Development of online use of theory of mind during adolescence: An eye-tracking study

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ABSTRACT

We investigated the development of theory of mind use through eye-tracking in children (9–13 years old, $n = 14$), adolescents (14–17.9 years old, $n = 28$), and adults (19–29 years old, $n = 23$). Participants performed a computerized task in which a director instructed them to move objects placed on a set of shelves. Some of the objects were blocked off from the director's point of view; therefore, participants needed to take into consideration the director's ignorance of these objects when following the director's instructions. In a control condition, participants performed the same task in the absence of the director and were told that the instructions would refer only to items in slots without a back panel, controlling for general cognitive demands of the task. Participants also performed two inhibitory control tasks. We replicated previous findings, namely that in the director-present condition, but not in the control condition, children and adolescents made more errors than adults, suggesting that theory of mind use improves between adolescence and adulthood. Inhibitory control partly accounted for errors on the director task, indicating that it is a factor of developmental change in perspective taking. Eye-tracking data revealed early eye gaze differences between trials where the director's perspective was taken into account and those where it was not. Once differences in accuracy rates were considered, all age groups engaged in the same kind of online processing during perspective taking but differed in how often they engaged

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in perspective taking. When perspective is correctly taken, all age groups' gaze data point to an early influence of perspective information.

Introduction

Over the last couple of decades, cognitive neuroscience research has shown that brain areas involved in theory of mind (the "social brain")—our ability to attribute the beliefs, thoughts, desires, intentions, and feelings of others—undergo changes not only during childhood but also during adolescence (Burnett, Sebastian, Cohen Kadosh, & Blakemore, 2011). A substantial number of studies have now provided evidence for structural and functional changes in the social brain during childhood and adolescence. In addition, there is a body of evidence that theory of mind (ToM) is applied more robustly or accurately with age through middle childhood (Devine & Hughes, 2013; Epley, Morewedge, & Keysar, 2004; Lecce, Bianco, Devine, Hughes, & Banerjee, 2014; Surtees & Apperly, 2012; Wang, Ali, Frisson, & Apperly, in press) and adolescence (Dumontheil, Apperly, & Blakemore, 2010; Vetter, Altgassen, Phillips, Mahy, & Kliegel, 2013). Previous studies have shown that children's performance on paradigms such as false-belief tasks reaches ceiling at around the age of 5 years (Surian, Caldi, & Sperber, 2007; Wellman, Cross, & Watson, 2001). The question arises as to what factors affect older children and adolescents' successful application of such abilities.

The Director paradigm has been used to investigate the ability to take the perspective of another individual into account in a communicative context (Apperly, Back, Samson, & France, 2008; Brown-Schmidt & Hanna, 2011; Fett et al., 2014; Keysar, Barr, Balin, & Brauner, 2000; Keysar, Lin, & Barr, 2003). In these studies, the participant interacts with another agent (a "director") to act on a set of objects (Director paradigm; Fig. 1). Crucially, some of the objects are blocked off from the director's point of view and are visible only to the participant. Thus, when the director talks about an object (e.g., "the large ball"; Fig. 2), the participant should ignore any object that is not visible to the director and instead select a referent from what is in the "common ground," that is, what is visible to both the participant and the director. This paradigm requires the participant to infer the speaker's referential intention (a mental state) based on beliefs that differ from his or her own due to the speaker's ignorance of the presence of an object that would be a potential referent for the instruction given. For example, in the setup shown in Fig. 2, the participant, but not the director, sees a third ball that best fits the description "the large ball" (the basketball) and needs to discount it as the intended referent because the director does not know about that ball.

The Director paradigm is useful for the study of the development of the social brain because it can be used to measure the application of aspects of ToM without asking participants to make an explicit
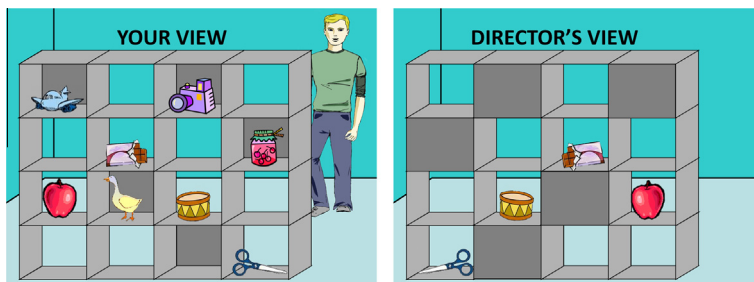

Fig. 1. Instruction screens used to explain the task to participants. The set of shelves on the left is shown from the participant's point of view, and the set of shelves on the right is shown from the director's point of view.