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Nonverbal components of Theory of Mind in typical and atypical development

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ABSTRACT

To successfully navigate the human social world one needs to realize that behavior is guided by mental states such as goals and beliefs. Humans are highly proficient in using mental states to explain and predict their conspecific's behavior, which enables adjusting one's own behavior in online social interactions. Whereas according to recent studies even young infants seem to integrate others' beliefs into their own behavior, it is unclear what processes contribute to such competencies and how they may develop. Here we analyze a set of possible nonverbal components of theory of mind that may be involved in taking into account others' mental states, and discuss findings from typical and atypical development. To track an agent's belief one needs to (i) pay attention to agents that might be potential belief holders, and identify their focus of attention and their potential belief contents; (ii) keep track of their different experiences and their consequent beliefs, and (iii) to make behavioral predictions based on such beliefs. If an individual fails to predict an agent's behavior depending on the agent's beliefs, this may be due to a problem at any stage in the above processes. An analysis of the possible nonverbal processes contributing to belief tracking and their functioning in typical and atypical development aims to provide new insights into the possible mechanisms that make human social interactions uniquely rich.

Everyday social interactions, from communication to joint actions such as playing football require monitoring what other people see, know and believe. Although such inferences seem to be a basic characteristic of our adult interactions, it is unclear what cognitive systems are involved in these processes, how they mature, and whether young children are able to grasp others' intentional states with a facility that is similar to adults.

The fundamental capacity to infer other people's mental states is usually termed as Theory of Mind (ToM) or mentalizing. ToM enables us to represent others' goals, beliefs and intentions, to predict and interpret their actions based on these mental states, and to plan our own reactions accordingly. Importantly, human behavior is governed by what one believes about the reality, which may or may not coincide with the true state of affairs. Research from the last 30 years targeting the development of ToM has led to a systematic investigation of reasoning about others' false beliefs. Instances of unexpected location change (when an object initially seen in location A is moved to location B in absence of a protagonist; Wimmer & Perner, 1983) proved to be a good test case. In these so-called standard ToM tasks, until about the age of four, typically developing children fail to take into account the protagonist's false belief when asked to make a verbal prediction regarding the protagonist's actions. Based on such data it was proposed that in typically developing children ToM abilities emerge around the age of four (Wellman, Cross & Watson, 2001).

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Research from the last ten years seems to uncover a different picture regarding the development of ToM abilities. If we measure children's spontaneous responses (e.g., their looking patterns) instead of asking them direct questions about a protagonist's beliefs and her consequent behavior, even young infants show sensitivity to others' mental states. Infants as young as 15 months were found to expect a protagonist to search for an object at the location where she (falsely) believes it to be hidden (Onishi & Baillargeon, 2005). Following this finding, a paradigm shift took place, which entailed switching from 'explicit' tasks involving verbal reports to non-verbal or 'implicit' measures. These implicit measures have in common that they target behavioral or neural correlates of representing mental states. In infants, a frequently used measurement is comparing looking time patterns to expected and unexpected outcomes that do or do not match infants' expectations based on the beliefs they ascribe to someone. Other non-verbal or implicit tasks involve assessing anticipatory gaze, where participants' expectations (about what an actor might do based on her belief) are measured before the actual behavior takes place. Some tasks in turn involve more active measurements such as probing whether infants adjust their helping behavior depending on another person's belief (e.g., when a protagonist tries to retrieve an object from a location about which he has a false belief, infants retrieve the object for him from the correct location instead). Such implicit ToM measurements have at least two obvious advantages. First, they do not overtly prompt participants to reflect on others' mental states, and thus tap on mentalizing processes that are spontaneously triggered by social interactions. Second, they provide a better means to investigate social cognition in populations with limited linguistic abilities and less efficient executive control functioning. Implicit tasks, unlike the standard explicit ToM tasks, rely much less on such orthogonal capacities (Scott, He, Baillargeon, & Cummins, 2012).

