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Rachelle H. Cantin
Illinois State University

Emily K. Gnaedinger
Illinois State University

Kristin C. Gallaway
Illinois State University

Matthew S. Hesson-McInnis
Illinois State University

Alycia M. Hund
Illinois State University

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Executive Functioning Predicts Reading, Mathematics, and Theory of Mind During the Elementary Years

Rachelle H. Cantin, Emily K. Gnaedinger, Kristin C. Gallaway,

Matthew S. Hesson-McInnis, & Alycia M. Hund

Illinois State University

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Abstract

The goal of this study was to specify how executive functioning components predict reading, mathematics, and theory of mind performance during the elementary years. Ninety-three 7- to 10-year-old children completed measures of working memory, inhibition, flexibility, reading, mathematics, and theory of mind. Path analysis revealed that all three executive functioning components (working memory, inhibition, and flexibility) mediated age differences in reading comprehension, whereas age predicted mathematics and theory of mind directly. In addition, reading mediated the influence of executive functioning components on mathematics and theory of mind, except that flexibility also predicted mathematics directly. These findings provide important details about the development of executive functioning, reading, mathematics, and theory of mind during the elementary years.

Keywords: executive functioning, reading, mathematics, theory of mind, working memory, inhibition, flexibility, middle childhood

Executive Functioning Predicts Reading, Mathematics, and Theory of Mind During the Elementary Years

Executive functioning is an umbrella term used to describe the cognitive processes responsible for purposeful, goal-directed behavior (Best & Miller, 2010; Carlson, Zelazo, & Faja, 2013; Müller & Kerns, 2015). Research and practice have provided evidence linking executive functioning with academic and social success, including theory of mind (e.g., Best, Miller, & Jones, 2009). To date, executive functioning and theory of mind research has disproportionately concentrated on the preschool years, demonstrating both robust individual differences and remarkable developmental gains during these early years (Carlson, 2005; Devine & Hughes, 2014; Garon, Bryson, & Smith, 2008; Hughes, 2011; Liu, Wellman, Tardif, & Sabbagh, 2008; Wellman, Cross, & Watson, 2001). Even so, there is a major gap in our understanding of executive functioning and theory of mind beyond age 5 years, as well as the mechanisms by which executive functioning predicts academic and social success across domains and age groups (Best & Miller, 2010; Best et al., 2009; Zelazo & Carlson, 2013). The goal of this study was to specify how executive functioning components predict reading, mathematics, and theory of mind performance during the elementary years. These domains were chosen given their importance for success in school and life (e.g., Best et al., 2009; Miller, 2009).

Despite ongoing debate regarding the core features of executive functioning, there is widespread agreement that executive functioning includes three distinct, yet overlapping, components—working memory, inhibition, and flexibility—during adulthood (Miyake et al., 2000). Recently, developmental scientists have extended this work, demonstrating the utility of similar three-component models during middle childhood (Brocki & Brohlin, 2004; Huizinga, Dolan, & van der Molen, 2006; Lee, Bull, & Ho, 2013; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Rose, Feldman, & Jankowski, 2011). Ongoing research probes the utility of these models during the preschool years (Hughes, Ensor, Wilson, & Graham, 2010; Wiebe, Espy, & Charak, 2008; Wiebe et al., 2011; Willoughby, Wirth, & Blair, 2011), leading some scientists to conclude that executive functioning begins as a unitary construct that becomes more differentiated across childhood (Garon et al., 2008; Lee et al., 2013).

This project focused on working memory, inhibition, and flexibility as three distinct, yet related executive functioning components. Working memory is the capacity to retain and manipulate information during a short period of time (Schneider & Bjorklund, 2003). Inhibition involves the capacity to delay prepotent responses, to interrupt ongoing responses when given feedback about performance, and to inhibit responding to sources of interference when engaged in tasks requiring self-regulation and goal-directed behavior (Barkley, 1999). Flexibility refers to the ability to switch fluidly between activities and adapt in the presence of new or changing information (Bock, Gallaway, & Hund, 2015). We know that all three components evince developmental gains extending to the elementary years (Anderson, 2002; Bock et al., 2015; Lee et al., 2013; Prencipe et al., 2011; Schneider & Bjorklund, 2003).

