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THEORY OF MIND AND EXECUTIVE FUNCTIONING

A Developmental Neuropsychological Approach

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Over the preschool years, young children develop an explicit "representational theory of mind" (RTM)—an understanding that mental states are representations, the contents of which are related to but also distinct from the real situations they represent. Research using the false-belief task (a widely accepted litmus test for explicit RTM understanding), has shown that children all over the world show a remarkably similar timetable for RTM development, with the achievement usually coming between children's fourth and fifth birthdays (Callaghan et al., 2005). The only exceptions to universal RTM competence have been seen in instances of brain injury (Apperley, Samson, Chiavarino, & Humphreys, 2004) or neurodevelopmental disability, such as autism (Baron-Cohen, 2005), in which RTM reasoning seems to be particularly impaired. Together, these findings raise the possibility that RTM development is paced, at least in part, by relatively specific neurological developments unfolding in the preschool years.

The goal of this paper is to offer some hypotheses about the nature of the neurodevelopmental changes associated with RTM development by considering research on the relation between RTM and children's developing response-conflict executive functioning (RC-EF). RC-EF enables individuals to negotiate situations in which habit or prior learning would typically impel them to respond in one manner, but the particular situation requires them to respond in an alternative way. In the following section we provide a brief overview of research describing specific characteristics of the relation between RC-EF and RTM development. We then describe and evaluate three possible explanations for this relation, and explore how each may provide insight into the neurodevelopmental factors associated with advances in RTM reasoning.

THE RELATION BETWEEN RTM DEVELOPMENT AND RESPONSE CONFLICT EF

Specific Relationship

A now sizeable collection of studies has identified a robust relation between children's RC-EF and their RTM task performance (e.g., Carlson & Moses, 2001; Carlson, Moses, & Breton 2002; Hughes, 1998; Perner, Lang, & Kloo, 2002). In children, RC-EF is typically assessed using Stroop-like tasks that require the suppression of a more dominant response in favor of a less dominant one (e.g., day–night Stroop, grass–snow Stroop, Dimensional Change Card Sort; see Carlson, 2005, for a review of measures). These studies show that as preschoolers' performance on RC-EF tasks improves, so, too, does their RTM task performance. The relation typically survives stringent partial correlation analyses in which factors such as age, sex, and language abilities are statistically controlled; after controlling for these variables, the correlation between RTM and RC-EF is typically around $r = .40$ (e.g., Carlson & Moses, 2001). This suggests that the relation between RTM and RC-EF cannot be attributed to general, age-related improvements in both skills, or to markers of general intelligence.

Perhaps most noteworthy is that there are two senses in which the relation between RTM and RC-EF is a specific one (see Moses & Sabbagh, 2007 for a review). First, RTM is robustly related to RC-EF tasks, but not as robustly related to other aspects of executive functioning, such as delay of gratification or working memory (e.g., Carlson & Moses, 2001). Second, RC-EF is related to the development of RTM, but not to the development of other aspects of theory of mind, such as the understanding of intentions, desires, or knowledge (Moses, Carlson, Stieglitz, & Claxton, under review). Perhaps some of the most compelling evidence for this second sense comes from research testing the relation between RC-EF and reasoning about false photographs. This research shows that RC-EF tasks are associated with RTM, but not with performance on the closely matched false-photograph task. (Müller, Zelazo, & Imrisek, 2004; Sabbagh, Moses, & Shiverick, 2006). Taken together, these findings strongly suggest that RC-EF makes a specific contribution to RTM reasoning itself, and is not simply required for reasoning about mental states or representations in general.

UNIDIRECTIONAL RELATIONSHIP

In addition to there being a concurrent relation between RC-EF and RTM development, several studies have now shown a robust longitudinal relation whereby early RC-EF skills predict later RTM skills, but not vice versa. Hughes (1998) found that 3- to 4-year-old children's early RC-EF skills predicted their performance on false-belief tasks a year later, even after controlling for age, verbal ability, and initial false-belief performance. In contrast, the relation did not hold in the opposite direction—that is, early RTM understanding did not predict later RC-EF abilities after relevant statistical controls.

