Relations between Executive Functions and different levels of Theory of Mind in children

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Abstract

ToM is a complex cognitive process consisting of a variety of sequenced achievements that develops gradually from infancy to adulthood. In this field, part of the debate focuses on identifying how individual differences influence the development of ToM. Several recent studies have found a relationship between ToM development and executive functioning, emphasizing working memory, inhibition, cognitive flexibility or planning. In line with these results, the aim of this research was to explore the role of different aspects of executive functions in ToM. To achieve this, 90 children aged between 4 and 8 years were assessed in ToM and executive function tasks. We found that executive functions were related to ToM in different ways depending on the level of ToM. This supports the view that as ToM skills evolve there is a change in the executive skills that support them.

Keywords: theory of mind; social cognition; executive functions; children

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Introduction

Research in the field of child development has paid considerable attention to Theory of mind (ToM), a concept that refers to the gradually developing human capacity to understand, predict, attribute and even manipulate our own and others' mental states (Wellman et al. 2011). Within this field, considerable amount of research has suggested a qualitative change in how children understand the mental world between the ages of 3 and 5 (Wellman et al. 2001). During this period, children come to understand the concept of desire and its relationship with emotions and beliefs (Wellman and Banerjee 1991), they start to understand how knowledge is related to visual experience (Wimmer et al. 1988), and to learn that beliefs may be false, which has been called (first-order) false belief understanding (Wellman et al. 2001). At the same time, they become increasingly better at understanding emotions, and begin to realize that external and internal emotions may be different (Harris et al. 1986; Sidera et al. 2013). From the age of 6 years, children start to understand second-order false beliefs (Miller 2009), which are connected to the ability to deceive and the growing capacity to understand non literal expressions such as lies (Talwar and Lee 2008), white lies (Williams et al. 2016) or ironies (Happé 1994). Between the age of 7 and adolescence, the capacity to understand and detect faux-pas will appear (Banerjee et al. 2011), as well as the capacity to recognize other complex mental states through the eyes (Baron-Cohen et al. 2001). Despite a sequence of increasingly difficult ToM milestones having been identified (Wellman et al. 2011), individual differences exist in the developmental patterns in which they are acquired (Repacholi and Slaughter 2003), which indicates that other factors have an influence on their development. This issue, regarding which factors influence ToM skills, has been addressed both in an interindividual and in an intraindividual level. As for the intraindividual level, many studies have tried to elucidate the contribution of other children's skills to understanding the mind, such as language (Astington and

Baird, 2005) or pretend play (Lillard et al. 2013). Among them, executive functions have gained significant attention. Executive functions (henceforth EF) are strongly related to the development of ToM. The term EF refers to a high-order mental process involved in the conscious control of thought, action and emotion (Anderson et al. 2001; Carlson and Moses, 2001; Zelazo and Müller, 2002). Tasks evaluating ToM usually require a high level of executive functioning, as they entail paying attention to and following a story, remembering its key elements, and using these to predict the behavior of the protagonist. Moreover, alternating between different perspectives regarding the same event or reality may be required, as well as inhibiting one's own perspective or knowledge of reality (Carlson et al. 1998; Russell et al. 1991). Evidence in favor of the relation between ToM and EF is robust in preschoolers, with much stronger evidence that EF predicts later ToM than the opposite (Benson et al. 2013; Devine and Hugues 2014; Müller et al. 2012; but see Wade et al. 2018). Furthermore, longitudinal studies found that children's EF predict the development of ToM at different stages in life (Devine et al. 2016), and that the influence of EF on ToM may vary according to age (Gao et al. 2019). Specifically, other studies found that different EF have a main role in predicting ToM depending on age (Wilson et al. 2018). Evidence on the relation between ToM and EF is less conclusive in older children, so EF may become less relevant for ToM once sufficient cognitive skills are developed (Austin et al. 2014; Vilenskaya and Lebedava 2017). There are two possible ways in which EF may have a role in ToM. First, the expression account suggests that EF skills are necessary for passing ToM tasks (Moses 2001; Gao et al. 2019). According to it, ToM performance may be poor despite good ToM competence when the executive demands are too high for the individual. In this sense, lowering the executive demands of ToM tasks may lead to higher levels of achievement in the latter (see Birch and Bloom 2010). Secondly, the emergence account proposes that EF skills are necessary for developing ToM (Moses 2001) by improving the capacity to learn from relevant experiences and reflect on our own knowledge (Gao et al. 2019), so the importance of EF for ToM is expected to diminish with age. The training studies of Lecce and Bianco (2018) and Gao et al. (2019) support this account by showing that children's differences in EF predicts children's improvement from ToM trainings. Different components of EF have been identified, such as working memory, inhibition, cognitive flexibility (Miyake et al. 2000) and planning (Anderson 2002). Some authors, like Moses and Tahiroglu (2010), suggest that the nature of the relationship between EF and ToM is complex, and possibly not uniform or unidirectional, as we shall now discuss. Working memory allows us to keep a specific representation in mind and temporarily manipulate it. In this sense, it has been proposed that the ability to mentally keep in mind two conflicting perspectives on the same stimulus simultaneously, an ability which requires working memory, is essential in promoting the development of children's understanding of mind (Gordon and Olson 1998). Various investigations provide support for this hypothesis (Davis and Pratt 1995; Hala et al. 2003). Examples are the works by Mutter et al. (2006) and Lecce et al. (2017), which reported that working memory predicted the score in a false belief task better than inhibition. As for inhibitory control, this allows us to deliberately inhibit predominant responses to a specific stimulus and activate a less automatic response (Carlson and Wang 2007). Different studies have found a strong association between inhibitory control and false belief (Carlson and Moses 2001; Carlson et al. 2002; Perner and Lang 1999). A relevant issue regarding EF and ToM is that most tasks used to evaluate EF are not pure, in the sense that they require other components aside from the one being evaluated (Brocki and Bohlin 2004; Miyake et al. 2000). For this reason, it might be reasonable to argue that the combination of working memory and inhibitory control produces a higher effect on ToM, as both components are relevant for ToM (Carlson et al. 2004; Hala, et al. 2003; Williams et al, 2016). Another line of research has focused on the relationship between ToM and cognitive flexibility, a mental process that allows us to change intermittently from one rule (or perspective) to another, and to act accordingly. This process has been called rule-switching (Miyake et al. 2000). Cognitive flexibility has been linked to false beliefs because in order to understand them we need to distinguish and alternate between the different knowledge and perspectives that people have of reality (Bunge and Zelazo 2006; Kloo and Perner 2003). Several authors argue that a greater association exists between ToM and cognitive flexibility than other EF (Low and Simpson 2012), especially in early school years (Bock et al. 2015; Farrant et al. 2014) and early adolescence (Im-Bolter et al. 2016). It has also been suggested that planning is involved in the development of ToM. Planning is a mental process that plans, manages and evaluates goal-directed behavior (Zelazo and Müller 2002). Thus, planning and understanding people's minds could be interconnected. Indeed, some researchers have found an association between planning and ToM (Tager-Flusberg and Joseph 2005). Nevertheless, this fourth proposal is the least supported empirically and different studies have failed to find this association (Carlson and Moses 2001; Carlson et al. 2004). On the other hand, there is support for the idea that the relationship between EF and ToM varies in intensity as a function of the ToM skill or level (Austin et al. 2014). In this regard, some studies suggest that false belief tasks may have higher executive demands as compared to other tasks (Sabbagh et al. 2006). Research has also suggested that different ToM skills may be more linked to some EF than others. For example, deception was found to be better predicted by inhibitory control (de Villiers and de Villiers 2011), or predicting false beliefs might be better predicted by working memory (Hughes 1998). This could be explained in part by the idea that more complex ToM skills may require more complex EF (Marcovitch et al. 2015). Consequently, it is important to distinguish between different levels of complexity of ToM. Given previous studies, there is no doubt that EF contribute to how understanding of the mind develops. However, very few studies have considered the changing role that executive skills have in