Reading comprehension involves constructing meaning from text. Comprehension depends on some degree of mastery of phonemic awareness, phonics, vocabulary, and fluency as readers seek to understand words, sentences, paragraphs, and entire text passages. We know that executive functioning predicts gains in literacy and reading during the preschool and elementary school years (Altemeier, Abbott, & Berninger, 2008; Carretti, Borella, Cornoldi, & De Beni, 2009; Locascio, Mahone, Eason, & Cutting, 2010; Sesma, Mahone, Levine, Eason, & Cutting, 2009). Conversely, deficits in executive functioning are evident in children who struggle with reading (Cain, 2006; Cutting, Materek, Cole, Levine, & Mahone, 2009; Gioia, Isquith, Kenworthy, & Barton, 2002). For instance, working memory is positively related to reading (and math) performance during preschool and early elementary school (Bull, Espy, & Wiebe, 2008; Gathercole & Pickering, 2000; Lan, Legare, Ponitz, Li, & Morrison, 2011; Swanson, 1994; Swanson & Jerman, 2007; van der Sluis, de Jong, & van der Leij, 2007; Welsch, Nix, Blair, Bierman, & Nelson, 2010; Willoughby et al., 2012). It is likely that working memory supports reading success by allowing children to hold in mind the multitude of words, concepts, and themes necessary to comprehend texts.

Similarly, flexibility is related to reading comprehension during the elementary school years (Cartwright, 2002; Cartwright, Marshall, Dandy, & Isaac, 2010; Colé, Duncan, & Blaye, 2014; Gaskins, 2008; van der Sluis et al., 2007; Yeniad, Malda, Mesman, van IJzendoorn, & Pieper, 2013). For example, Cartwright (2002) found that reading-specific flexibility contributed to reading comprehension even after controlling for age, domain-general shifting performance, decoding skill, and verbal ability. Moreover, Cartwright (2002, 2006) demonstrated that training of reading-specific flexibility skills resulted in gains in reading comprehension. Flexibility is important for reading because it allows readers to make use of multiple features, especially orthographic, phonological, and semantic information, that support successful comprehension (Cartwright, 2002; Colé et al., 2014). Although there is some research linking inhibition and reading comprehension (Altemeier et al., 2008; Borella, Carretti, & Pelegrina, 2010; Cain, 2006), more work is needed in this area. Perhaps inhibition is linked with reading comprehension through overriding irrelevant concepts and thereby focusing more precisely on comprehending the passage at hand. In fact, Cain (2006) found that poor comprehenders were more likely than good comprehenders to recall items that should have been inhibited because they were no longer relevant. Additional research is needed to clarify the links between all three executive functioning components and reading comprehension.

Mathematics is another central tenet of academic curriculum that is necessary for many everyday tasks. Several cognitive processes, such as working memory, processing speed, phonological processing, attention, and long-term memory, support arithmetic ability (Fuchs et al., 2006). Executive functioning during the preschool years is a powerful predictor of mathematics performance during the elementary years (Welsch et al., 2010). For example, one recent longitudinal study found that executive functioning at 4 years predicted mathematics achievement at 6 years. This finding persisted even after controlling for individual differences in cognitive ability and reading achievement (Clark, Pritchard, & Woodward, 2010). Research evidence provides widespread support for a strong link between working memory and arithmetic success (Bull & Lee, 2014; Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007; Lan et al., 2011; Lee, Ng, & Ng, 2009; McLean & Hitch, 1999; Passolunghi & Cornoldi, 2008; St. Clair-Thompson & Gathercole, 2006; Swanson, 1994; Swanson & Sachse-Lee, 2001; van der Sluis et al., 2007; Welsch et al., 2010). Andersson (2007) found that elementary school students' working memory skills substantially contributed to their math problem-solving abilities. Similarly, lower working memory is associated with poorer mathematics performance (Alloway, 2009; Bull & Scerif, 2001). Why is working memory vital for mathematics success? According to Swanson and Kim (2007), children with greater working memory capacity have more cognitive resources available for storage and maintenance of information while carrying out computations and solving math problems.

Inhibition also has been implicated in mathematics performance, though the evidence is somewhat mixed (Bull & Lee, 2014; St. Clair-Thompson & Gathercole, 2006). For instance, research shows that children with poor inhibition demonstrate lower mathematics ability (Bull & Scerif, 2001). In contrast, Lee et al. (2012) found that only working memory, not a combined inhibition/flexibility factor, predicted mathematics achievement. Monette, Bigras, and Guay (2011) suggest that the links between inhibition and mathematics evident in past studies were the result of measurement issues, especially the omission of working memory measures. Similarly, Bull and Lee (2014) note that links disappear when reading and IQ are taken into account. Nonetheless, it is important to consider whether inhibition is related to mathematics, perhaps helping children suppress ineffective strategies or misconceptions. For example, children must suppress details about larger numbers indicating larger quantities (which is true for whole numbers) when attempting to understand fractions, where larger denominators represent smaller quantities. Inhibition also may be important for ignoring irrelevant details in story problems and for suppressing the tendency to work from left to right and instead follow the order of operations. Bull and Lee (2014) claim that evidence linking flexibility and mathematics is lacking, though a recent meta-analysis revealed significant links between flexibility and math (Yeniad et al., 2013). It is possible that flexibility supports math problem solving by enabling children to focus on divergent strategies, problem-solving goals, and computation operations needed. For example, both multiplication and subtraction are needed to solve long division problems using traditional strategies. Overall, additional research is needed to clarify the extent to which all three executive functioning components relate to mathematics performance.