Two additional studies replicated these results on different timescales. Flynn (2007) found 3- and 4-year-olds' early RC-EF to be predictive of false-belief performance 5 months later, after controlling for age, verbal ability, and initial RTM knowledge. Again, early RTM knowledge did not predict later RC-EF skills. Similarly, Carlson, Moses, and Breton (2002) found that 24-month-olds' RC-EF was predictive of RTM after a 10-month period, when controlling for the combined effects of age, sex, verbal ability, maternal education, and initial theory-of-mind understanding (e.g., intentions and desires). This pattern of longitudinal correlations, seen now across varying timescales, is typically used as evidence for a unidirectional, potentially intrinsic relation between early RC-EF and later RTM skills.

There is, however, a caveat with respect to making this strong interpretation in that very few of these analyses controlled for Time 2 RC-EF in the longitudinal analyses. To the extent that early RC-EF is correlated with later RC-EF, any significant relations between early RC-EF and later RTM may exist because each are related to later RC-EF. Although neither Hughes (1998) nor Flynn (2007) address this issue, Carlson, Moses, and Hix (1998) report results of a limited partial correlation analysis in which early RC-EF performance remained predictive of later RTM reasoning after controlling for later RC-EF skills, though no other control variables were included. Taken together, these studies provide suggestive (though, not conclusive) evidence for a unidirectional and potentially intrinsic relation between RC-EF and RTM abilities in development.

RC-EF Is Not Sufficient for RTM Reasoning

Although it does appear that RC-EF plays some role in supporting RTM performance, some cross-cultural and clinical research suggests that the relation may not be entirely straightforward. For instance, Sabbagh, Xu, Carlson, Moses, and Lee (2006) tested Chinese (Beijing) and U.S. preschoolers on extensive batteries of both RC-EF and RTM tasks (see Carlson & Moses, 2001). Comparisons across the two groups showed that Chinese children were advanced on RC-EF relative to their U.S. counterparts; indeed, the Chinese 3.5-year-olds had executive skills on par with U.S. 4.0-year-olds. Yet, the two groups showed very similar performance on the RTM battery. This pattern of findings suggests that developmental advances in RC-EF alone are not sufficient to promote performance on RTM reasoning tasks; otherwise, the Chinese preschoolers would have outperformed the U.S. preschoolers on RTM tasks as well. Most interesting, however, within the group of Chinese preschoolers, RC-EF was predictive of false-belief task performance; the relation was roughly the same magnitude in the Chinese preschoolers as it was in the U.S. preschoolers. This latter finding suggests that even in cases where the timetable of RC-EF is advanced, individual differences in RC-EF still predict RTM task performance.

Similar findings were reported by Oh and Lewis (2008), who examined RTM and EF development in Korean preschoolers. In line with Sabbagh et al.'s findings, these researchers found notably advanced RC-EF performance in Korean children as compared to age-matched English preschoolers; on three of the four RC-EF measures administered, young 3-year-old Korean children obtained higher RC-EF scores than 4.5-year-old English participants. Again, this substantial executive performance advantage was not mirrored in false-belief task scores; Korean children's performance across four false-belief tasks was comparable to scores obtained by their English counterparts. These cross-cultural findings demonstrate that there are populations that show a relatively advanced developmental timetable of RC-EF skills, and that group advances in those skills do not themselves seem to give rise to advances in the timetable of RTM skills.

Findings from research on children with autism provide corroborating evidence that RC-EF skills may be necessary but not sufficient for RTM task performance. Although the autistic spectrum disorder is most commonly characterized by deficits in the realm of theory of mind (including the more specific RTM skills), a number of researchers have shown that those with autism also have EF difficulties (e.g., Ozonoff, Pennington, & Rogers, 1991; Pellicano, 2007). That is, autistic participants obtain significantly lower scores on both types of tasks in comparison to controls. Moreover, individual-differences research has shown that EF and RTM performance are correlated in autistic populations (Joseph & Tager-Flusberg, 2004; Ozonoff et al., 1991; Pellicano, 2007; Zelazo, Jacques, Burack, & Frye, 2002). In one study of mildly impaired children (Zelazo et al., 2002), the zero-order correlation between RC-EF and RTM was particularly strong ($r = .82$); the only children with autism who did well on the RTM tasks were those who showed strong performance on the RC-EF tasks.