ToM development, beyond the understanding of false belief. For these reasons, the main objective of this research was to explore the contribution of different executive components to the different levels of complexity of ToM between the ages of 4 and 8. We expected that EF would be closely associated with ToM tasks, but also that the different components of EF would have a different predicting weight for different levels of ToM.

Materials and methods

Participants

The sample consisted of 90 typically-developing children aged between 4 and 8 years (see Table 1) from 5 different schools in the north-east of Spain. They were divided into 3 age groups (4-, 6- and 8-year-olds) of 30 participants (15 of each gender). No significant gender differences emerged in the mean age of the participants within each age group (Mann-Whitney test; $p > .05$). Furthermore, neither non-verbal intelligence nor language differed according to gender in any age group either (ANOVA test; $p > .05$).

Materials and procedure

Written parental informed consent was obtained for each participant before starting the study. No approval from an ethical committee was required from the institution where the researchers work. Nevertheless, in the present study we have considered the ethical principles established by the European Commission (2013). One assessment session of between 45 and 60 minutes in length were carried out individually in a quiet place at the children's schools. ToM, EF, vocabulary and nonverbal intelligence were evaluated in a session. The same order was always followed for administration of the tests. The tasks are described below. In order to simplify the data analyses, and according to previous research, the ten ToM tasks were divided into three levels of increasing difficulty, and are explained in that order here. In addition, the direct scores for each of the three levels were transformed to a range of 0 to 9 points. A total ToM score was calculated by adding the scores of the 3 ToM levels, having a range of scores from 0 to 27.

The first ToM level (ToM1) was composed of the three following tasks: First-order false belief. A version of the task by Perner et al. (1987) was used to evaluate children's understanding of first-order false beliefs. Participants were shown a closed egg box and asked about the contents of the box. They were then shown the real contents (coins). Following this, they were asked test questions: a) about their beliefs concerning the contents of the box before opening it; b) about what another child would think was inside; c) and why. One point was awarded for each correct question, meaning the total score ranged from 0 to 3. Belief-desire based emotion reasoning. An adaptation of the task used by Hughes et al. (2000) was administered using two characters drawn in black and white, a box of Lacasitos® and some lentils. First, children were told that one of the characters liked Lacasitos but not lentils, and they were asked to attribute the correct emotion to the character according to the food they were offered. Then the story continued, and in the absence of the first character, a second one substituted the Lacasitos inside the tube for lentils. Following this, the children were asked test questions about the emotion of the first character before and after looking at the real contents of the tube. Moreover, they were asked to justify their answers. Correct answers were awarded 1 point, and correct justifications 0.5 points, meaning the score in this task ranged from 0 to 3. Real-apparent emotion. One of the stories by Harris et al. (1986) with two drawings in black and white was used to study the children's capacity to distinguish between real and apparent emotion. Children were told a story in which the protagonist experienced a sad event, but had a reason to hide her real emotion and display happiness. Participants were asked to identify and justify both the emotion expressed and felt by the protagonist. Questions regarding the emotion of the protagonist were awarded 1 point, and their justifications 0.5 points each, meaning the total score ranged from 0 to 3.