Theory of mind is the ability to understand mental states, such as thoughts, desires, beliefs, and emotions, in ourselves and others. It improves dramatically during early childhood (Frye, Zelazo, & Palfai, 1995; Hughes, 1998; Wellman & Liu, 2004) and shows continued improvement throughout the elementary years and beyond (Apperly, Warren, Andrews, Grant, &

Todd, 2011; Bock et al., 2015; Miller, 2009, 2012; White, Hill, Happé, & Frith, 2009). For instance, children show increased abilities to detect and understand subtleties in conversations and social interactions, such as irony, sarcasm, and figures of speech across the elementary years (Devine & Hughes, 2013; Filippova & Astington, 2008; Happé, 1994). We know that theory of mind is related to social-emotional competence, and it may mediate the relation between executive functioning and social skills (e.g., Riggs et al., 2006b; Watson, Nixon, Wilson, & Capage, 1999). Many researchers have shown that executive functioning is related to theory of mind during their emergence in early childhood (Carlson, Claxton, & Moses, 2015; Carlson & Moses, 2001; Devine & Hughes, 2014; Frye et al., 1995; Hughes & Ensor, 2007; Hughes & Graham, 2002; Oh & Lewis, 2008; Sabbagh, Xu, Carlson, Moses, & Lee, 2006). These researchers have suggested that the links between executive functioning and theory of mind emerge because understanding mental states requires holding multiple perspectives or potential realities in mind, switching adeptly between them, and overriding appearances and one's own perspectives to understand other people's perspectives, including false beliefs. Moreover, theory of mind supports social competence, including emotion regulation, play, positive social skills, competent peer interactions, and laudable classroom behavior (Riggs et al., 2006b). Recently, Bock et al. (2015) demonstrated that flexibility predicted social understanding during the elementary years. Nonetheless, additional research is needed to assess the relation between executive functioning components and theory of mind during the elementary years, as well as to specify the developmental trajectory. These findings will provide important details with the potential to shed light on the etiology of competent social skills, including emotion regulation, positive peer interactions, and successful classroom behavior.

Our goal was to specify how executive functioning components predict reading, mathematics, and theory of mind performance during the elementary years. Including all three executive functioning components along with multiple indicators of academic and social understanding is important for gleaning a more complete understanding of the interrelation among domains. We know that schooling is an important aspect of middle childhood development, and that success in school depends on academic achievement, social and emotional functioning, and self-control, among many factors. Understanding how three executive functioning components—working memory, inhibition, and flexibility—relate to reading and mathematics achievement and theory of mind thereby provide important details about developmental mechanisms, which may have valuable theoretical implications for increased understanding and practical implications that support success in school, which includes academic and social-emotional functioning (Best et al., 2009; Liew, 2012). Toward that end, 7- to 10-year-old children completed a battery of age-appropriate tasks that assessed working memory, inhibition, flexibility, reading comprehension, mathematics, and social understanding. We predicted that age would predict all three executive functioning components, which would predict reading, mathematics, and theory of mind performance during the elementary years. These findings would clarify developmental aspects of the relations between executive functioning, academic achievement, and social understanding during the elementary school years.

Method

Participants

Ninety-three 7- to 10-year-old children (45 boys, 48 girls, M = 9 years 0 months, SD = 13.88 months) participated. Participants were recruited from a child research participant database maintained by the Department of Psychology at a large state university in the Midwestern United States. The sample was mostly White and middle class (race/ethnicity: 81% White, 3% Asian, 2% Hispanic, 1% Black, 12% Other, and 1% did not respond; mother's education: 7% had obtained a high school diploma (finished Grade 12), 4% had obtained an associate's degree (typically 2 years beyond high school), 53% had obtained a bachelor's degree (typically 4 years beyond high school), 25% had obtained a Master's degree (typically 2 years beyond a bachelor's degree), 10% had obtained a doctoral or professional degree (typically 4 or more years beyond a bachelor's degree), 1% did not respond; family income: 22% of families earned less than US$20,999, 52% of families earned between US$21,000 and US$99,999, 20% of families earned more than US$100,000, and 6% did not respond). Children's matrix reasoning scores were in the average range (see Table 1). Data from three additional participants were omitted due to examiner error. Children received a small gift at each session, and parents were reimbursed for parking expenses.