Despite this strong individual differences relationship, group analyses of children with autism show an intriguing pattern of impairment associations and dissociations. For instance, Pellicano (2007) reported that within an autistic sample, in all instances where RC-EF was impaired, so too was RTM. Although RTM impairments sometimes existed in the absence of RC-EF deficits, the reverse dissociation did not occur. Thus, while intact RC-EF skills appear to be necessary for RTM reasoning, it seems that atypical RTM performance in this special population is not, at least in its entirety, a result of underdeveloped RC-EF. Taken together, these findings show that in both atypical and typical cases, RC-EF may be necessary but not sufficient for RTM performance.

Summary

This brief review illustrates three basic characteristics of the relation between RC-EF and RTM. First, it is a relatively specific relation: RC-EF (but not usually other aspects of EF more generally) predicts RTM (but not other aspects of theory of mind or reasoning about representations in general). Second, the relation is a unidirectional, potentially intrinsic one whereby early RC-EF predicts later RTM, and not vice versa. Third, RC-EF is likely to be necessary but not sufficient for performance on RTM tasks. With these three characteristics in mind, we will now turn to some explanations of the relation between RC-EF and RTM, with particular attention given to the implications of these explanations for understanding the neuromaturational bases of RTM development.

NEURAL BASES OF RTM AND RC-EF

To begin this discussion, we should start with the caveat that little is known about the neural bases of either RTM or RC-EF in preschoolers. In contrast, much is known about the neural correlates of both RTM and RC-EF in adults. With respect to RC-EF, Ridderinkhof and colleagues (Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004) recently reviewed the imaging work from tasks that have investigated RC-EF skills and highlighted the involvement of a relatively circumscribed region of the MPFC. This finding is intriguing for understanding the relation between RC-EF and RTM reasoning, because most studies also show a role for the MPFC in RTM reasoning (see Gallagher & Frith, 2003 for a review). However, the fact that both tasks rely, at least in part, on MPFC functioning may not be all that interesting. The MPFC is a relatively large cortical region, and a recent review by Kain and Perner (2005) has established that for adults, there are, in fact, clear distinctions between areas of MPFC that are important for RC-EF and those responsible for RTM reasoning. Specifically, RC-EF task performance is typically associated with activation in areas of the MPFC that lie posterior to regions typically activated during RTM tasks. Of course, it is important to note that this separation does not necessarily characterize RC-EF and RTM activations in younger populations. Some studies have found more extensive, less specified regions of the prefrontal cortex to be recruited during executive tasks in children as compared to adults (Durston et al., 2002). It is possible, then, that RC-EF and RTM tasks share a common neural substrate during the preschool years. By developing a reasonable theoretical argument regarding the relation between RC-EF and RTM development, we hope that we will be able to develop hypotheses about the neural underpinnings of both skills.

EXPLANATIONS FOR THE RELATION BETWEEN RC-EF AND RTM

Cortical Neighbor Hypothesis

Perhaps the most straightforward developmental hypothesis based upon the adult imaging findings is that the neural systems underlying RC-EF and RTM development are proximal, but separable. That is, there may be one region of the MPFC that contributes to RC-EF, and a nearby but separate region that performs computations necessary for RTM reasoning. Developmentally speaking, then, it would be reasonable to argue that because of their proximity, the neural bases of RTM and RC-EF might be subject to the same endogenous neuromaturational factors that promote functional development within this broad region (e.g., Ozonoff et al., 1991). Although there are likely to be many such factors, one example of such an endogenous factor might be developmental changes in dopaminergic functioning. Dopamine is critical for the normal development of the frontal lobes (Diamond, 1996, 2001), and the MPFC is a primary site of dopamine projection. If critical neural substrates for both RTM and RC-EF are neighbors in the MPFC, they might share relatively specific ontogenetic variance because of their common reliance on dopaminergic enervation. It follows that a reliance on common or proximal regions of the MPFC may lead two otherwise disparate processes to share some developmental variance because of dopamine's influence on this region as a whole.