The second ToM level, or second-order ToM (ToM2), comprised two tasks: Second-order false belief. The administered task was adapted from Hughes et al. (2000) and used four black and white drawings. In the first part of the task, a first-order change of location question was asked and justification requested, both answers being awarded 0.5 points. In the second part of the task, the story continued and a question was asked about the protagonist's second-order falsebelief, requiring justification for the answer. One point was given for the correct answer and another for its correct justification. Finally, two memory control questions were asked. The score for the task ranged from 0 to 3. Deception. An adaptation of the procedure by García et al. (2006) was used to evaluate the capacity to understand deception, with the support of 5 drawings. After explaining that a box of crayons had changed location in the absence of the protagonist, participants were asked about the false belief of the protagonist and the justification for this. A score of 0.5 points was awarded for the correct answer, and 0.5 for the justification. Afterwards, participants were told that the protagonist intended to deceive another character and asked what he would say and why. Two control questions were used. In this case, 1 point was awarded for the correct answer and another for its justification. The third ToM level (ToM3) was called advanced ToM and included three stories: Non-literal language. The stories developed by Happé (1994) to evaluate the understanding of lies, white lies and irony were used. In each case, participants were told a social story with the support of black and white drawings. The score ranged from 0 to 3 for each story, giving 1 point if the untruthfulness of the message was identified, 2 points if the intention of the character was also understood, and 3 if an explanation was given for that intention. Children's responses were categorized by the first author of the article. In those tasks which required it, inter-rater agreement was calculated by using a second researcher who coded the answers of 5 participants from each age group. Cohen's Kappa were: k = 1 for first-order false belief, belief-desire based emotion reasoning, real-apparent emotion, second-order false belief and deception; k = .84 for the white lie story; k = .86 for the lie story; and k = .93 for the irony story. To evaluate EF, four tasks were administered: a working memory task, an inhibition task, a planning task, and a measure of cognitive flexibility. The raw score for each task was transformed to a score ranging from 0 to 16. A total EF score was calculated by adding the scores of the 4 EF tasks, so it has a range of scores from 0 to 64. The test was administered following the procedure of its manual. Working memory. The backward digit-span task from the WISC-III (Wechsler 1991) was administered and scored following its manual. The maximum raw score for the task is 16, one for each correct item. Inhibition. The task developed by Gerstadt et al. (1994) was used. Participants were asked to say "day" when they saw a white moon on a black background and "night" when they saw a yellow sun on a white background. A trial was carried out to ensure that participants understood the aim of the task. After this preparation phase, 16 items were presented (without feedback) following the pattern proposed by Simpson and Riggs (2005): ABBABAABBABAABAB. The task was administered using the program Superlab Pro version 2.0; the time of exposure to each image was 8 seconds and the time between images 2 seconds. One point was awarded for each correct answer. Planning. The mazes subtest from the WISC-III (Wechsler 1991) was administered and scored following the manual's instructions. Cognitive flexibility. The Spanish version of the Wisconsin test (Grant and Berg 1997) was used. The number of persistent mistakes was chosen as a measure of cognitive flexibility, since several studies agree that cognitive flexibility decreases as the number of persistent mistakes increases (see, for example: Máximo et al. 2004). In accordance with the manual, the number of persistent mistakes was transformed to percentiles. Non-verbal intelligence. The progressive matrices test by Raven et al. (1996) was administered following the manual instructions and scoring criteria. The raw score was transformed to percentiles following the Spanish scales. Vocabulary. Receptive verbal ability was assessed by using the Spanish version of the Peabody Picture Vocabulary Test by Dunn et al. (2006). This test includes 150 items ordered by level of difficulty. Children are shown drawings in groups of 4 and asked to indicate which one corresponds to the word stated verbally. The test was administered following the procedure of its manual.

Data analysis

Data were analyzed using the statistical package SPSS (version 22). Age group differences in EF and ToM were studied with ANOVA. Pearson correlations were carried out to examine the relationship between ToM and EF. Also, linear regressions with the stepwise method were used to study the influence of EF on ToM development. Repeated-measures Student's T tests were conducted in order to obtain empirical support for differentiation among ToM levels.

Results

In this section, we will first show the descriptive values of the EF and ToM variables. Then, we will present, for each age group, correlations between ToM and EF, as well as linear regressions to study the predictive value of EF for ToM.

Descriptive statistics

In the Table 1 we describe the results for each ToM level (and Total ToM) in each age group. Age group comparisons were conducted using ANOVA. We found age group differences in all ToM levels and in Total ToM ($p < .001$). Tamhane's T2 post hoc test showed that 8-year-olds obtained higher scores in all ToM levels (and Total ToM) compared to 6-year-olds ($p < .005$), and 6-year-olds higher scores than 4-year-olds ($p < .005$). In the Table 1 we describe the results for the different EF (and Total EF) in each age group. The ANOVA showed significant age differences in all EF tasks and in Total EF ($p < .001$). Tamhane's T2 post hoc test showed significant differences between 8-year-olds and 6-year-olds in all EF tasks and Total EF ($p < .001$); when comparing 6- and 4-year-olds, significant differences ($p < .001$) emerged in all comparisons except for inhibition ($p > .05$). There were significant differences between Level 1 and Level 2 of ToM in all age groups, and the same occurred between Levels 2 and 3 ($p < .001$). Hence, the grouping of the ToM tasks in 3 levels was empirically supported.

Relations between ToM and EF in 4-year-olds

Different significant correlations were observed between ToM and EF and ToM for the three ToM levels and for the total ToM score (see Table 2). Specifically, working memory, inhibition and cognitive flexibility correlated significantly with ToM1, ToM2 and Total ToM, whereas planning only correlated significantly with ToM3. We therefore deemed it appropriate to study the predictive value of EF for the different levels of ToM scores and for the Total ToM score through linear regressions (see Table 3). When considering the Total ToM score, the EF variables that best predicted this score were cognitive flexibility and working memory. After conducting a linear regression with ToM1 as a dependent variable, the best predictor was inhibition, whereas working memory and cognitive flexibility were the best predictors for ToM2, and planning for ToM3.

Relations between ToM and EF in 6-year-olds

As occurred with 4-year-olds, ToM correlated significantly with several EF variables in 6-year-olds (see Table 2). Explicitly, cognitive flexibility correlated significantly with ToM1, ToM2 and Total ToM. Working memory and inhibition obtained significant correlations with ToM3 and Total ToM. Finally, planning correlated significantly with ToM2, ToM3 and Total ToM. When we carried out linear regressions to study the predictive value of EF for ToM in 6-year-olds (see Table 4), we found that the best predictors of Total ToM were cognitive flexibility and working memory, as occurred in 4-year-olds. The best predictors for ToM 1 and ToM 2 were cognitive flexibility, and for ToM 3 working memory.