Procedure

This project was approved by the university Institutional Review Board. Parents provided written permission, and children provided assent prior to participation. Children completed a battery of tasks to assess executive functioning components (working memory, inhibition, flexibility), reading comprehension, mathematics, theory of mind, and matrix reasoning at our campus laboratory during two sessions.

Working Memory. Participants completed the Digit Span subtest from the *Wechsler Intelligence Scale for Children—Fourth Edition (WISC-IV*, Wechsler, 2003*).* Children were asked to repeat sequences of numbers in forward and backward order, and the lists grew longer if they responded correctly. The task was administered and scored according to the procedures outlined in the *WISC-IV* manual. Raw total digit span scores, which combine details from performance on the forward and backward tasks, were used in analyses. Higher scores indicate greater working memory.

Inhibition. Participants completed a Color Word Stroop task in which they viewed two lists of 25 color words and were asked to say the color of ink for each word. In the congruent list, the color of the ink was the same as the word. In the incongruent list, the color of the ink was different from the word. The time it took to read each list was recorded live by the researcher. The incongruent time was used as our measure of inhibition. For modeling purposes, scores were reversed so that higher scores indicated greater inhibition.

Flexibility. Participants completed a modified Dimensional Change Card Sorting (DCCS) task designed for elementary aged children in which they sorted cards facedown into three trays based on specified dimensional rules (Bock et al., 2015; Cragg & Chevalier, 2012). Trays and cards were presented in a different random order for each participant. The researcher first described each sorting tray marked with two yellow triangles, four red squares, and six blue circles. The sorting cards differed on three dimensions (number: 2, 4, or 6 items; shape: triangles, squares, or circles; and color: yellow, red, or blue) such that no cards were identical to the tray markings, and equal numbers of cards belonged in each tray. There were three training trials (one demonstration then sorting with feedback), six Pre-switch trials (first rule), six Post-switch I trials (second rule), and six Post-switch II trials (third rule), three Border training trials (demonstrations), and 12 Border trials (mixed block using all three rules depending on card border). No feedback was provided during test trials. The order of sorting rules was counterbalanced across participants. The researcher introduced a new sorting rule at the beginning of each trial block and described each tray based on the specific dimensional rule prior to each trial "(Red ones go here…"). Then, the researcher introduced the card (e.g., "This card is blue, where would it go?"). The border phase was a mixed block in which solid borders, dashed borders, and no borders were used to indicate which sorting rule should be utilized. Sorting rules were counterbalanced. The researcher reminded participants of the border rules prior to each trial and noted the particular border when presenting the card. Sorting performance was coded from video recordings. Accuracy (number correct out of 12 trials) during the border phase was analyzed here. Higher scores indicated greater flexibility. Mean accuracy ranged from 8.23 to 10.46 out of 12 for each grade, demonstrating that interpretation of the results from our modified task was not limited by ceiling effects. Inter-rater reliability was assessed by independently coding responses from 11 participants via video recordings, yielding an intraclass correlation coefficient of 1.0.

Reading Comprehension. The reading comprehension subtest from the *Wechsler Individual Achievement Test – Third Edition* (*WIAT-III,* Wechsler, 2009) was used to measure reading comprehension. A trained researcher administered the subtest according to standard protocol. Participants read passages based on grade level, and the researcher read the comprehension questions after each passage. Responses were provided orally and were recorded and scored based on standard scoring procedures. Raw scores were converted to proportions based on the total number of possible points at each grade level. Higher scores indicated higher reading comprehension levels.

Mathematics Performance. Three subtests from the *WIAT-III* were administered to assess mathematics performance (i.e., Math Problem Solving, Numerical Operations, Math Fluency; Wechsler, 2009). Math Problem Solving assessed four domains: basic concepts, everyday applications, geometry, and algebra. Numerical Operations was administered to assess math calculation skills in the following domains: basic skills, basic operations with integers, geometry, algebra, and calculus. Math Fluency assessed speed of computation. Administration and scoring were based on standard procedures outlined in the *WIAT-III* manual. We planned to combine math scores into one composite for parsimony, given we were interested in math, reading, and theory of mind. Exploratory factor analysis yielded one factor that included all three math subtests. Z-scores of the raw scores from all three subtests were combined to create a math composite score with good internal consistency (Cronbach's alpha = .85). Higher scores indicated better math performance.