Some support for a direct role for dopamine in the development of both RTM and RC-EF comes from studies of children with early and continuously treated phenylketonuria (PKU). PKU is a genetic metabolic disorder in which children lack the enzyme necessary for changing phenylalanine into tyrosine, a precursor of dopamine (Diamond, 2001). The result is that children with PKU have depleted dopamine, which in turn affects dopamine projections to the frontal lobes (Scriver, Kaufman, Eisensmith, & Woo, 1995). It is now well documented that children with early and continuously treated PKU have detectable difficulties in RC-EF tasks (Diamond, 1998), even in the face of relatively typical IQ scores. Although we know of no work investigating the performance of children with PKU on RTM tasks per se, there is some evidence that they may have a broad social–cognitive deficit. In particular, Dennis and colleagues (Dennis et al., 1999) showed that children with PKU have difficulty with the "Comprehension" subscale of the Weschler scales, which assesses children's ability to understand social roles, and explain others' behaviors. The fact that deficiencies in dopamine are leading to both of these difficulties is consistent with the possibility that they each rely on the MPFC, and share variance accordingly.

It is worth noting that unlike a number of competing theories, the cortical neighbor hypothesis posits no intrinsic connection between RC-EF and RTM. Several researchers have presented compelling theoretical analyses that have identified candidate structural relations between RTM and RC-EF tasks that could account for the correlation between the two constructs (e.g., Frye, Zelazo, & Palfai, 1995; Russell, 1997; Perner & Lang, 1999). The cortical neighbor hypothesis promotes a radically different view, namely that the correlation is epiphenomenal; it exists only because of a common reliance on endogenous factors that promote development in the cortical regions where both skills have their neural substrates.

The cortical neighbor hypothesis offers a clear explanation for the concurrent, specific relation between RTM and RC-EF. However, it faces a challenge from the longitudinal findings described above; data in support of a unidirectional, potentially intrinsic relation between RC-EF and RTM run counter to the main prediction from the cortical neighbor hypothesis that the two skills are not intrinsically related.

It is worth noting, however, that the cortical neighbor hypothesis does provide a reasonable explanation of the cross-cultural and clinical findings. Specifically, common endogenous developmental factors could account for the shared variance in RTM and RC-EF development, even if the overall trajectory of each skill varies independently because of other domain-specific experiential and exogenous influences. Indeed, the role of experiential factors is well documented for both RTM and RC-EF development. With respect to RTM development, factors such as parent–child talk about mental states and having older siblings affects the developmental timetable of RTM development (see e.g., Carpendale & Lewis, 2004 for a review). With respect to RC-EF, a number of studies have suggested that being bilingual from an early age may be associated with an advanced trajectory of RC-EF development (e.g., Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008). Put simply, then, the individual differences relations between RC-EF and RTM reasoning might be attributable to endogenous factors (e.g., dopaminergic functioning in MPFC) while across-group variability in the developmental trajectories of the individual skills might be attributable to relatively independent exogenous experiential factors.

Common Computation Hypothesis

A number of theorists have suggested that the relation between RTM and RC-EF exists because performance on the two kinds of tasks relies, at least in part, on a common computation or cognitive process. There are two variations of this general hypothesis: the first suggests that RC-EF contributes to RTM task performance, while the second suggests that both RC-EF and RTM rely on a common subcomponent process.

RTM Task Performance Requires RC-EF. The relation between RTM and RC-EF task variability was first thought to reflect performance demands inherent to RTM tasks; standard RTM measures require children to resist their habitual tendency to reference what they know to be true in order to provide an alternate response (Carlson & Moses, 2001). As children become better able to negotiate the response demands of RTM tasks, they became better able to reveal their RTM knowledge. Initial empirical support for this hypothesis came from studies showing that children's performance on RTM tasks improves when researchers ease the RC-EF demands of the tasks (e.g., Wellman & Bartsch, 1988; Carlson et al., 1998). Likewise, RTM performance worsens when researchers increase the RC-EF demands of RTM tasks (Cassidy, 1998; Friedman & Leslie, 2005; Leslie, German, & Polizzi, 2005).

In addition to the possibility of response biases, some researchers have proposed that attributing false beliefs to others poses a special sort of RC-EF problem. As children gain some experience reasoning about beliefs through the preschool years, they may notice that people typically act in accordance with true beliefs. This may lead to a sort of "bias" to assume that others' beliefs are true. In those relatively rare contexts in which another's beliefs are not true (such as the false-belief task), RC-EF may be required to overcome a true-belief bias in order to correctly attribute a false belief (e.g., Leslie, Friedman, & German, 2004). Importantly, this theory suggests that children have acquired the knowledge that beliefs can theoretically be false; the difficulty lies in inhibiting the learned assumption that beliefs will match reality in order to ascribe false beliefs when appropriate, as is the case during false-belief tasks. Some evidence for RC-EF's role in overcoming the true-belief bias comes from Sabbagh et al. (2006), who showed that preschoolers' RTM skills are associated with their abilities to reason about false signs—another kind of representation that may have a "true" bias (see also Parkin & Perner, 1996). In that same study, the ability to reason about false signs was also associated with RC-EF to the same magnitude as RTM skills.