Relations between ToM and EF in 8-year-olds

At the age of 8, inhibition correlated significantly with ToM2, and cognitive flexibility for ToM2 and Total ToM (see Table 2). Planning or Working memory did not show significant correlations. When regressions were conducted (see Table 5), the Total ToM score was best predicted by cognitive flexibility, the same as for ToM2. The rest of ToM levels did not have EF predictors.

Total ToM

The intensity of the relationship between Total ToM and Total EF diminishes with age (see Table 2). When we look closer at it, we observe that the strength of the relationship between each EF and Total ToM is reduced with age. In other words, there is a significant relationship between EF components and Total ToM at the age of 4 years (with the exception of planning), but the intensity of this relationship is lower at the age of 6 years, and even lower at the age of 8 years, when there is only a significant relationship between cognitive flexibility and Total ToM (and between Total EF and Total ToM).

Discussion

The main aim of this study is to explore the influence of EF in ToM in children aged from 4 to 8 years. Our results reveal that the predictive role of EF components varies according to the developmental level of ToM. We will now analyze these results in detail, attending to the three ToM levels.

ToM1

The best predictors of ToM1 were inhibition at the age of 4 and cognitive flexibility at the age of 6. On the other hand, although working memory and cognitive flexibility were not found to be predictors of ToM1 at the age of 4, they displayed significant correlations. Our results are consistent with those that found an important contribution of cognitive flexibility, inhibitory control and working memory to basic understanding of the mind (Carlson and Moses 2001; Hala et al. 2003; Kloo and Perner 2003; Mutter et al. 2006). Our results do not support the idea that working memory might be a better predictor of ToM than inhibition (for example, Lecce et al. 2017). However, those studies only considered false belief, while our measure of ToM1 also included other measures of basic ToM understanding. Additionally, no correlations were found between EF and ToM1 at the age of 8, which might be explained by a ceiling effect of ToM1 in this group, and partially by a ceiling effect in inhibition scores, in accordance with previous studies showing high percentages of answers in this task even in very young children (Montgomery and Koeltzow 2010; Simpson and Riggs 2005).

ToM2

With regard to ToM2, cognitive flexibility was the best predictor in all age groups, and working memory also predicted this level of ToM at the age of 4 years. Therefore, the degree of correlation between ToM and EF abilities varies according to the developmental level of the child, as working memory has an important role for this level only at the age of 4 years. Allegedly, most of the older children already might have mastered the minimum level of working memory required to pass the tasks that belong to this level, and thus, what could make a difference at these older ages is cognitive flexibility, which seems to be the most important EF for this level of ToM. In spite of this fact, other EF seem to play a role in being able to pass this level of ToM, as inhibition correlated with it at the age of 4 and 8 years, and planning at the age of 6. Thus, our study is a contribution to the few studies that have found a relationship between planning and ToM (Hughes 1998; Tager-Flusberg and Joseph 2005), and suggests that this EF skill could gradually gain in importance in ToM development, and especially for advanced levels of ToM. In fact, planning was not found to correlate with ToM1 level, correlated significantly with ToM2 level (at the age of 6 years) and ToM 3 level (at the ages of 4 and 6 years).

ToM3

The ToM3 level was best predicted by planning at the age of 4 and working memory at the age of 6 (age in which inhibition and planning also correlated significantly with ToM3). On the other hand, no individual EF predicted ToM3 at the age of 8, and only the total EF score correlated with ToM3 at this age. The ToM3 level was best predicted by planning at the age of 4 and working memory at the age of 6 (age in which inhibition and planning also correlated significantly with ToM3). On the other hand, no individual EF predicted ToM3 at the age of 8, and only the total EF score correlated with ToM3 at this age. Before we argued that planning could be more important for higher levels of ToM, but what could explain that planning only correlated with ToM3 at the age of 4 and 6, but not at the age of 8? One possibility is that a minimum level of planning capacity is required to pass the ToM tasks involved at this level (Happé's tasks), and in this sense 8-year-olds might already possess this level of planning.

In this way, only those 4- and 6-year-olds with very good planning skills are able to understand these ToM tasks that involve an understanding of non-literal statements. The fact that planning skills at the age of 4 were very low supports this idea. It is noticeable that we did not find correlations between cognitive flexibility and ToM3. These results seem to contradict Im-Bolter et al. (2016), who found that decentration or shifting (which corresponds to our construct of cognitive flexibility) was related to high ToM capacities (as measured by Happé's Strange Stories task, as we did in our ToM3 level). These authors suggested that decentration had a more important role in this level of ToM in older (11 - 12 years of age) than in younger children (7-8 years of age), but still it does not explain why we did not have any association between ToM3 and cognitive flexibility in the group of 8-year-olds. Maybe these differences could be explained by the tests and type of measures selected in each study (e.g., their measure included the speed in the task but not ours). Future studies could address this issue.

Total ToM

Total ToM was best predicted by cognitive flexibility in all age groups, and working memory was also a predictor at the ages of 4 and 6. Inhibition, despite not being a predictor, also correlated with Total ToM at the ages of 4 and 6, and planning correlated with Total ToM at the age of 6. These results support the view hold by several authors that certain EF are more related to ToM than other EF (e.g., Bock et al. 2015; Low and Simpson 2012), and that at different ages ToM skills are better predicted by some EF than others (Im-Bolter et al. 2016; Su and Yu 2015). On the other side, the intensity of the link between Total Tom and the different EF (with the exception of planning) diminishes with age, which is compatible with the emergence account. The results of our study however cannot be used to discuss the expression account, mainly because we did not control the executive demands of the different ToM tasks.