Theory of Mind. To measure social understanding, participants listened as the researcher read seven vignettes that were presented in a specified random order: pretend, white lie, joke, irony, figure of speech, lie, and double bluff. The eighth vignette was a control story that described physical causes for gardening failures (i.e., birds eating seeds before they could grow; (Bock et al., 2015; adapted from Strange Stories, Happé, 1994). Children's responses to this vignette were used to ensure that they understood the question and answer format described below. All children responded correctly to the control story, indicating they understood the task format. Each printed vignette was accompanied by a simple line drawing depicting the main details. A comprehension question was included at the end of each story ("Is it true what X says?"). Next, a justification question was asked ("Why does X say this?"), and participants' responses were recorded. Justifications for social stories were considered correct if children referred to mental states, yielding 7 points possible. Higher scores indicated better social understanding. Inter-rater reliability for 18 participants yielded an intraclass correlation of .97.

Matrix Reasoning. The Matrix Reasoning subtest from the *WISC-IV* was used to describe the sample (Wechsler, 2003). Participants viewed colored matrices or visual patterns that had one stimulus missing and were asked to select the missing stimulus from a range of options. Administration and scoring were based on standard procedures from the *WISC-IV* manual. Raw scores can be seen in Table 1.

Results and Discussion

Descriptive statistics and bivariate correlations for all variables can be seen in Table 1. The goal of this study was to specify how executive functioning components predict reading, mathematics, and theory of mind performance during the elementary years. We used path analysis. Although many path analysis studies use much larger samples, our sample of 87 participants (with complete data) represents a reasonable ratio of participants to estimated parameters that is within recognized guidelines for a ratio of at least five (but preferably eight to ten) participants per parameter (87 participants and 15 estimated parameters results in a ratio of 5.8 participants per parameter; Bentler & Chou, 1988). We first tested a parsimonious latent path analysis model that included age, executive functioning, and performance (i.e., academic/social outcomes, see Figure 1). Although including a combined performance variable may be uncommon, it is consistent with contemporary views that recognize the importance of academic and social indicators of school success (e.g., Blair, 2002; Zins, Bloodworth, Weissberg, & Walberg, 2004). We chose not to include matrix reasoning scores in the model because we were more interested in age as a developmental variable, and age and matrix reasoning scores were highly correlated. As such, we preferred the parsimony of including age, not matrix reasoning, in the model. A variety of indicators suggested that this model was a poor fit for our data: The likelihood ratio χ^2 test statistic was substantial, χ^2 (13, n = 87) = 33.94. Further, the Root-Mean-Square-Error-of-Approximation (RMSEA) was .27; the Normed Fit Index (NFI) was .53; the Non-Normed Fit Index (NNFI) was .34, the Comparative Fit Index (CFI) was .59; and the S-

RMR was .15, all of which suggest a poor fit between the model and data (Browne & Cudeck, 1993; Hu & Bentler, 1999). In contrast to the overall fit, however, individual component fit was excellent in that the model accounted for 88% of the variance in the executive functioning latent variable and accounted for 98% of the variance in the performance latent variable. As can be seen in Figure 1, the standardized path coefficient from age to executive functioning was 0.94 and from executive functioning to performance was 0.99, suggesting the connections between these constructs was strong and unequivocal. The lack of overall fit, however, suggests that the correlations between the observed measures were not consistent enough to be explained by a single latent variable for executive functioning and a single latent variable for performance and may require a more nuanced model to explain unique effects of various pairs of specific executive functioning indicators with specific performance indicators. Next, we tested a model that included age, executive functioning, and three separate outcome measures (i.e., mathematics performance, reading comprehension, theory of mind). Again, a variety of indicators suggested that this model exhibited fairly poor overall fit to the data: χ^2 (14, n = 87) = 33.97; RMSEA = .26; the NFI = .53; the NNFI = .42, the CFI = .61; and the S-RMR = .15 (Browne & Cudeck, 1993; Hu & Bentler, 1999).

Given the results from our initial models, we then tested models that treated executive functioning indicators and performance indicators as separate constructs using path analysis without latent variables to explore the unique connections between specific aspects of executive functioning and performance. The final model is depicted in Figure 2. This model fits quite well according to a multitude of criteria. The likelihood ratio χ^2 test statistic was small, χ^2 (8, n = 87) = 7.45. We also considered the RMSEA to test approximate fit (Browne & Cudeck, 1993). Our model produced a RMSEA of .07, providing further evidence for the fit. The NFI was .90, and the NNFI value was 1.03, supporting our conclusion of a good fit (Hu & Bentler, 1999). The S-RMR was .05. Additionally, the CFI value of 1.00 was very high (Hu & Bentler, 1999). Together, these statistics provided strong evidence that this model fit the data well. It is tempting to examine each path coefficient in the model to determine the significance of each parameter estimate, but doing so is problematic. Instead, we calculated the t-value as the ratio of each parameter to its estimated standard error to provide a descriptive framework for assessing the relative size of each parameter estimate, noting the absolute value of these t-ratios with asterisks in the path diagram.