A key feature of these performance accounts is that the computations associated with solving RTM tasks are separable from those associated with the ability to generate RTM concepts. This separation gives rise to the possibility of a distinction between RTM competence (i.e., the ability to generate representations of others' false beliefs) and performance on RTM tasks. Some researchers have proposed that RTM competence computations may be carried out by an early-emerging modular mechanism with direct correlates in neural architecture (e.g., Leslie's theory of mind module, Leslie, 1994; Leslie et al., 2004). However, performance accounts that include a strong commitment to early competence in RTM reasoning do not easily provide a compelling account of the finding that RC-EF is not alone sufficient for RTM task performance in young preschoolers. On the early competence view, once children acquire a certain level of RC-EF they should be able to demonstrate their skills in reasoning about false beliefs. Findings from the cross-cultural studies run counter to this prediction; they show that 3-year-old Chinese and Korean children who were at floor on RTM tasks had attained the same level of RC-EF functioning as had 4-year-old U.S. preschoolers, who showed strong RTM performance. Thus, performance theories that make strong claims about early competence seem unlikely.

It should be noted, though, that a strong commitment to early RTM competence is not a necessary feature of a performance account. The only necessary hypotheses are that the neural substrates of RC-EF are dissociable from the neural substrates of RTM reasoning, and that the distinct RC-EF networks are recruited alongside RTM networks when there are executive demands associated with RTM task performance. There is now some evidence that these hypotheses are supported, at least for adults. Saxe, Schulz, and Jiang (2006) compared the neural systems recruited during a location change false-belief task with those recruited during a task that involved the same sorts of executive demands as a typical false-belief task, but no mental state reasoning. Results indicated that brain regions associated with domain-general attention, response selection, and inhibitory control were activated during both the control and false-belief conditions. However, one additional brain region—the right temporo-parietal junction—was exclusively recruited during the false-belief condition. These findings lend support to the performance accounts' assertion that standard false-belief tasks recruit domain general RC-EF neural networks, in addition to more specific "mentalizing" brain regions (e.g., the right temporo-parietal junction).

From a developmental perspective, both versions of the performance account are generally in line with studies showing a specific, concurrent relation between RTM and RC-EF. It is worth noting, though, that the evidence is now tilting towards the notion that overcoming the true-belief bias may represent the more important contribution of RC-EF to RTM development, as opposed to negotiating superficial task demands. First, if RC-EF was critical for negotiating superficial task demands, there should be a relation between RC-EF and performance on the false photograph task; however, as reviewed above, no research has detected such a relation. Second, RC-EF also predicts performance on false-belief "explanation" tasks in which children are asked to explain the behavior of a story character who acts in accordance with a false belief. This task is intriguing because children still presumably have to overcome the true-belief bias, but they do not need to suppress a prepotent motor response (e.g., Perner & Lang, 1999; Perner et al., 2002). Finally, a meta-analysis by Wellman, Cross, and Watson (2001) showed that even in false-belief tasks that were modified with the goal of lowering the executive response demands, young preschoolers did not demonstrate an explicit, systematic (i.e., responding different from chance) understanding of RTM. Taken together, these findings support the notion that RC-EF may be required to help children overcome a true-belief bias as they engage in RTM reasoning.

These performance accounts, and in particular the “true-belief bias” account, provide a compelling explanation for why there is a specific, concurrent relation between RC-EF and RTM reasoning. Moreover, they can account for the cross-cultural and clinical data through the proposal that RC-EF and RTM are essentially separate; although RC-EF is necessary for RTM reasoning in everyday settings, some other developments are necessary to render specific RTM computations. However, the performance account does not provide an easy explanation for the longitudinal data. That is, no performance account would predict the apparent unidirectional, intrinsic relation between RC-EF and RTM; if RC-EF is solely enabling children to reveal the extent of their RTM knowledge on RTM tasks, then there is no a priori reason to expect a predictive, intrinsic relationship between preschoolers’ early RC-EF and their later RTM after taking relevant controls into account.