Regarding the developmental relationships between ToM and EF, Devine and Hugues (2014) proposed a hybrid emergency-expression explanation, according to which EF are important for ToM skills to emerge and can help or hinder their expression. We believe our results to be compatible with this proposal, as we have seen that different levels of ToM have different associations with EF at different levels of development. Nevertheless, more longitudinal and training studies are necessary to clarify the exact way in which different EF allow the emergence and expression of various ToM skills at different age points (see Devine et al. 2016; Doenyas et al. 2018).

Limitations and Future Studies

One limitation is that the ToM tasks we used are not comparable in format, and consequently neither in the executive demands they involve (see, for example, Henning et al. 2011). Nevertheless, it should also be taken into account that the social understanding skills we use in our everyday reasoning are not homogeneous either, so it might be useful to study the executive demands that different types of ToM tasks may involve at different developmental levels. Future studies should find other measures of inhibitory control that reflect how this skill develops, as we found very high scores even in 4-year-olds. Future studies should also take into account the distinction between conflict tasks (which are decontextualized and abstract) and delay tasks (which involve an affective component), as some studies have found that the former but not the latter type of inhibition tasks are related to ToM (Bellagamba et al. 2015).

Conclusions

The overall results from this investigation confirm that EF are important for understanding the mind. As predicted, EF played a different role at different developmental levels. Furthermore, we observed specific EF skills linked to each ToM level, which also depended on age. Future research should aim at elucidating the mutual influence of ToM and EF skills along development, analyzing the role of EF skills in the emergence and expression of different ToM skills at each developmental point.

Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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References

Anderson, C., John, O. P., Keltner, D., & Kring, A. (2001). Who attains social status? Effects of personality and physical attractiveness in social groups. *Journal of Personality and Social Psychology, 81*, 116-132. doi:10.1037/0022-3514.81.1.116

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child neuropsychology, 8*, 71-82. doi:10.1076/chin.8.2.71.8724

Astington, J. W., & Baird, J. (2005). Introduction: Why Language Matters. In J. W. Astington & J. Baird (Eds.), *Why language matters for theory of mind* (pp. 3-25). New York: Oxford University Press.

Austin, G., Groppe, K., & Elsner, B. (2014). The reciprocal relationship between executive function and theory of mind in middle childhood: a 1-year longitudinal perspective. *Frontiers in Psychology*, *5*, 655. doi:10.3389/fpsyg.2014.00655.

Banerjee, R., Watling, D., & Caputi, M. (2011). Peer Relations and the Understanding of Faux Pas: Longitudinal Evidence for Bidirectional Associations. *Child Development, 82,* 1887–1905. doi:10.1111/j.1467-8624.2011.01669.x

Baron-Cohen, S., Wheelwright, S., Scahill, V., Lawson, J., & Spong, A. (2001). Are intuitive physics and intuitive psychology independent? *Journal of Developmental and Learning Disorders, 5*, 47-78. doi:10.1080/17470210701508749

Bellagamba, F., Addessi, E., Focaroli, V., Pecora, G., Maggiorelli, V., Pace, B., & Paglieri, F. (2015). False belief understanding and "cool" inhibitory control in 3-and 4-years-old Italian children. *Frontiers in psychology, 6.* doi:10.3389/fpsyg.2015.00872

Benson, J. E., Sabbagh, M. A., Carlson, S. M., & Zelazo, P. D. (2013). Individual differences in executive functioning predict preschoolers' improvement from theory-of-mind training. *Developmental Psychology, 49*, 1615-1627. doi:10.1037/a0031056.

Birch, S. A., & Bloom, P. (2007). The curse of knowledge in reasoning about false beliefs. *Psychological Science, 18(*5), 382-386. doi:10.1111/j.1467-9280.2007.01909.x

Bock, A. M., Gallaway, K. C., & Hund, A. M. (2015). Specifying links between executive functioning and theory of mind during middle childhood: Cognitive flexibility predicts social understanding. *Journal of Cognition and Development, 16,* 509-521. doi:10.1080/15248372.2014.888350

Brocki, C. K., & Bohlin, G. (2004). Executive Functions in Children Aged 6 to 13: A Dimensional and Developmental Study. *Developmental Neuropsychology, 26*, 571-593 doi:10.1207/s15326942dn2602_3

Bunge, S. A., & Zelazo, P. D. (2006). A Brain-Based Account of the Development of Rule Use in Childhood. *Current Directions in Psychological Science, 15*, 118-121. doi:10.1111/j.0963-7214.2006.00419.x

Carlson, S., & Moses, L. J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development*, *72*, 1032-053. doi:10.1111/1467-8624.00333

Carlson, S. M., Moses, L. J., & Breton, C. (2002). How specific is the relation between executive function and theory of mind? Contributions of inhibitory control and working memory. *Infant and Child Development,11,* 73-92. doi:10.1002/icd.298

Carlson, S. M., Moses, L. J., & Claxton, L. J. (2004). Individual differences in executive functioning and theory of mind: An investigation of inhibitory control and planning ability. *Journal of Experimental Child Psychology*, *84*, 299-319. doi:10.1016/j.jecp.2004.01.002

Carlson, S. M., Moses, L. J., & Hix, H. R. (1998). The role of inhibitory control in young children's difficulties with deception and false belief. *Child Development*, *69,* 672-691. doi:10.1111/j.1467-8624.1998.tb06236.x

Carlson, S. M., & Wang, T. S. (2007). Inhibitory control and emotion regulation in preschool children. *Cognitive Development, 22*, 489-510. doi:10.1016/j.cogdev.2007.08.002

de Villiers, P. A., & de Villiers, J. G. (2011). Deception dissociates from false belief reasoning in deaf children: Implications for the implicit versus explicit theory of mind distinction. *British Journal of Developmental Psychology, 30*, 188-209. doi:10.1111/j.2044-835X.2011.02072.x

Davis, H. L., & Pratt, C. (1995). The development of children's theory of mind: The working memory explanation. *Australian Journal of Psychology*, *47*, 25-31. doi:10.1080/00049539508258765

