Neural Networks 23 (2010) 1043–1050

Contents lists available at ScienceDirect

Neural Networks

journal homepage: www.elsevier.com/locate/neunet

2010 Special Issue

Conceptual change and preschoolers' theory of mind: Evidence from load–force adaptation

Mark A. Sabbagh *, Sydney F.R. Hopkins, Jeannette E. Benson, J. Randall Flanagan

Psychology Department, Queen's University, Kingston K7L 3N6, ON, Canada

ARTICLE INFO

Keywords:
Theory of mind
Load–force adaptation
Theory theory
Social cognitive development
Developmental cognitive neuroscience

ABSTRACT

Prominent theories of preschoolers' theory of mind development have included a central role for changing or adapting existing conceptual structures in response to experiences. Because of the relatively protracted timetable of theory of mind development, it has been difficult to test this assumption about the role of adaptation directly. To gain evidence that cognitive adaptation is particularly important for theory of mind development, we sought to determine whether individual differences in cognitive adaptation in a non-social domain predicted preschoolers' theory of mind development. Twenty-five preschoolers were tested on batteries of theory of mind tasks, executive functioning tasks, and on their ability to adapt their lifting behavior to smoothly lift an unexpectedly heavy object. Results showed that children who adapted their lifting behavior more rapidly performed better on theory of mind tasks than those who adapted more slowly. These findings held up when age and performance on the executive functioning battery were statistically controlled. Although preliminary, we argue that this relation is attributable to individual differences in children's domain general abilities to efficiently change existing conceptual structures in response to experience.

1. Introduction

Between the ages of 3- and 5-years, children come to explicitly understand that the epistemic mental states that motivate observable behavior (e.g., belief, knowledge), are person-specific, idiosyncratic representations of reality (Perner, 1991). This representational theory of mind understanding (RTM) is often diagnosed with the "false belief" task (Wellman, Cross, & Watson, 2001; Wimmer & Perner, 1983) whereby children are asked to either predict or explain how a person will act when that person's beliefs do not match some true state of affairs. Scores of studies have shown that young 3-year-olds fail this task, and correct performance begins to develop around children's fourth birthday (see Wellman et al., 2001). However, much less work has been focused on the mechanisms underlying children's RTM development. In the present study, we used an individual differences approach to examine whether children's abilities to change their expectations about the weight of an object in a motor adaptation task is associated with preschoolers' theory of mind development.

Our focus on children's abilities to change their expectations stems from a consideration of one of the more prominent frameworks for investigating mechanisms that support preschoolers' development of an explicit RTM: the "theory theory" (Gopnik & Wellman, 1994; Wellman, 1990; Wellman & Gelman, 1998). The theory theory starts by emphasizing that mental states are theoretical constructs that can be used to generate expectations (i.e., hypotheses and predictions) about how people will act in particular situations. From a developmental standpoint, the question is not whether young children have some theory of mind; even young infants are presumed to have some understanding of the fact that behavior is motivated by internal mental states. These early understandings can be diagnosed in paradigms that investigate how infants react when expectations putatively generated by a consideration of internal mental states are violated (Onishi & Baillargeon, 2005; Phillips, Wellman, & Spelke, 2002; Woodward, 1998). Rather the developmental question is what kinds of expectations and explanations for behavior children's theories of mind tend to generate at different ages. Wellman and colleagues (Bartsch & Wellman, 1994; Wellman & Liu, 2004) have argued that children gradually change through a series of qualitatively different understandings of how mental states motivate behavior, finally arriving at a rudimentary but explicit adult-like theory of mind, sometime between children's third and fourth birthday.

For the present discussion, the most notable and perhaps also most controversial aspect of the theory theory is its proposal for how children's theories and expectations change. Change within theory theory is conceptualized as a process of adapting one's theories via a process akin to how formal scientists change the theories they use to explain empirical phenomena (Gopnik &

* Corresponding author.
E-mail address: sabbagh@queensu.ca (M.A. Sabbagh).

0893-6080/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.neunet.2010.08.007

Meltzoff, 1997; Gopnik & Wellman, 1992). As children navigate the world with one naïve theory, they may encounter instances in which their current theory leads to incorrect predictions or incoherent explanations for particular events. These experiences accumulate and spur children to adapt their theoretical constructs to achieve a better (i.e., more accurately predictive, more coherently and parsimoniously explanatory) understanding of how mental states relate to human behavior.

Evidence cited as generally consistent with theory theory comes from two literatures. First, 3-year-olds seem to have very different ways of explaining human actions than do 5-year-olds (Bartsch & Wellman, 1994). For instance, 3-year-olds tend to focus on the role that desire plays in explaining human action whereas 5-year-olds refer more to concepts of knowledge and belief (Bartsch, Campbell, & Troseth, 2007). This provides evidence suggesting that children do indeed go through qualitatively different phases of explaining how mental states relate to the world. Second, individual differences in experiential factors seem to predict the age at which preschoolers pass false belief tasks (Carpendale & Lewis, 2004). For instance, parent–child talk about mental states (Ruffman, Slade, & Crowe, 2002), number of siblings in the family (Ruffman, Perner, Naito, Parkin, & Clements, 1998), and socio-economic status (Pears & Moses, 2003) are all positively related to children's false belief development. These effects are expected if the processes that support changing their initial theories based upon their experiences are crucial for RTM development—those with more relevant experiences will change their theories more quickly than those with fewer relevant experiences (Bartsch, 2002).

