Cognitive Development 33 (2015) 40–55

Contents lists available at ScienceDirect

Cognitive Development

A longitudinal assessment of the relation between executive function and theory of mind at 3, 4, and 5 years

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ARTICLE INFO

Keywords:
Executive function
Theory of mind
Expression and emergence accounts, Social reasoning

ABSTRACT

This longitudinal study contributes to the growing literature on the predictive nature of the relation between executive function (EF) and theory of mind (ToM). A latent variable model was fit to the data acquired from 226 socioeconomically and racially diverse children (52% female) at 3, 4, and 5 years of age on a number of age-appropriate tasks designed to assess EF and ToM. After controlling for sex, income-to-needs, and receptive language ability, there was substantial stability within each construct as children aged. In addition, EF at 3 years predicted ToM at 4 years but ToM did not predict EF, replicating earlier results. This pattern also appeared from 4 to 5 years of age, suggesting that the developmental precedence of EF persists later in development. Implications of these findings are discussed in terms of contemporary cognitive development theories, as well as the relation between EF and social reasoning in general.

The preschool years are characterized by a period of rapid growth in cognitive functioning. Notably, there are impressive developments from 3 to 5 years of age in executive function (EF), the set of cognitive processes (e.g., attention, inhibitory control, shifting, maintaining goals in memory) that

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http://dx.doi.org/10.1016/j.cogdev.2014.07.001
0885-2014/

work in concert to perform controlled goal directed behavior (see Garon, Bryson, & Smith, 2008, for a comprehensive review). For example, in the Dimensional Change Card Sort (DCCS; Frye, Zelazo, & Palfai, 1995; Zelazo, Müller, Frye, & Marcovitch, 2003) considered a standard EF task, children initially learn to match test cards based on one of the two relevant dimensions (e.g., color such that red boats are matched with a target card of a red bunny and blue bunnies are matched with a target card of a blue boat). After several trials, which are typically performed correctly as early as 3 years of age, the rule changes such that cards must now be matched based on the other relevant dimension (e.g., shape such that red boats are now matched with a target card of a blue boat and blue bunnies are now matched with a target card of a red bunny). Successful responding after the rule change, typically seen between 4 and 5 years of age, requires shifting attention from the original dimension to the new dimension, keeping the relevant rule in mind, and inhibiting the tendency to match the card in the manner that was previously correct (see Simpson & Riggs, 2005, 2007; Simpson et al., 2012, for discussion on what leads to response prepotency).

Interestingly, similar age-related improvements have been observed in tasks designed to assess children's developing theory of mind (ToM), the ability to ascribe mental states to oneself and others and to make behavioral predictions how people will act based on their mental states. For example, in the classic Smarties task (Gopnik & Astington, 1988), children observed that a familiar container contained surprising contents (e.g., a Smarties box contained pencils). When asked what another child would think is in the container, 3-year-olds incorrectly claimed that this other child would know the surprising contents of the container. In contrast, older children correctly inferred that in the absence of privileged knowledge, the other child would think that the container holds its typical contents.

ToM tasks require an understanding that one's own current knowledge is not accessible to other people, nor was it available in the past. To succeed on a ToM task, children must suppress the natural inclination to respond based on a prepotent response and instead reason from a naïve perspective, which renders the structure similar to a conflict EF task. To illustrate this commonality, consider both the DCCS and Smarties task. Correct performance on both tasks requires recognizing the prepotent response (i.e., to continue matching by the 1st dimension in the DCCS and to respond based on the current belief that the container holds pencils in the Smarties task) and then successfully inhibiting it so as to switch to the correct response (i.e., to match by the 2nd dimension in the DCCS and to respond based on the false belief that the container holds Smarties in the Smarties task). The structural similarities in both inhibition and ToM tasks prompted speculation that the characteristic errors in ToM tasks, such as responding based on the actual state of affairs and not based on the ignorance of the character, can be explained by limitations in EF. EF processes such as attentional flexibility, inhibitory control, and working memory are likely to be implicated in ToM tasks. In addition, according to Cognitive Complexity and Control theory (Frye, 1999; Frye et al., 1995; Zelazo & Frye, 1997), both types of tasks require the coordination of "if–if–then" rule structures.

One compelling argument against the notion that EF and ToM tasks can be reduced to common architecture is from the neuropsychological study by Sabbagh, Bowman, Evraire, and Ito (2009). In this study, although EF and ToM were correlated, activity in the dorsal medial prefrontal cortex and the right temporal – parietal juncture was associated with ToM even after controlling statistically for associations with EF. This provides evidence that neural substrates of ToM reasoning are dissociable from EF reasoning (see also Sabbagh, Xu, Carlson, Moses, & Lee, 2006, for additional evidence in a cross-cultural study).

Other theorists have speculated that EF and ToM are causally related (see Moses & Tahiroglu, 2010, for a recent review; Perner & Lang, 1999). Notably, Kloo and Perner (2003) have demonstrated that training on a false belief task improved DCCS performance and training on the DCCS improved false belief performance. This finding is convincing in that advancement of skills in one domain can improve the other, but it does not directly address which domain has developmental precedence.

It is possible that ToM aptitude is necessary for development of EF. Wimmer (1989, as cited by Perner & Lang, 1999) argued that with growing sophistication of mental concepts, children become more capable of controlling mental processes. Similarly, Perner (1991, 1998) has claimed that metarepresentational capacities, such as the ability to represent goal states and the impediments to achieving these states, arise from developing ToM, are necessary for execution of EF tasks. Specifically,