Devine, R. T., & Hughes, C. (2014). Relations between false belief understanding and executive function in early childhood: A meta-analysis. *Child Development, 85*, 1777-1794. doi:10.1111/cdev.12237

Devine, R. T., White, N., Ensor, R., & Hughes, C. (2016). Theory of mind in middle childhood: Longitudinal associations with executive function and social competence. *Developmental Psychology, 52*(5), 758. doi:10.1037/dev0000105

Doenyas, C., Yavuz, H. M., & Selcuk, B. (2018). Not just a sum of its parts: How tasks of the theory of mind scale relate to executive function across time. *Journal of Experimental Child Psychology*, *166*, 485-501. doi:10.1016/j.jecp.2017.09.014

Dunn, Ll. M., Dunn, L. M., & Arribas, D. (2006). *PEABODY, Test de vocabulario en imágenes*. Madrid: TEA Ediciones.

European Commission (2013). *Ethics for researchers. Facilitating Research Excellence in FP7.* Luxembourg: Publications Office of the European Union.

Farrant, B. M., Fletcher, J., & Maybery, M. T. (2014). Cognitive flexibility, theory of mind, and hyperactivity/inattention. *Child Development* Research, *2014,* Article ID 741543, 1-10. doi:10.1155/2014/741543

Gao, Q., Huang, Q., Zhang, Q., & Chen, W. (2019). Does executive function influence the development of theory of mind in elementary students?. *Current Psychology, 1-8*. doi:10.1007/s12144-018-0107-1

García, M. J. M., Becerra, I. G., Brown, M. C., & Geer, D. (2006). Toma de perspectiva y teoría de la mente: Aspectos conceptuales y empíricos. Una propuesta complementaria y pragmática. *Salud Mental, 29*(6), 5-14.

Gerstadt, C., Hong, Y., & Diamond, A. (1994). The relationship between cognition and action: Performance of 3½-7 year old children on a Stroop-like day–night test. *Cognition*, *53*, 129-153. doi:10.1037/0012-1649.38.3.352

Gordon, A. C., & Olson, D. R. (1998). The relation between acquisition of a theory of mind and the capacity to hold in mind. *Journal of Experimental Child Psychology*, *68*, 70-83. doi:10.1006/jecp.1997.2423

Grant, D. A., & Berg, E. A. (1997). *Test de Clasificación de Tarjetas de Wisconsin (WCST).* Madrid: TEA Ediciones.

Hala, S., Hug, S., & Henderson, A. (2003). Executive function and false-belief understanding in preschool children: Two tasks are harder than one. *Journal of Cognition and Development, 4,* 275-298. doi:10.1207/S15327647JCD0403_03

Happé, F. (1994). An advanced test of theory of mind: Understanding of story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. *Journal of Autism and Developmental Disorders, 24,* 129 -154. doi:10.1007/BF02172093

Harris, P. L., Donnelly, K., Guz, G. R., & Pitt-Watson, R. (1986). Children's understanding of the distinction between real and apparent emotion. *Child Development*, 57, 895-909. doi:10.1111/ j.1467-8624.1986.tb00253.x

Henning, A., Spinath, F. M., & Aschersleben, G. (2011). The link between preschoolers' executive function and theory of mind and the role of epistemic states. *Journal of Experimental Child Psycholog, 108*, 513-531. doi:10.1016/j.jecp.2010.10.006

Hughes, C. (1998). Finding your marbles: Does preschoolers' strategic behaviour predict later understanding of mind? *Developmental Psychology, 34,* 1326-1339. doi:10.1037/0012-1649.34.6.1326

Hughes, C., Adlam, A., Happé, F., Jackson, J., Taylor, A., & Caspi, A. (2000). Good test-retest reliability for standard and advanced false-belief tasks across a wide range of abilities. *Journal of Child Psychology Psychiatry, 41*, 483-490. doi:10.1111/1469-7610.00633

Im-Bolter, N., Agostino, A., & Owens-Jaffray, K. (2016). Theory of mind in middle childhood and early adolescence: Different from before? *Journal of Experimental Child Psychology*, *149*, 98-115. doi:10.1016/j.jecp.2015.12.006

Kloo, D., & Perner, J. (2003). Training transfer between card sorting and false belief understanding: Helping children apply conflicting descriptions. *Child Development*, *74*, 1823-1839. doi:10.1046/j.1467-8624.2003.00640.x

Lecce, S., Bianco, F., Devine, R. T., Hughes, C., & Banerjee, R. (2014). Promoting theory of mind during middle childhood: A training program. *Journal of Experimental Child Psychology, 126*, 52-67. doi:10.1016/j.jecp.2014.03.002.

Lecce, S., Bianco, F., Devine, R. T., & Hughes, C. (2017). Relations between theory of mind and executive function in middle childhood: A short-term longitudinal study. *Journal of Experimental Child Psychology, 163*, 69-86. doi:10.1016/j.jecp.2017.06.011

Lecce, S., & Bianco, F. (2018). Working memory predicts changes in children's theory of mind during middle childhood: A training study. *Cognitive Development, 47,* 71-81. doi:10.1016/j.cogdev.2018.04.002

Lillard, A. S., Lerner, M. D., Hopkins, E. J., Dore, R. A., Smith, E. D., & Palmquist, C. M. (2013). The impact of pretend play on children's development: A review of the evidence. *Psychological Bulletin*, *139*, 1-34. doi:10.1037/a0029321.

