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Reaction time profiles of adults' action prediction reveal two mindreading systems

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ABSTRACT

Human beings are able to quickly step into others' shoes to predict peoples' actions. There is little consensus over how this cognitive feat might be accomplished. We tested the hypotheses that an efficient, but inflexible, mindreading system gives rise to appropriate reaction time facilitation in a standard unexpected transfer task, but not in a task involving an identity component. We created a new behavioural paradigm where adults had to quickly select whether an actor would reach, or not reach, for an object based on the actor's false belief about the object's location. By manipulating the type of object we compared participants' responding behaviour when they did and did not have to take the actor's perspective into account. While the overall accuracy reflected a high level of flexible belief reasoning across both tasks, the pattern of response times across conditions revealed a limit in the processing scope of an efficient mindreading system. Thus, we show, for the first time, that there are indeed different profiles of reaction times for object-location scenarios and for object-identity scenarios. The results elevate growing evidence that adult humans have not one, but two mindreading systems for dealing with mental states that underlie action.

1. Introduction

Decades of research on standard false-belief tasks requiring direct verbal reasoning, indicate that theory-of-mind (TOM, also referred to as mindreading) emerges in humans from about 4 years of age (Wellman, Cross, & Watson, 2001). Younger children fail to explicitly reason about others' minds in tasks that present a disparity between the child and the target agent. For example, in the "unexpected transfer" task (e.g., Maxi-chocolate or Sally-Anne test; Baron-Cohen, Leslie, & Frith, 1985; Wimmer & Perner, 1983) a character sees a desirable object in one location before leaving the scene. During the character's absence another character switches the item to a different location. When the protagonist returns, 3-year-olds incorrectly predict that the character will look in the new location rather than in the place they left it. At this age, children also fail the "unexpected contents" test (e.g., Perner, Leekam, & Wimmer, 1987). In this task children are asked what they think is inside a container that looks like it should hold one type of content (e.g., a Smarties tube). It is then revealed to them that the box contains, for example, paperclips instead of Smarties. Three-year-olds incorrectly predict that a naïve agent would guess the true contents of the container, whereas most 4–5-year-olds grasp that the newcomer's belief would be incongruent with reality. For these older children TOM is conceptually unified: they appreciate that beliefs can be true or false and that people's representations of the world come from a specific, subjective viewpoint (Rakoczy, 2015; Rakoczy, Bergfeld, Schwarz, & Fizke, 2015).

There is considerable evidence that belief reasoning is cognitively demanding; it requires input from executive resources (e.g., Apperly, Back, Samson, & France, 2008; McKinnon & Moscovitch, 2007; Rowe, Bullock, Polkey, & Morris, 2001) and also succumbs to egocentric biases (Birch & Bloom, 2007; Epley, Keysar, Van Boven, & Gilovich, 2004; Keysar, Barr, Balin, & Brauner, 2000; Keysar, Lin, & Barr, 2003). The classical view is that advances in language, executive function and participation in complex social interactions help children learn about subjective mental representations (Low & Perner, 2012; Perner, 1991; Wellman, 2014). However, indirect response procedures (e.g., measuring anticipatory or expectant looking) appear to challenge the idea that TOM undergoes significant conceptual change over the preschool years. For example, 3-year-olds show correct eye gaze anticipations in false-belief tasks despite giving incorrect (reality-based) verbal predictions (e.g., Clements & Perner, 1994; Low, 2010; Wang, Low, Jing, & Qinghua, 2012). Young children in small-scale societies also show correct gaze anticipations whilst giving incorrect verbal

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predictions in standard object-location false-belief tasks (e.g., Wang, Hadi, & Low, 2015). More dramatically, infants as young as 13 months of age show some sensitivity to others' mistaken belief-based actions: infants look longer when they observe other people searching in locations that are inconsistent with their false belief of an object's whereabouts (for a review see Sodian, 2016). If TOM is cognitively effortful, then why do non-verbal studies reveal impressive performances from infants?

Adding to the mystery, research with adults indicates that mindreading is sometimes automatic and sometimes not automatic. Schneider, Nott, and Dux (2014) found that a character's false belief affected participants' behaviour even though it had no bearing on their task. They asked one group of participants to track a character's belief and another to track the location of a ball; both looked longer at an empty box in which the character falsely believed a ball to be, compared to a true belief condition in which the character's belief and ball location were consistent. Task-irrelevant tracking of a character's belief was also revealed in a Kovács, Téglás, and Endress' (2010) reaction time study. Adult participants were asked to press a button if they detected an object on removal of an occluder. As expected, reaction times were facilitated by their own belief that the object would be present, but more importantly, they were also speeded when a passively observing character believed that the ball would be present, despite the participant having witnessed the ball leave the scene. Van Der Wel, Sebanz, and Knoblich (2014) also found that adults automatically tracked a bystander's belief about the location of a ball even though there was no reason to do so. These findings, along with those from the visual perspective-taking domain (e.g., Qureshi, Apperly, & Samson, 2010; Samson, Apperly, Braithwaite, Andrews, & Scott, 2010) indicate that mindreading may be in some respects automatic. However, there is also evidence to show that mindreading is not a compulsory, stimulus-driven mechanism (Apperly, 2011). Apperly, Riggs, Simpson, Chiavarino, and Samson (2006) presented participants with a typical unexpected transfer false-belief scenario and instructed them to track the location of a ball. They found that, despite a scenario that was conducive to mindreading, people were slower to react to a question regarding the character's false belief than to a reality probe. If participants undertook automatic mindreading they would be equally as fast. Subsequent work of this nature has reinforced the idea that although not automatic, mindreading can occur spontaneously, given the requisite context, cues and motivation (Back & Apperly, 2010; Biervoye, Dricot, Ivanoiu, & Samson, 2016; Cohen & German, 2009). As adult humans, we recognize from our everyday experiences that we possess the capacity to make snap judgments about, *and* slowly cogitate over someone's behaviour. The challenge is to determine the cognitive components that underlie these distinct mindreading abilities.

1.1. Rich versus lean

There have been attempts to reconcile the contradictory findings in developmental and adult TOM research. Advocates of the early mindreading account (e.g., Carruthers, 2013, 2015, 2016) claim that infants have an abstract (possibly innate) psychological reasoning system and that standard TOM tasks, relying on direct measures, underestimate children's abstract mentalistic competencies. Essentially, 3-year-olds fail where infants succeed because they lack the necessary language, knowledge and executive function to respond explicitly in standard belief testing. Carruthers describes a high-level, one-system account in which infants start out with core mental-state concepts (e.g., thinks, likes) and that they can attribute meta-representational states to others (e.g., "Daddy thinks there is a toy in my box") without an explicit understanding of what is true and false. Mastery of these concepts occurs in time, but there is no change to the fundamental architecture of the representational mechanism from infant to adult.

At the other extreme, infant success is construed as the result of low-level processes. Perner and Ruffman (2005) point to infants' sensitivity to behaviour rules; they rely on past experiences to predict an agent's action (e.g., people tend to look for things in the last place they saw them). Following a systematic assessment of infant false-belief studies, Ruffman (2014) concludes that infant performances can be explained by (domain general) statistical learning combined with an innate or early developing curiosity for eyes, faces and biological movement. The transition to adult-like mind reasoning is facilitated by language development and vital inputs from the social environment. Another non-mentalistic account interprets infant success in terms of low-level novelty wherein looking behaviour reflects the extent to which the perceived stimuli are novel with respect to previously encoded events (e.g., Heyes, 2014). These interpretations strongly oppose the idea of a modular, representational mechanism for infant mindreading. Theoretically, in infants and non-human animals there is always room for a non-TOM explanation wherein there is no way to empirically test between behaviour-reading and mind-reading (termed 'the logical problem' by Lurz, 2011). Mental states come with behavioural correlates, so how can we be sure that infants are using mental state concepts rather than learnt associations when predicting others' behaviours (Ruffman, Taumoepeau, & Perkins, 2012)? The problem with such a viewpoint is that it can explain findings, but not necessarily predict them.

1.2. 2-Systems

Confronted with such an impasse, Apperly and Butterfill (2009) offer a promising two-systems solution that features both 'lower level' (System 1) and 'higher level' (System 2) processing. According to this account, human adults have an efficient as well as a flexible mindreading system. System 2 supports direct verbal predictions and abstract mental state reasoning, and develops from age 4 years. However, the flexibility of such a system is cognitively costly as it makes deep and lasting demands on executive function resources. System 1 (available in infants, children and adults) guides indirect responses in fast-moving situations (e.g., eye gaze in certain tasks), and imposes relatively fewer demands on general cognitive resources. This lower level system operates outside awareness and may interact with the flexible system in a circumscribed manner (Apperly, 2011; Low, 2010; Ruffman, Garnham, Import, & Connolly, 2001). System 1 uses a minimal model of mind that involves tracking *belief-like* states, called registrations – relational attitudes whose contents can be picked out by simple relationships between agents, objects and locations. By contrast, System 2 guides action deliberations and justifications. It uses a canonical model of mind where mental states like belief are treated as propositional attitudes that are essentially subjective in nature (Butterfill & Apperly, 2013; Low, Apperly, Butterfill, & Rakoczy, 2016). The limited processing scope of System 1 precludes representation of belief as such but is sufficient to enable infants to pass certain false-belief tasks. Crucially, whilst adults have full-blown belief reasoning capabilities, they also have at their disposal, an efficient system enabling fast paced anticipations and responses pertaining to others' actions. The apparent contradictions in adult studies are explained by the fact that mindreading is governed by circumstances which determine which system is utilized.

Low and Watts (2013) tested the 2-Systems account by investigating whether the efficient mindreading system, as compared to the flexible system, would be subject to certain signature limits. A signature limit of a system is a pattern of behaviour that the system exhibits which is both defective, given what the system is set up to handle, and peculiar to that system. Identifying signature