Overall, our findings provide support for four conclusions. First, it is important to point out that the latent models did not fit our data well, whereas our final model included working memory, inhibition, and flexibility as three separate, yet related, executive functioning components fit our data. The balance of unity and diversity in executive functioning components is debated among developmental scientists. Most research findings suggest that the three executive functioning components are unique but interrelated by middle childhood (Brocki & Brohlin, 2004; Huizinga et al., 2006; Lehto et al., 2003; Rose et al., 2011). Our findings lend further support for this notion.

Second, all three executive functioning components mediated age differences in reading comprehension. These findings are consistent with a growing body of literature demonstrating tight links between executive functioning and reading comprehension (e.g., Carretti et al., 2009; Locascio et al., 2010; Sesma et al., 2009). Importantly, our findings demonstrated links not only for working memory (Gathercole & Pickering, 2000; Lan et al., 2011; Swanson & Jerman, 2007; van der Sluis et al., 2007; Welsch et al., 2010; Willoughby et al., 2012) and flexibility (Cartwright, 2002; Cartwright et al., 2010; Gaskins, 2008; van der Sluis et al., 2007), but also for inhibition (Borella et al., 2010). This demonstrated link between inhibition and reading comprehension is an important extension of the literature and lends further support for research and practice linking all three executive functioning components with successful reading comprehension.

Third, age directly predicted mathematics and theory of mind performance in our final model. Strong developmental gains in mathematics performance are widely supported in the literature (e.g., Aunola, Leskinen, Lerkkanen, & Nurmi, 204; Crosnoe et al., 2010). Developmental gains in social understanding during the elementary years also are consistent with previous findings (Bock et al., 2015; Filippova & Astington, 2008; Miller, 2009, 2012), though this literature is small, so our replication is helpful, as it sets the stage for additional research and practice (Lecce et al., 2014; White et al., 2009). Together, these findings are important for understanding the development of academic and social skills, including theory of mind, during middle childhood. As such, these findings add important details about developmental trajectories and relations and set the stage for practical applications aimed at improving academic and social aspects of school success.

Fourth, reading mediated the influence of executive functioning components on mathematics and theory of mind performance, except that flexibility also predicted mathematics performance directly. It is possible that the symbolic demands and the construction of meaning necessary for reading also are important for mathematics and theory of mind understanding (e.g., Kintsch, 1988; Rousselle & Noël, 2007). Moreover, the reading effects may stem, in part, from the heavy verbal and print-based nature of testing in middle childhood (e.g., math story problems; complex scenarios about irony, sarcasm, etc. in our theory of mind measure). Links between reading and mathematics are commonly demonstrated in the literature (e.g., Clark et al., 2010; Rousselle & Noël, 2007; Swanson, 2006), so our findings are consistent in that regard. We know that links between language and theory of mind are important (Astington & Baird, 2005; Astington & Jenkins, 1999), so our findings involving reading are consistent with the literature in that regard. Our work suggests that it is helpful not only to examine multiple executive functioning components in a single study, but also to include a variety of outcome measures, including multiple indicators of academic and social success (e.g., Best et al., 2009; Liew, 2012). It is possible that the full complexity of interrelations between factors is only beginning to be understood, but our work suggests that reading plays an important role. One novel aspect of the present findings is the direct link between flexibility and mathematics performance, which contrasts with previous evidence noting no clear links between these domains (Bull & Lee, 2014). Given emerging science demonstrating links between flexibility and reading, mathematics, and social understanding here and in recent studies (e.g., Bock et al., 2015; Yeniad et al., 2013), further research is warranted to replicate the findings and to provide clear explanations for the overall pattern of results. A clear focus on flexibility is needed; however, it is important to include measures of all three executive functioning components to provide specific details about unique links with different domains of academic and social success.

Although the present results are promising, this study has several limitations that must be noted. One major limitation was the relatively small sample size. In addition, the sample was demographically homogeneous and relatively low risk. Therefore, future research should attempt to include a larger sample that is more diverse with regard to race/ethnicity, maternal education, and household income, among other factors. Another limitation involved measurement issues. Whenever studying executive functioning, it is always a challenge to isolate the components to study them independently, a challenge often referred to as task impurity (Best & Miller, 2010).