Shared Metacognitive Processes. The Performance Accounts posit that RC-EF and RTM are related because RTM tasks make RC-EF demands. Another possibility is that RC-EF and RTM tasks might each require some general metacognitive capabilities, which themselves rely on common neural substrates in the MPFC. Although this suggestion may seem counterintuitive, given the very different seeming functions of RTM and RC-EF, consider the problem posed by RC-EF tasks. In a typical RC-EF task, children are faced with two active representations of competing responses and have to decide which one is most appropriate. On some level, the decision-making process may invoke metacognitive processes for explicitly representing both competing response options and evaluating which one is most appropriate. Perner (1998) has suggested that these metacognitive processes might have a lot in common with those that are required to engage in RTM reasoning (see also Zelazo, 2004).

This view fits together well with a hypothesis offered by Gallagher and Frith (2003) regarding the role of MPFC in RTM reasoning. Based on their review of a wide-range of adult studies on medial frontal contributions to mental state reasoning, they suggested that this region might be involved in “decoupling” mental states from the reality they represent (Leslie, 1987). One possibility is that decoupling is a metacognitive ability to explicitly separate mental states from reality and then evaluate those mental states with respect to a given task context. When put in this way, one might argue that decoupling is involved in both RTM tasks and RC-EF tasks. A similar idea was put forth by Sommer and colleagues (Sommer et al., 2007), who suggested that regions of the ACC may be involved in cognitive processing that is detached from information in the immediate sensory environment. It seems reasonable that decoupling may be necessary for this process of disengaging oneself from the immediate sensory input to focus on internal mental representations.

From a neural perspective, this account makes a slightly different prediction from the performance accounts described above. Specifically, decoupling may be one computation that is shared by RC-EF and RTM tasks. If we make the assumption that this decoupling mechanism has a single neural substrate which is commonly recruited across task contexts, then we might assume that the neural bases of RTM and RC-EF would be partially overlapping. A decoupling mechanism would be only one overlapping part of the otherwise separable neurocognitive systems that underlie EF and RTM.

In some ways, this explanation bears similarities to the cortical neighbor hypothesis in how they account for all three aspects of the RC-EF–RTM relation. The main difference is that, whereas the cortical neighbor hypothesis stipulates two independent neural circuits that rely on common endogenous factors, the common computation hypothesis stipulates a partially overlapping cortical region that can provide the basis for shared variance between the two tasks. Like the cortical neighbor hypothesis, then, this account provides a reasonable explanation for the specific, concurrent relation between RC-EF and RTM, and also for the cross-cultural and clinical data. Specifically, RC-EF and RTM may share variance as a result of a shared metacognitive process, but across populations the individual trajectories of RC-EF and RTM development could vary as a function of other domain-specific influencing factors.

Conversely, it is less clear that this account is compatible with the longitudinal, unidirectional relation between RC-EF and RTM. There does not seem to be any reason that this common computation account would predict advances in RC-EF skills to be related to the later (and not simply concurrent) development of RTM skills.

The Emergence Hypothesis

Although the common computation hypotheses are perhaps the most commonly proposed explanations for the relation between RC-EF and RTM reasoning, the collection of sometimes incongruent data on the relation between RC-EF and RTM has led some researchers to suggest an alternative "emergence" account. The emergence account asserts that RC-EF may actually facilitate the development of RTM concepts through the preschool years (Moses, 2001). Though there may be nontrivial RC-EF demands inherent to RTM reasoning, the emergence account suggests that these demands are not the primary cause of the ontogenetic relation between RC-EF and RTM task performance. Instead, the hypothesis is that RTM knowledge develops over time, and RC-EF skills, along with relevant experiential factors, make a significant contribution to that development.