Although these lines of evidence are largely consistent with theory theory, a number of authors have argued that both lines of evidence are also consistent with alternative theoretical perspectives (see e.g., Scholl & Leslie, 1999). Of course, no one line of evidence is likely to provide conclusive support for a broad theoretical framework such as the theory theory. One way of approaching this issue is to focus more squarely on the mechanisms that theory theorists propose to support change in theory of mind over the preschool years. At a glance, we might suggest that a suite of domain-general cognitive processes are involved in changing cognitive structures to better reflect experience. For one, to even see that change is necessary, one would need to notice prediction errors—instances in which a naïve expectation or hypothesis did not match what really happened. As an example in the theory of mind domain, if one thought that action was based primarily on desires (i.e., people do what they want to do), then viewing someone act on the basis of a false belief might result in a prediction error; there, someone wants to do something (i.e., find a stashed object) but acts in a way that does not straightforwardly comport with that desire (i.e., looks where the object is not). When prediction errors are made and identified as such, one might evaluate the quality and integrity of the new data, and then, based upon that analysis make a change to the existing conceptual structures responsible for generating the expectation. These changes would be made with the aim of making future expectations better match outcomes. It is important to note that this process of change is likely to be gradual rather than sudden. After all, a predictive system that changed too radically in response to any one piece of information would likely be too unstable for regular predictive power (e.g., Siegler & Chen, 1998). With respect to RTM development, it would seem that the transition from one theory of mind to another is gradual rather than abrupt, even when children are provided with a steady concentrated diet of rich information relevant to transitions in theory of mind (Amsterlaw & Wellman, 2006).

We know of no studies that have shown that these processes that enable cognitive change in response to experience are associated with RTM development, or any other transition in children's theory of mind reasoning. Part of this may be due to the somewhat protracted window within which changes in RTM occur (over roughly 18–24 months), and a general inability to parametrically assess how much impact a given experience has on the emergence of an RTM. Here, we propose that everyday phenomena in the domain of motor learning might provide a window on these processes. Several studies now have shown that people will lift a newly encountered object based upon prior expectations about the likely weight of the object. When lifting an object, people typically increase the vertical lift (or load) force to a target level that slightly exceeds the predicted weight of the object. When lifting a newly encountered object, weight predictions are based upon prior knowledge — or "internal models" — linking the size, material and identity of the object to weight (e.g., Flanagan & Beltzner, 2000; Flanagan, Bittner, & Johansson, 2008). The use of these predictions becomes manifest when people mis-lift (apply too much or too little force) objects because the object is unexpectedly light or heavy (Flanagan et al., 2008). Over repeated interactions with the object, people gradually (not suddenly) change their expectations about the force required to lift appropriately, and ultimately lift the object smoothly (Flanagan, Bowman, & Johansson, 2006).

What is perhaps most intriguing is that the processes that are thought to underpin load force adaptation (see e.g., Wolpert & Flanagan, 2009) broadly parallel those that theory theorists believe are important for spurring transitions in theory of mind. That is, both load force adaptation and theory change are thought to entail using a prior existing body of knowledge to generate a testable expectation about the world (either what an object will weigh or what a person will do). When prediction errors are made, the detection of the error promotes some adjustment to the system. The end result is that the systems that generate the expectations (either about object weight or about how mental states cause behavior) are revised to deliver more accurate expectations. Given these similarities of process, then, our main research question concerned whether children's abilities in a simple load–force adaptation paradigm might be associated with their RTM abilities. Finding such a relation could constitute evidence that domain general mechanisms that promote incremental change in conceptual structures are associated with RTM development.

In addition to this focal question, we included a battery of executive functioning (EF) tasks in our design as a potential control measure. Prior research has established that there is a connection between RTM and EF skills (see Benson & Sabbagh, 2009, for a recent review). In particular, RTM is associated with EF tasks that require children to inhibit a dominant or prepotent action or response in order to follow a rule that requires them to do something else. A number of researchers have noted that these "response-conflict" EF tasks require children to keep in mind two possible ways of acting on the world and select the one to engage based upon their awareness of the task context (Frye, Zelazo, & Burack, 1998). On the surface, it seems possible that similar processes may be at work when children encounter an unexpectedly heavy object; after becoming aware of the heavy object, children may need to recognize that the object can be lifted two ways and apply the force appropriate to the context. To determine whether this is the case, we included two well-established measures of children's response–conflict EF skills for inclusion in analyses.

2. Method

2.1. Participants

Thirty-three 42–54-month-old children (14 girls, $M_{age} = 47.01$ months, $SD = 3.62$) were recruited to participate through a