This project included a small subset of age-appropriate tasks, but a larger battery of executive functioning tasks would be helpful in future projects. Including additional measures of academic functioning, perhaps incorporating curriculum-based measures, and of theory of mind also would be helpful. Our limited set of measures meant that path analysis was utilized rather than structure equation modeling, which would be helpful in overcoming limitations due to measurement error. We recognize that ideal path analysis research involves not only testing competing models but also cross-validating the findings with an independently drawn sample. Although we were able to test competing models in this study, an independent sample of elementary children is necessary to confirm the validity of these findings.

In spite of these limitations, the present results add to the literature and have meaningful implications for research and practice. First, our findings extend the sparse literature focusing on the elementary years by demonstrating clear gains in theory of mind and executive functioning from 7 to 11 years. Our findings also are consistent with a growing body of research demonstrating the importance of different aspects of executive functioning for academic and social success (Best et al., 2009; Bull et al., 2008; Clark et al., 2010; Lan et al., 2011; Riggs, Greenberg, Kusche, & Pentz, 2006a). For instance, age differences in reading comprehension were mediated by executive functioning components, implicating all three executive functioning components in reading success during the elementary years. In addition, executive functioning components were important for mathematics and theory of mind, though their influence was mediated by reading. Interestingly, flexibility predicted mathematics directly. These findings highlight the importance of all three executive functioning components and place special emphasis on flexibility in understanding academic and social outcomes. Although we cannot draw causal conclusions from the results of this study, our findings are consistent with the broader literature that supports causal interpretations, especially those that posit that executive functioning is influential for academic and social success (e.g., Best et al., 2009; Blair, 2002; Carlson et al., 2015). As such, it is possible that theory of mind and executive functioning skills could be considered alongside traditional academic domains for screening, curriculum development, and intervention. This approach is consistent with the Multi-Tiered System of Supports movement in education. Although evidence still is emerging regarding effective curricula and techniques to support the development of executive functioning and theory of mind, several recent studies provide promising findings (Diamond, Barnett, Thomas, & Munro, 2007; Kloo & Perner, 2008; Lecce, Bianco, Devine, Hughes, & Banerjee, 2014; Riggs et al., 2006a). Overall, educators should strive to create classroom atmospheres of low stress, high confidence, complex conversations, and social bonding to support executive functioning (Diamond & Lee, 2011), which could also provide positive benefits for social understanding and academic success.

In conclusion, our findings indicate that all three executive functioning components—working memory, inhibition, and flexibility—mediated age differences in reading comprehension, whereas age predicted mathematics and theory of mind performance directly during the elementary years. In addition, reading mediated the influence of executive functioning components on mathematics and theory of mind performance, except that flexibility also predicted mathematics performance directly. Together, these findings provide important details about the development of executive functioning, reading, mathematics, and theory of mind during the elementary years, moving beyond the intense focus on early childhood.

