.g., a partner trying to pour coffee into a cup placed close to us and out of reach for her), we pre-activate the hand muscles suitable to grasp the cup and approach it to the partner, implementing a spontaneous social response [11]. This activation is not evident if the partner finally moves the hand back towards herself, without approaching the cup positioned out-of-reach. Crucially, detailed movement analysis reveals that wrist rotation is the only *salient* kinematic parameter upon which observers rely to discriminate the intention of the partner, before the request is fully expressed. This points to the existence of heuristics that would help intention discrimination despite the small amount of available information [9].

In other circumstances, it has been revealed that the visual context (i.e., kinematics) is not sufficient for the interpretation of a social intention triggering an appropriate response. This is the case of children with ASD who ascribe intentionality to an observed action only when paired with their own mother's odor. In other words, the odorous context is increasing the perceptual efficacy of the visuo-motor information which can be picked up and facilitate the performance of typical motor responses [7]. When considering the role of the context, it becomes clear how experimental manipulations can be carried out to investigate the threshold for detecting different intentions (Step 2) and the salience of the (kinematic) features on which intention discrimination is based (Step 3). Additionally, we highlight the importance of the intrinsic motivation with which we approach the decoding of other's intentions. Indeed, the faster we can judge others' intentions, the more time we have to select a suitable, adaptive response [2]. At a mechanistic level, the sensory consequences of one's own actions may also be employed to predict what others will do next [13]. Such a mechanism, when highly intolerant of deviations from precise patterns – whether one's own or other's – may be at the basis of both the sensory and social deficits seen in ASD, as posited by aberrant precision model of ASD [6]. Investigating the kinematics revealing intentions in the context of this model would help not only clarifying the mentalizing difficulties in ASD, but also further map the mechanisms underlying dual (or multiple) interactions.

Finally, moving to the possibility of altering the behavioral manifestations of intentions in order to modulate the observer's intention decoding skills, the world of robotics provides an excellent test-bed for the Becchio et al. model (for an example of computational models based on neuroimaging and neurophysiological data see Demiris et al. [4]). It has been recently described how robots could learn new movement patterns and action goals based on the analysis of kinematic parameters of human movements [3]. For example, the transport and the grip component of a reach-to-grasp movement can be broken down into basic primitives (such as "move arm forward", "adduct a finger"). Artificial neural networks, able to mimic the commands embedded in specific motor plans, can implement such primitives, by considering them from an egocentric perspective, as humans would. This possibility raises an intriguing issue: to endow a humanoid robot with the ability to read and clarify one's own intentions, would it be sufficient to allow the machine to evaluate actions based on a set of egocentric computations which could be compared to those of another actor to assess similarities and differences in a reliable way? These conjectures have already been raised in reference to ASD. In the effort to make social situations and actions more understandable to the ASD mind, researchers have tried to maximize the predictability of actions by using robots. Indeed, robotic movements elicit visuo-motor priming in children with ASD [8], making the robot model to prime typical intention-driven performances. Furthermore, robots

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have been used to train individuals with ASD in social skills more broadly, with the aim of producing positive and rewarding interactions [5], which keenly depend on the accurate detection of the intention of co-agents.

All in all, we believe that operationalizing a number of research questions such as those we raised in the framework proposed by the Becchio et al. model will allow to further our knowledge on the observability of other minds and to contribute the clinical endeavors posed by ASD.

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