RC-EF may facilitate children's RTM understanding in several ways. First, RC-EF skills may enable children to suppress their own perspectives in order to consider and reflect upon the mental states of others (Carlson & Moses, 2001). Second, having advanced RC-EF may enable children to competently engage in social interactions that, in turn, provide them with experiences relevant to furthering their RTM knowledge (Flynn, 2007; Hughes, 1998). Third, having the ability to ignore irrelevant stimuli may increase children's capacity to use information from both discourse with others and experience observing others' actions to develop the understanding that beliefs are sometimes false (Moses & Sabbagh, 2007). Finally, acquiring conceptual information that beliefs can be subjective and false may be particularly difficult because beliefs are meant to be true. Just as overcoming the "true-belief bias" may be important for reasoning about well-established belief concepts, it could be that overcoming the true-belief bias is particularly important for even acquiring the concept that beliefs can be false. Each of these provide a potential mechanism by which RC-EF might support the conceptual developments associated with RTM reasoning.

Perhaps more than any other account, the emergence account emphasizes the interaction between endogenous and exogenous (experiential) factors in shaping the developmental timetable of RTM reasoning. The straightforward prediction from the emergence hypothesis is that RC-EF may mediate the influence of the exogenous factors on the development of RTM skills. Thus, early maturation of the neural systems associated with RC-EF should predict later RTM performance and related neural substrates, while the reverse should not hold true. Possibly the most striking prediction from this account is that relevant experiential factors (e.g., parental use of mental state terms and number of older siblings in the home) may affect the development of brain regions associated with RTM skills, with RC-EF maturation acting as a rate-limiting factor on that developmental pathway. Although theoretical models regarding how experience affects the neural substrates of high-level cognitive activity are only emerging (see Quartz & Sejnowski, 1997), a burgeoning body of research findings have clearly demonstrated the effects of experience on the neural substrates of both perceptual and conceptual developments (e.g., Neville, 2006; Maguire et al., 2003).

The emergence hypothesis offers a plausible explanation for many of the reported characteristics of the relation between RTM and RC-EF. Most notably, the emergence account is the only account that straightforwardly explains the findings from longitudinal studies showing that RC-EF skills are unidirectionally predictive of later RTM skills. If RTM skills develop as a function of the interaction between RC-EF and experience over time, then we would expect early RC-EF abilities to predict variance in the subsequent development of RTM.

This account also provides some insight into the results suggesting that RC-EF is necessary but not sufficient for RTM understanding. According to this theory, RC-EF abilities enable children to capitalize on the types of experiences that provide them with information on others' mental states, thus fostering the development of a RTM. With respect to the cross-cultural findings, while the Chinese and Korean preschoolers were advanced in RC-EF, it may be that they had less exposure to the kinds of experiences that facilitate RTM development. In the case of the Chinese preschoolers, there is evidence to suggest that there are indeed substantial cultural differences in exposure to experiential factors that are related to RTM. For instance, when preschoolers have older siblings, they show adult-like performance on RTM tasks sooner than preschoolers who are the oldest child in the home (e.g., Ruffman, Perner, Naito, Parkin, & Clements, 1998). Because the Chinese government enforces a law that prohibits more than one child per household, Chinese children will likely not benefit from whatever advantages having older siblings confides. It is thus possible that the advantages afforded to Chinese children as a result of superior RC-EF abilities are offset by their relatively limited exposure to important experiential factors.

SUMMARY

We started with the notion that we might gain insight into the neurodevelopmental factors that affect RTM reasoning through a detailed analysis of the relation between RTM reasoning and children's developing RC-EF skills. To this end, we evaluated several hypotheses from the extant literature that have been marshaled to explain the relation between RC-EF and RTM reasoning, and explored their implications for understanding the neurodevelopmental bases of RTM. We would like to conclude by suggesting that although each of the hypotheses has been presented and evaluated separately, we do not have any strong reason to think that they would be mutually exclusive. For instance, it does seem clear that RTM tasks have nontrivial RC-EF demands, and although we do not feel that this captures the cause for the relation between RC-EF and RTM, it might be a mistake to suggest that negotiating these task demands plays no role. Further, it is possible that each of the explanatory hypotheses we offered may capture different aspects of the developmental process. These are important questions for future discussion.

Finally, we would like to note that a common thread that runs through the majority of these accounts of the relation between RC-EF and RTM reasoning is a role for experiential factors. In many cases, the neurodevelopmental implications of the relation between RC-EF and RTM pointed to the interplay of both endogenous neuromaturational factors and exogenous experiential factors. We feel that understanding the interaction between endogenous and exogenous factors in RTM development is perhaps the most promising and exciting avenue for future research in this area.

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