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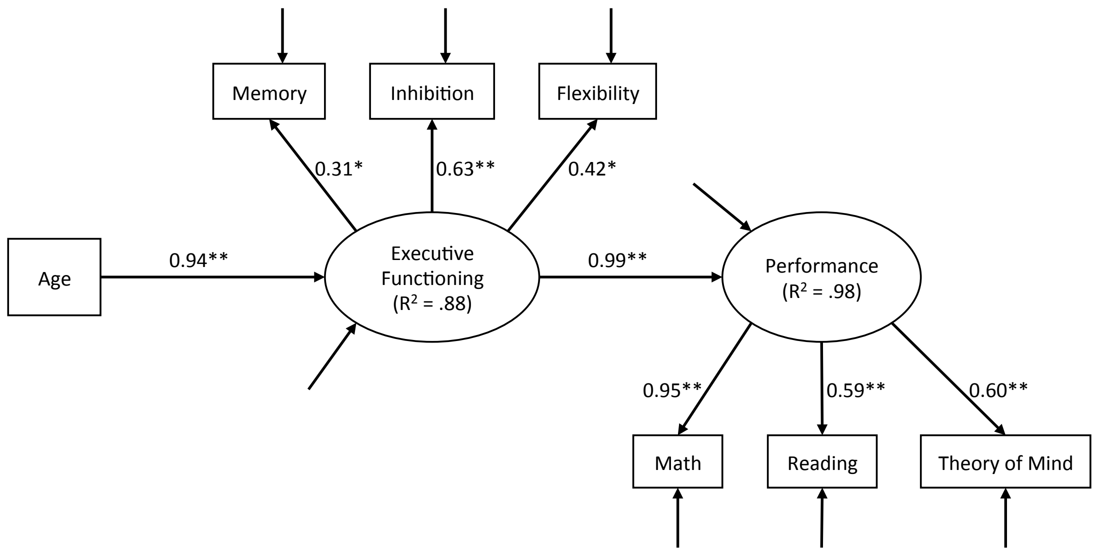
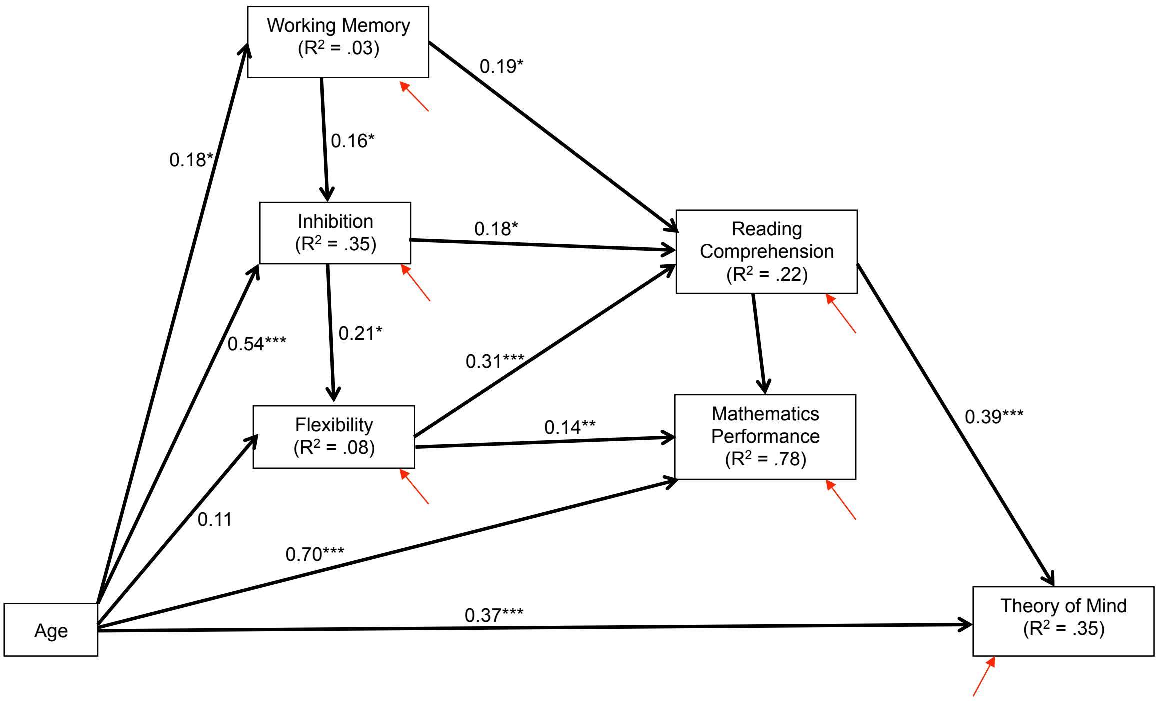
Figure Captions

Figure 1. Path diagram with standardized parameter estimates of the effects of executive functioning on academic/social performance, controlling for age with coefficients of determination for endogenous variables in parentheses. Note that χ^2 (8, N= 87) = 33.94, RMSEA = .27, NFI = .53, NNFI = .34, CFI = .59, and S-RMR = .15.

Figure 2. Path diagram with standardized parameter estimates of the effects of executive functioning on reading, mathematics, and theory of mind performance, controlling for age with coefficients of determination for endogenous variables in parentheses. Note that χ^2 (8, N= 87) = 7.45, RMSEA = .07, NFI = .90, NNFI = 1.03, CFI = 1.00, and S-RMR = .05.


Memory
Inhibition
Flexibility
0.31*
0.63**
0.42*
Age
0.94**
Executive Functioning
(R² = .88)
0.99**
Performance
(R² = .98)
0.95**
0.59**
0.60**
Math
Reading
Theory of Mind


Working Memory
(R^2 = .03)
0.19*
0.16*
0.18*
Inhibition
(R^2 = .35)
0.18*
Reading
Comprehension
(R^2 = .22)
0.54***
0.21*
0.31***
Flexibility
(R^2 = .08)
0.14**
Mathematics
Performance
(R^2 = .78)
0.39***
0.11
0.70***
Age
0.37***
Theory of Mind
(R^2 = .35)