Low, J., & Simpson, S. (2012). Effects of labeling on preschoolers' explicit false belief performance: outcomes of cognitive flexibility or inhibitory control? *Child development, 83*(3), 1072-1084. doi:10.1111/j.1467-8624.2012.01738.x

Marcovitch, S., O'Brien, M., Calkins, S. D., Leerkes, E. M., Weaver, J. M. & Levine, D. W. (2015). A Longitudinal Assessment of the Relation between Executive Function and Theory of Mind at 3, 4, and 5 Years. *Cognitive Development*, *33,* 40-55. doi:10.1016/j.cogdev.2014.07.001

Miller, S. A. (2009). Children's understanding of second-order mental states. *Psychological Bulletin, 135*(5)*,* 749-773. doi:10.1037/a0016854.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wagner, T. D. (2000). The unity and diversity of executive functions and their contributions to complex 'frontal lobe' tasks: a latent variable analysis. *Cognitive Psychology*, *41*, 49-100. doi:10.1006/cogp.1999.0734

Montgomery, D. E., & Koeltzow, T. E. (2010). A review of the day-night task: The Stroop paradigm and interference control in young children. *Developmental Review, 30,* 308-330. doi:10.1016/ j.dr.2010.07.001

Moses, L. J. (2001). Executive accounts of theory-of-mind development. *Child development*, *72*(3), 688-690. doi:10.1111/1467-8624.00306

Moses, L. J., & Tahiroglu, D. (2010). Clarifying the Relation between Executive Function and Children's Theories of Mind. In B. W. Sokol, U. Müller, J. M. Carpendale, A. R. Young, & G. Iarocci (Eds.), *Self and Social Regulation. Social Interaction and the Development of Social Understanding and Executive Functions,* (pp. 218-233). New York: Oxford University Press.

Müller, U., Liebermann-Finestone, D. P., Carpendale, J. I., Hammond, S. I., & Bibok, M. B. (2012). Knowing minds, controlling actions: The developmental relations between theory of mind and executive function from 2 to 4years of age. *Journal of experimental child psychology, 111*(2), 331-348. doi:10.1016/j.jecp.2011.08.014

Mutter, B., Alcorn, M. B., & Welsh, M. (2006). Theory of mind and executive function: working-memory capacity and inhibitory control as predictors of false-belief task performance. *Perceptual and Motor Skills, 102,* 819-835. doi:10.2466/pms.102.3.819-835

Perner, J., & Lang, B. (1999). Development of theory of mind and executive control. *Trends in Cognitive Sciences*, *3*, 337-344. doi:10.1016/S1364-6613(99)01362-5

Perner, J., Leekman, S. R., & Wimmer, H. (1987). Three-year-olds' difficulty with false-belief: the case for a conceptual deficit. *British Journal of Developmental Psychology, 5*, 127-135. doi:10.1111/j.2044-835X.1987.tb01048.x

Raven, J. C., Court, J. H., & Raven, J. (1996). *Raven: Matrices Progresivas. Manual. (2ª edición ampliada)*. Madrid: TEA.

Repacholi, B. & Slaughter, V. (2003) (Eds.). *Individual Differences in Theory of Mind. Implications For Typical and Atypical Development*. New York: Psychology Press.

Russell, J., Mauthner, N., Sharpe, S., & Tidswell, T. (1991). The "window task" as a measure of strategic deception in preschools and autistic subjects. *British Journal of Developmental Psychology*. **9**, 173-178. doi: 10.1111/j.2044-835X.1991.tb00881.x

Sabbagh, M. A., Xu, F., Carlson, S. M., Moses, L. J., & Lee, K. (2006). The development of executive functioning and theory of mind: a comparison of Chinese and US preschoolers. *Psychological Science, 17*, 74-81. doi:10.1111/j.1467-9280.2005.01667.x.

Sidera, F., Amadó, A., & Serrat, E. (2013). Are you really happy? Children's understanding of real vs. pretend emotions. *Current Psychology, 32(*1), 18-31. doi:10.1007/s12144-019-00314-w.

Simpson, A., & Riggs, K. J. (2005). Factors responsible for performance on the day–night task: response set or semantics? *Developmental Science*, *8*, 360-371. doi:10.1111/j.1467-7687.2005.00424.x

Su, Y., & Yu, J. (2015). Meta-analysis of The Relation Between Executive Function and Theory of Mind: The Role of Inhibitory Control and Set Shifting. *Psychological Development and Education,* (1), 8.

Talwar, V., & Lee, K. (2008). Social and cognitive correlates of children's lying behavior. *Child development, 79*(4), 866-881. doi:10.1111/j.1467-8624.2008.01164.x

Tager-Flusberg, H., & Joseph, R. M. (2005). How language facilitates the acquisition of false belief in children with autism. In J.W. Astington & J. A. Baird (Eds.), W*hy language matters for theory of mind* (pp. 298-318). New York: Oxford University Press.

Vilenskaya, G. A., & Lebedeva, E. I. (2017). The Relations Between Theory of Mind and Behavioral Control Among Primary School Age Children. *The Russian Journal of Cognitive Science, 4*(4), 29-36.

Wade, M., Prime, H., Jenkins, J. M., Yeates, K. O., Williams, T., & Lee, K. (2018). On the relation between theory of mind and executive functioning: A developmental cognitive neuroscience perspective. *Psychonomic Bulletin & Review, 25*(6), 2119-2140. doi:10.3758/s13423-018-1459-0

Wechsler, D. (1991). *Escala de Inteligencia Wechsler para Niños-Tercera Edición (WISC-III)*. Madrid: TEA Ediciones.

Wellman, H. M., & Banerjee, M. (1991). Mind and emotion: Children's understanding of the emotional consequences of beliefs and desires. *Journal of Developmental Psychology, 9*, 191-214. doi:10.1111/j.2044-835X.1991.tb00871.x

Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-Analysis of Theory-of-Mind Development: The Truth about False Belief. *Child Development, 72*, 655-684. doi:10.1111/1467-8624.00304

Wellman, H. M., Fang, F., & Peterson, C. C. (2011). Sequential Progressions in a Theory-of-Mind Scale: Longitudinal Perspectives. *Child Development, 82*, 780-792. doi:10.1111/j.1467-8624.2011.01583.x

Wilson, J., Andrews, G., Hogan, C., Wang, S., & Shum, D. H. (2018). Executive function in middle childhood and the relationship with theory of mind. *Developmental neuropsychology, 43*(3), 163-182. doi: 10.1080/87565641.2018.1440296

Williams, S., Moore, K., Crossman, A. M., & Talwar, V. (2016). The role of executive functions and theory of mind in children's prosocial lie-telling. *Journal of experimental child psychology, 141,* 256-266. doi:10.1016/j.jecp.2015.08.001

Wimmer, H., Hogrefe, G. J., & Perner, J. (1988). Children's understanding of informational access as source of knowledge. *Child Development, 59*, 386-396. doi:10.1111/j.1467-8624.1988.tb01474.x

Zelazo, P. D., & Müller, U. (2002). Executive function in typical and atypical development. In U. Goswami (Ed.), *Handbook of Childhood Cognitive Development* (pp. 445-469). Oxford: Blackwell.

Table 1.

Descriptive statistics (mean and SD scores)

	4-year-olds (range: 4;0 to 4;6)	**6-year-olds** (range: 6;0 to 6;6)	**8-year-olds** (range: 8;0 to 8;6)
Age	51.03 (2.08)	75 (2.02)	99 (1.98)
Non-verbal intelligence	57.83 (25.85)	53.17 (24.96)	55.5 (25.54)
Peabody	99.1 (14.46)	98.6 (12.64)	92.4 (13.56)
ToM_1	5.57 (1.97)	7.61 (1.61)	8.92 (.32)
ToM_2	2.83 (1.49)	5.5 (1.9)	7.95 (1.31)
ToM_3	1.08 (.82)	2.43 (1.93)	4.31 (1.82)
Total ToM	9.48 (3.09)	15.56 (4.18)	21.18 (2.48)
Working memory	2.43 (1.1)	4.13 (1.79)	6.87 (1.04)
Inhibition	13.03 (3.06)	13 (2.91)	15.73 (.69)
Planning	1.55 (1.41)	4.78 (1.93)	7.06 (1.69)
Cognitive flexibility	1.71 (.96)	6.84 (3.75)	10.7 (2.81)
Total EF	18.72 (5.18)	28.75 (7.7)	40.36 (4.27)

Note: Maximum score for ToM_1, ToM_2 & ToM_3 is 9. Maximum score for Total ToM = 18. Maximum score for Executive Function Tasks is 16. Maximum score for Total EF is 64.

Table 2.

Pearson correlations between EF and ToM according to age group

		ToM$_1$	**ToM$_2$**	**ToM$_3$**	**Total ToM**
4-year-olds	Working Memory	.549**	.642**	-.019	.655**
	Inhibition	.604**	.629**	.051	.702**
	Planning	.220	.074	.458*	.297
	Cognitive Flexibility	.594**	.609**	.211	.728**
	Total EF	.643**	.641**	.190	.769**
6-year-olds	Working Memory	.29	.279	.595**	.516**
	Inhibition	.210	.317	.513**	.462*
	Planning	.167	.387*	.363*	.408*
	Cognitive Flexibility	.383*	.589**	.334	.569**
	Total EF	.378*	.569**	.587**	.674**
8-year-olds	Working Memory	.119	.045	.334	.286
	Inhibition	.359	.364*	.123	.331
	Planning	.103	.098	.267	.262
	Cognitive Flexibility	.092	.398*	.332	.468**
	Total EF	.198	.371*	.427*	.536**

$^{*1}p < .05; ^{**}p < .01$

Table 3.

Linear regressions of the EF components predicting ToM in 4-year-olds group

	Non-standardized coefficients		Standardized coefficients		
	B	**Typ. Error**	**Beta**	**T**	**Sig.**
Total ToM[a]					
Constant	4.218	.925		4.562	.000
Cognitive flexibility	1.689	.476	.525	3.545	.001
Working memory	.977	.415	.349	2.356	.026
ToM_1[b]					
Constant	.495	1.297		.382	.705
Inhibition	.389	.097	.604	4.013	.000
ToM_2[c]					
Constant	.448	.508		.881	.386
Working memory	.589	.228	.435	2.585	.015
Cognitive flexibility	.553	.262	.355	2.110	.044
ToM_3[d]					
Constant	.674	.203		3.328	.002
Planning	.266	.298	.458	2.727	.011

[a] R^2 adjusted .581
[b] R^2 adjusted .342
[c] R^2 adjusted .458
[d] R^2 adjusted .182

Table 4.

Linear regressions of the EF components predicting ToM in 6-year-olds group

	Non-standardized coefficients		**Standardized coefficients**		
	B	**Typ. Error**	**Beta**	**T**	**Sig.**
Total ToM[a]					
Constant	8.548	1.647		5.189	.000
Cognitive flexibility	.502	.168	.450	2.980	.006
Working memory	.865	.352	.372	2.461	.021
ToM_1[b]					
Constant	6.495	.581		11.173	.000
Cognitive flexibility	.164	.075	.383	2.191	.037
ToM_2[c]					
Constant	3.456	.602		5.737	.000
Cognitive flexibility	.299	.078	.589	3.855	.001
ToM_3[d]					
Constant	-.200	.733		-.272	.787
Working memory	.638	.163	.595	3.913	.001

[a] R^2 adjusted .407
[b] R^2 adjusted .116
[c] R^2 adjusted .323
[d] R^2 adjusted .331

Table 5.

Linear regressions of the EF components predicting ToM in 8-year-olds group

	Non-standardized coefficients		Standardized coefficients		
	B	**Typ. Error**	**Beta**	**T**	**Sig.**
Total ToM[a]					
Constant	16.774	1.626		10.317	.000
Cognitive flexibility	.412	.147	.468	2.799	.009
ToM_2[b]					
Constant	5.959	.896		6.649	.000
Cognitive flexibility	.186	.081	.398	2.295	.029

[a] R^2 adjusted .191
[b] R^2 adjusted .128