The implicit-explicit distinction is at the core of recent two-system proposals of ToM, which assume that only the explicit system involves representing others' mental states, and the implicit system relies on encoding simple object-agent-location relations (Apperly & Butterfill, 2009; Rakoczy, 2012). However, there are reasons to assume that implicit and explicit mentalizing rely on the same core mechanisms. Recent neuroimaging evidence suggests that implicit and explicit inferences about other people's traits activate the same mentalizing areas, and ERP studies reveal that goal and trait inferences triggered by implicit and explicit instructions have a similar early timing (for a review see Van Overwalle & Vandekerckhove, 2013). With regard to inferences in belief reasoning, neuroimaging data (involving fMRI, Kovács, Kühn, Gergely, Csibra, & Brass, 2014; or NIRS, Hyde, Betancourt, & Simon, 2015) suggest that the temporo-parietal junction that is regularly involved in explicit tasks is also activated during implicit belief processing.

In the present paper we will use this latter, unitary view of ToM as starting point. Although we will focus on processes involved in implicit mentalizing, we believe that these core processes are likely common between implicit and explicit ToM. We aim to provide a fine-grained analysis of ToM and discuss three sets of component processes that may capture different steps involved in mentalizing (see also Kovács, 2015 for a different analysis). In such an approach explicit access to mental state representations can be considered as one of the final steps involved in ascribing a mental state to another agent. Crucially, failure on a ToM task can therefore result from a problem at one (or more) of the preceding stages.

In the following parts we will examine three sets of processes contributing to ToM reasoning. In this analysis, we will address only those aspects of ToM that entail understanding others' epistemic states, specifically belief reasoning, as a case study. Other kinds of mental states, such as emotional states, are outside the scope of the present inquiry. We will target mechanisms that can be tackled using implicit, non-verbal measures investigating inferences about what other agents see, know or believe. First, we will focus on studies that investigate how infants identify social agents and their focus of attention. Preference for biological motion and face-like configurations, and spontaneous gaze following are fundamental capacities that guide our attention to relevant aspects of the physical and social world from early on. These capacities enable us to detect *potential* mental state holders and *potential* mental state contents. The processes discussed in this initial part do not entail mental state attributions *per se,* nevertheless their early onset and intact and efficient functioning may play an important role in successful mentalization. Second, we will discuss processes that likely build on the ability to detect potential mental state holders and mental state contents, and that result in forming and sustaining representations of others' beliefs. Finally, successful mentalization also entails a third set of processes involved in integrating the represented mental states into inferential schemas that allow to predict others' actions and to modify our own behavior accordingly. We will discuss how these three sets of processes develop, and how they might build upon each other.

In addition to reviewing studies targeting these non-verbal ToM components in typical development, we will discuss findings from atypical development suggesting that some of these processes may function differently. Specific aspects of social cognition, in particular explicit Theory of Mind performance has been found to be impaired in certain populations, as children with various neurodevelopmental disorders often show lower performance on the verbal ToM tasks than their typically developing peers. For instance, children with autism spectrum disorder (ASD) seem to have problems with such tasks even at a much later age compared to typically developing children; a performance that was taken as a core signature for specific social deficits (Baron-Cohen, Leslie, Frith, 1985; Leslie & Frith, 1988). ASD is a neurodevelopmental disorder characterized by severe and persistent deficits in reciprocal social interactions and social communication, as well as mild to profound intellectual disability in approximately half of the individuals (American Psychiatric Association, 2013). Difficulties on explicit ToM tasks were also found in children with Williams syndrome (Tager-Flusberg & Sullivan, 2000; Van Herwegen, Dimitriou &, Rundblad, 2013), a genetic disorder entailing relatively spared linguistic capacities and excessive sociability on the one hand, but severe impairment in visuo-spatial abilities, a general intellectual disability, and difficulties in social interactions and pragmatic use of language on the other hand (Martens, Wilson, & Reutens, 2008).