

Children's and adults' neural bases of verbal and nonverbal 'theory of mind'

Chiyoiko Kobayashi^{a,*}, Gary H. Glover^b, Elise Temple^c

^a Department of Psychology, Cornell University, NY 14853, USA

^b Center for Advanced MR Technology at Stanford, Department of Diagnostic Radiology, Stanford University School of Medicine, CA 94305, USA

^c Department of Human Development, Cornell University, NY 14853, USA

Received 22 March 2006; received in revised form 24 November 2006; accepted 25 November 2006
Available online 8 January 2007

Abstract

Theory of mind (ToM) – our ability to predict behaviors of others in terms of their underlying intentions – has been examined through verbal and nonverbal false-belief (FB) tasks. Previous brain imaging studies of ToM in adults have implicated medial prefrontal cortex (mPFC) and temporoparietal junction (TPJ) for adults' ToM ability. To examine age and modality related differences and similarities in neural correlates of ToM, we tested 16 adults (18–40 years old) and 12 children (8–12 years old) with verbal (story) and nonverbal (cartoon) FB tasks, using functional magnetic resonance imaging (fMRI). Both age groups showed significant activity in the TPJ bilaterally and right inferior parietal lobule (IPL) in a modality-independent manner, indicating that these areas are important for ToM during both adulthood and childhood, regardless of modality. We also found significant age-related differences in the ToM condition-specific activity for the story and cartoon tasks in the left inferior frontal gyrus (IFG) and left TPJ. These results suggest that depending on the modality adults may utilize different brain regions from children in understanding ToM.

© 2006 Elsevier Ltd. All rights reserved.

Keywords: fMRI; Theory of mind; Cognitive development; Language; Temporo-parietal junction

1. Introduction

Theory of mind (ToM) – the ability to understand others' desires and intentions that can be the same as (or different from) one's own – is critical for human cognitive development (Frith & Frith, 2003). ToM has been tested in normally developing children and children with autism through a variety of verbal and nonverbal tasks (Baron-Cohen, 2000). Among these ToM tasks, the false-belief (FB) paradigm (Perner & Wimmer, 1985; Wimmer & Perner, 1983) is perhaps the most widely used task among ToM researchers (Wellman, Cross, & Watson, 2001). The purpose of the FB task is to assess one's understanding of others' beliefs that may be different from his/her own (Baron-Cohen, Leslie, & Frith, 1985; Baron-Cohen, Ring, et al., 1999). The nearly universally observed results are that 4- and 5-year old are successful at the FB tasks, while 3-year old are not (Baron-Cohen et al., 1985; Baron-Cohen, Leslie, & Frith, 1986).

A number of neuroimaging studies have explored ToM in adults and implicated the mPFC as being important for ToM processing (Brunet, Sarfati, Hardy-Baylé, & Decety, 2000; Fletcher et al., 1995; Gallagher et al., 2000; Gallagher, Jack, Roepstorff, & Frith, 2002; Goel, Grafman, Sadato, & Hallett, 1995; Happé et al., 1996; Vokeley et al., 2001). There has been some evidence for modality-dependent ToM processing in laterality effects seen in ToM-related brain activity. Most ToM neuroimaging studies have used text-based ToM tasks and found left lateralized mPFC activity (Fletcher et al., 1995; Gallagher et al., 2000; Goel et al., 1995; Happé et al., 1996). A few studies have used pictorial or cartoon-based ToM tasks, claiming them to be nonverbal ToM tasks, and implicated the right mPFC (Brunet et al., 2000; Gallagher et al., 2000). One study that used both story-based and cartoon-based ToM tasks found a convergent activity for the both story and cartoon tasks in the left mPFC (Gallagher et al., 2000). Some studies have found more significant brain activity in the left and/or right TPJ than in the mPFC during mental attribution tasks (Saxe & Kanwisher, 2003; Saxe & Wexler, 2005). Most recently, Saxe and Wexler (2005) found that verbal belief concepts about others were primarily related to the right

* Corresponding author. Fax: +1 607 255 8433.
E-mail address: ck227@cornell.edu (C. Kobayashi).

TPJ activity. These results suggest that ToM may be represented in the left- or right-lateralized mPFC, respectively, and/or TPJ region(s) depending on the task-modality, in adults.

In order to understand the developmentally important ToM neural bases, a comparison between children and adults is needed. Previous studies of ToM that implicated the mPFC (Brunet et al., 2000; Fletcher et al., 1995; Gallagher et al., 2000; Goel et al., 1995; Happé et al., 1996; Vogeley et al., 2001) and the TPJ (Gallagher et al., 2000; Saxe & Kanwisher, 2003; Saxe & Wexler, 2005) have used adult subjects only. To the best of our knowledge, no brain imaging study to date has examined both children and adults with both story- and cartoon-based ToM tasks.

The present study sought to explore the neural correlates of the verbal and nonverbal (using story- and cartoon-based stimuli, respectively) ToM in pre-pubertal children and adults. The main aim was to find both task modality-independent and -dependent neural bases of ToM that might be important for both age groups and either group separately. In addition, we wished to identify age-related differences and similarities in brain activity during verbal and nonverbal ToM tasks. We recorded hemodynamic responses while the subjects performed a verbal (story) FB task (Fig. 1a) and a nonverbal (cartoon) FB task (Fig. 1b) in

an MRI scanner. We predicted that if there are neural bases of ToM that are modality-independent (as proposed in Gallagher et al. (2000)) these should be present even in children and we would observe convergence of activity in these regions between the two age groups for both task modalities. In terms of the age-related differences, those regions that show more activity in children than adults would be more important for understanding ToM during childhood. Conversely, those brain regions that exhibit more activity in adults would have developed later. In addition, interactions between task- and age-groups would illustrate modality-specific developmental differences in the neural bases of ToM.

2. Method

2.1. Participants

Sixteen (8 male and 8 female) healthy adults with mean age of 27 ($SD=6$, range 18–39) and 12 (6 male and 6 female) healthy children with mean age of 9 years 8 months ($SD=1$, range 8–11 years 6 months) participated in the experiment. Fourteen children were initially recruited, however, two children showed excessive movement during fMRI scanning (>5 mm) and were excluded from both behavioral and fMRI analyses. All had no known physical or psychiatric disease and were right-handed as assessed by our internal



Fig. 1. Examples of story (a) and cartoon (b) ToM tasks. The ToM story task was second-order FB in the form of “x thinks that y thinks that...”. The cartoon ToM task depicted the characteristics of the second-order FB scenario by enclosing one person’s thought-bubble in another person’s thought-bubble. All slides were presented serially. There were six slides in each story/cartoon episode. On the sixth slide, subjects were asked to choose from two possible answers, A or B (for story), or, Red Star or Blue Star (for cartoon).

متن کامل مقاله

دریافت فوری ←

ISIArticles

مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات