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Critical Review

Are there associations between Executive Functions and Theory of Mind in attention deficit hyperactivity disorder? Results from a systematic review with meta-analysis

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Abstract

Background: Deficits in Executive Function (EF) and Theory of Mind (ToM) are common and significant in attention deficit hyperactivity disorder (ADHD), impacting self-regulation and social interaction. The nature of ToM deficits is believed to be partially associated with preexisting deficits in other core cognitive domains of ADHD, such as EF, which are essential for making mental inferences, especially complex ones. Evaluating these associations at a meta-analytic level is relevant. **Objective:** To conduct a systematic literature review followed by a meta-analysis to identify potential associations between EF and ToM among individuals with ADHD and their healthy counterparts, considering different developmental stages. **Method:** A systematic review was conducted in seven different databases. The methodological quality of the studies was assessed using the Newcastle-Ottawa Scale. The meta-analytic measurement was estimated with the correlation coefficient as the outcome. Due to the presence of heterogeneity, a random-effects model was adopted. Independent meta-analyses were conducted for different EF subdomains and ADHD and healthy control groups. Subgroup analyses were performed to examine the influence of age on the outcome of interest. **Results:** Fifteen studies were analyzed. Moderate associations were found when comparing EF and ToM between individuals with ADHD (0.20–0.38) and healthy subjects (0.02–0.40). No significant differences were found between child and adult samples ($p > 0.20$). **Conclusion:** The association between EF and ToM was significant, with a moderate effect size, although no significant differences were found according to age, the presence of ADHD, or EF subdomains. Future research is suggested to expand the age groups and overcome the methodological limitations indicated in this review.

Keywords: Executive Function; Theory of Mind; mentalization; mental processes; attention deficit hyperactivity disorder; correlation measures

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Statement of research significance

Research question(s) or topic(s): Cognitive deficits are frequently identified in cases of attention deficit hyperactivity disorder (ADHD), particularly in Executive Functions and Theory of Mind. The correlation between these cognitive domains has been observed in other clinical groups. However, its presence and magnitude in ADHD remain to be fully understood. To enhance clinical reasoning and inform future interventions, we analyzed this correlation by investigating its magnitude, potential differences across developmental stages (children and adults), and comparisons with a control group without the disorder.

Main findings: Our results confirmed a significant correlation of moderate magnitude between different components of Executive Functions and Theory of Mind. We found no differences between children and adults, nor did we observe significant differences between the ADHD and control groups.

Study contributions: This study provides new insights into Theory of Mind and Executive Function performances in ADHD and critically examines how both domains have been studied in this clinical context.

Introduction

Attention deficit hyperactivity disorder (ADHD) is characterized by a persistent inattention and/or hyperactivity-impulsivity behavioral pattern that leads to a significant functional impairment (Antshel & Barkley, 2020). It is one of the most prevalent neurodevelopmental disorders, with global rates reaching 7.6% in children/adolescents (Salari et al., 2023) and 6.7% in adults (Song et al., 2021). Deficits in Executive Functions (EF) are common and significant in ADHD (Silverstein et al., 2018). EFs can be understood as a set of mental abilities that regulate behavior, providing the individual with self-control, concentration, focus, and adaptability in the face of changes in context (Diamond, 2013). Several theoretical models have been developed to explain this construct and its subdomains (e.g., Baddeley, 1996; Barkley, 1997;

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Diamond, 2013; Miyake et al., 2000; Stuss & Alexander, 2007; Zelazo et al., 2003), with the most commonly associated deficits in ADHD being inhibitory control (Jiménez-Figueroa et al., 2017), working memory (Kofler et al., 2020), cognitive flexibility (Roshani et al., 2020), planning (Willcutt et al., 2005), and attention processes (Miklós et al., 2019).

Alterations in these EF subdomains imply impaired self-regulation and social interaction (Barkley, 2012). Furthermore, other impairments in the cognitive sphere are also observed in ADHD, such as language (Milligan et al., 2007; San Juan & Astington, 2011), learning (Bora & Pantelis, 2015; Tucci & Easterbrooks, 2020), memory (Imanipour et al., 2021) and social cognition (Uekermann et al., 2010), with an emphasis on the Theory of Mind (ToM; Carlson et al., 2004; Hughes, 1998; Milligan et al., 2007). It is worth noting that these cognitive domains exhibit significant and moderate correlations, particularly among individuals with ADHD. For example, Sarıyer et al. (2023) reported correlations between language skills and working memory ranging from 0.25 to 0.42. Similarly, Babarczy et al. (2024) found a correlation of 0.44 between ToM and pragmatic comprehension, while Çiray et al. (2021) reported a correlation of 0.28 between ToM and text comprehension ability. Likewise, Şahin et al. (2018) identified correlations ranging from 0.27 to 0.48 between ToM and global intelligence, while Imanipour et al., (2021) found a correlation of 0.60 between ToM and working memory.

ToM is defined as a set of skills necessary to capture information, interpret, and make inferences about the mental states, intentions, and desires of others, as well as oneself (Premack & Woodruff, 1978). It is relevant in prosocial behaviors and when interacting with peers (Rix et al., 2023). Evidence shows that individuals with ADHD presented a significantly lower performance on ToM tasks than their healthy counterparts (Mary et al., 2015; Maoz et al., 2017). A meta-analysis including 17 studies found differences of a moderate effect size (Hedges' $g = 0.66$; Nejati, 2022). Additionally, these impairments were found in samples from different age groups (Mary et al., 2015; Tatar & Cansız, 2020).

The nature of ToM impairments is believed to be partially associated with pre-existing deficits in ADHD's other central cognitive domains, such as EF (Russell, 1996). Extensive literature focuses on healthy individuals, supporting that EF, in general, and specifically its subdomains, are essential for performing the most complex mental inferences. These are also predictors of later performance in ToM tasks (Russel, 1996; Devine & Hughes, 2014; Putko, 2009). However, the nature and direction of the association between EF and ToM remain undetermined (Wade et al., 2018). Some findings suggest a strict interdependence, where each skill reciprocally predicts the other, while others indicate partial dependence due to shared brain regions. These hypotheses may partially explain the robust correlation between EF and ToM throughout childhood, as observed in behavioral measures and findings on normative brain development.

Neuroimaging studies indicates the presence of neural networks activated both during the performance of specific ToM tasks and those related to EF (Molehnberg et al., Johnson, Henry, & Mattingley, 2016; Salehinejad et al., 2021). Evidence also indicates that the performance of ToM and EF tasks is mediated by cortical regions very close to each other; for example, the prefrontal cortex (specifically the medial, orbitofrontal, and dorsolateral areas) and the temporoparietal junction (Schurz et al., 2014). Nonetheless, depending on the type of stimulus task to which an individual is subjected, whether ToM or EF, distinct, diverse and independent cortical networks might also be activated (Molenberghs et al., 2016). These networks appear to be specially designed for mental representation or executive control (Wade et al., 2018), supporting the explanation of directional relationships (EF → ToM or even ToM → EF).

Pineda-Alhucema et al., (2018) conducted a systematic literature review to assess associations between EF and ToM among children with ADHD. They analyzed 15 studies, of which only eight analyzed data statistically. Inhibitory control was the EF subdomain, showing the strongest association, though working memory, cognitive flexibility, and attention were also subdomains associated with ToM. However, due to the studies' limitations, the degree of prediction and predictability between ToM and EF was not established. To the best of our knowledge, no systematic literature reviews or meta-analyses have addressed samples of adults with ADHD to verify these associations.

Note that associations between EF and ToM are not exclusive to ADHD and have already been evidenced among healthy individuals (Wilson et al., 2018; Cho & Cohen, 2019) and other clinical groups, though with specificities. For example, such a correlation in Autism Spectrum Disorder is more robust in tasks that require social, linguistic, and emotional recognition skills for mental inferences (Jones et al., 2017). It tends to be more expressive in Schizophrenia, when the individual is faced with tasks that require inhibitory control and cognitive flexibility (López-Navarro, 2018; Li et al., 2017). Hence, it is relevant to verify such an association in ADHD and whether any EF subdomain presents more significant correlations with ToM.

Although it remains uncertain whether EF is best represented by a single central executive component or by interactions between specialized, potentially dissociated from each other, this topic continues to be debated. Nonetheless, the findings highlight the importance of assessing EF at a more specific level of analysis, as different disorders involving EF impairments may exhibit distinct executive profiles (Diamond, 2013; Ozonoff & Jensen, 1999; Robbins, 1996).

Another matter involves the developmental aspect: does the association between these domains persist throughout one's life cycle and maintain the same specificities? Studies comparing different age groups indicate that specific deficits in EF subdomains explain the deterioration of ToM skills as age advances (Cho & Cohen, 2019). Phillips et al. (2011) verified the influence of age on EF and whether this influence could explain one's performance on ToM tasks in a sample of young, middle-aged, and older adults. They concluded that differences between age groups in the performance of ToM tasks decreased significantly when the EF variable was controlled (especially working memory). Wilson et al. (2018), in turn, assessed the performance of children and adolescents and found significant correlations between increased age and decreased errors when performing EF tasks, resulting in more accurate and faster responses and, consequently, an increased number of correct answers in ToM tasks. Therefore, this evidence shows the relevance of investigating the role of age in moderating the association between EF and ToM in more depth.

Given the foregoing arguments, this study's primary objective was to conduct a systematic literature review, followed by a meta-analysis, to identify the magnitude of the associations between EF and ToM among individuals with ADHD. The secondary objective was to verify whether there are differences in the magnitudes of the correlations and variations depending on the different EF subdomains and developmental stages (children *vs.* adults).

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Additionally, as part of this objective, correlations with groups of healthy individuals were verified.

Based on previous studies conducted with healthy participants across different age groups and various clinical conditions (Chainay & Gaubert, 2020; Devine & Hughes, 2014; Jones et al., 2017; Kong et al., 2021; Lochmann et al., 2023), it is hypothesized that there is a correlation between the constructs, with at least a moderate magnitude. Additionally, the magnitude of these correlations is expected to vary significantly depending on age group (Ferguson et al., 2021; Meinhardt-Injac et al., 2020), specific EF subdomain (Carlson et al., 2002; Pineda-Alhucema et al., 2018), and clinical condition (Tatar & Cansız, 2020).

Method

This study complied with the methodological guidelines recommended by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA – Shamseer et al., 2015) and was registered on the PROSPERO platform (CRD42023449055). A specialist librarian recommended a systematic research strategy to identify the studies in the following databases: PubMed, Web of Science, Embase, Scopus, PsycInfo, Redalyc, and Scielo (the last search was performed on January 8, 2024). The following combinations of keywords were based on the study by Pineda-Alhucema et al. (2018): ("attention deficit disorder with hyperactivity" OR "attention deficit disorders with hyperactivity" OR "attention deficit disorder" OR "attention deficit disorders" OR "attention deficit hyperactivity disorder" OR "attention deficit hyperactivity disorders" OR "ADHD" OR "ADDH" OR "hyperactivity" AND "theory of mind" OR "social cognition" OR "mentalizing" OR "false belief" OR "false beliefs" OR "mental attribution" OR "mindread" OR "mindreading" OR "mental attribution" OR "ToM abilities" OR "ToM ability" OR "mindblindness" AND "executive functions" OR "executive control" OR "inhibitory control" OR "cognitive flexibility" OR "working memory" OR "shifting" OR "planning" OR "executive functioning").

The following were included in the review: a) original articles regardless of the date of publication, language, or methodological design; b) addressing human subjects regardless of gender or age and including at least an independent/exclusive group of people diagnosed with ADHD according to the criteria of the Diagnostic and Statistical Manual of Mental Disorders (DSM) or the International Statistical Classification of Diseases and Related Health Problems (ICD) (note - the studies were not required to have a group of healthy controls); and c) simultaneously assessing EF (and/or its subdomains) and ToM and analyzing potential associations. Exclusion criteria were articles: a) using duplicate samples; b) addressing a sample of people with ADHD and comorbidities with other neurodevelopmental disorders; and c) missing raw data (even after a request was sent to the authors by email).

Two researchers, experts in mental health (DAF and FLO), independently verified the studies' eligibility. Disagreements were discussed until a consensus was reached. Next, a manual search for articles was conducted based on the reference lists of the studies already included. The Rayyan software (Ouzzani et al., 2016) was used in the identification and screening stages. Figure 1 and the Supplementary Material (SM1) present the selection process.

The authors also extracted data independently using a form addressing the following variables: a) study characteristics (author(s), year, and country of publication); b) sociodemographic and clinical characteristics of the samples with ADHD and healthy controls (number of subjects, gender, age, education, recruitment source, diagnostic criteria, severity, subtype, comorbidities, intellectual quotient, and medications in use); c) methodological characterization (methodological design, primary objective, and instruments used to assess the outcomes); and d) primary results (comparison of performance between the ADHD and control groups – in the presence of a control group, and correlation coefficients with the respective levels of significance).

The studies' methodological quality was assessed using the Newcastle-Ottawa Scale (NOS; Peterson et al., 2011). Three parameters were considered: sample selection (four items), comparability (two items), and exposure (three items). The researchers performed the analysis independently, then reviewed the scores and resolved disagreements: the more stars, the better the study's methodological quality.

Independent meta-analyses were conducted according to the different EF subdomains and ADHD and healthy control groups. The highest magnitude was chosen when the studies presented more than one correlation measure. Analyses were only performed for subdomains and groups addressed by at least two studies. Subgroup analyses were performed to verify the influence of age groups on the outcome of interest; samples of children and adults were considered separately.

The meta-analytic measurement was estimated, considering the correlation coefficient as the outcome. A random effects model was adopted considering the presence of heterogeneity inherent to the studies (Dersimonian & Laird, 1986). Heterogeneity between the studies was assessed using the Q test (Cochran, 1954) and the I^2 statistic (Higgins, 2003), analyzed according to the following: rates close to zero indicate the absence of heterogeneity; close to 25% indicate low heterogeneity; close to 50%, moderate heterogeneity; and rates close to or above 75% indicate high heterogeneity (Borenstein et al., 2009). Student residuals and Cook's distances were used to verify whether studies would be outliers or influential in the model's context. Studies with a studentized residual larger than the $100 \times (1–0.05/(2 \times k)^{th}$ percentile of a standard normal distribution were considered potential outliers (Pope, 1976). Studies with a Cook's distance above the median plus six times the interquartile range of the Cook's distances were considered influential (Cook, 1979).

The Rank Correlation and Regression Tests were used to assess the presence of potential publication biases, and the standard error of the observed results was used as a predictor to verify the asymmetry of the Funnel Plot (Sterne & Egger, 2001).

The meta-analytic result was interpreted according to the parameters proposed by Streiner & Norman (2003): correlations of magnitude between 0–0.25 were considered absent/weak; between 0.26–0.50, moderate; between 0.51–0.70, strong; and above 0.71 were considered very strong. Jamovi, version 2.3.28, was used to perform the analyses (Jamovi Project, 2023).

Results

Fifteen articles assessing the correlations between EF and ToM in samples of people with ADHD were analyzed (Abdel-Hamid et al., 2019; Aydin et al., 2021; Bigorra et al., 2016; Caillies et al., 2014; Charman et al., 2001; Dyck & Piek, 2012; Farahi et al., 2014; Imanipour et al., 2021; Lavigne et al., 2020; Mary et al., 2015; Miranda et al., 2017; Şahin et al., 2021; Tatar & Cansiz, 2021; Thoma et al., 2020; Yılmaz et al., 2019). Of these, seven separately assessed the outcome of interest in samples of healthy controls (Charman et al., 2001; Dyck & Piek, 2012; Caillies et al., 2014;

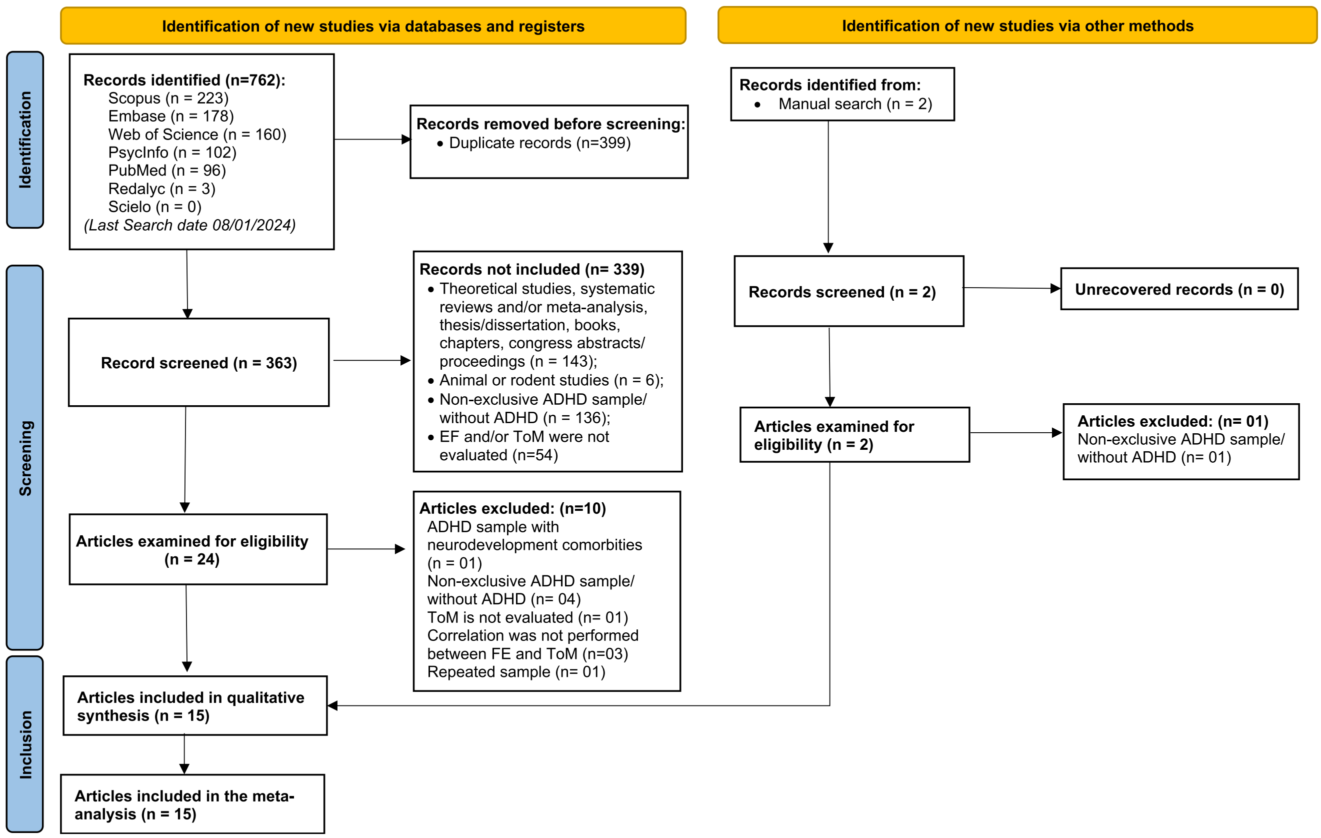

Figure 1. Flow diagram of the process of article search and selection for the systematic review based on the PRISMA protocol (by Page et al., 2021).

Farahi et al., 2014; Thoma et al., 2020; Thoma et al., 2020; Imanipour et al., 2021). The studies were published from 2001 onwards, and the number of publications on this topic significantly increased in the last five years (N = 8; 53.3%), with 80% of the studies conducted in Euro-Asian countries (N = 12). Details about the sampling of the selected articles are presented in Table 1 and SM2.

Table 1 and SM2 show a total of 560 subjects with ADHD and 377 healthy controls. The smallest sample comprised 15 participants and the largest 85; on average, there were 20.7 (± 12.7) participants with ADHD and 18 (± 9.3) in control groups. All studies addressed samples recruited in outpatient settings. On average, the adult participants were 28, and children were 9.5 years old (range 7–14). All studies included samples of both genders, except for Charman et al. (2001), in which the sample exclusively comprised male participants.

Regarding years of schooling, the adult participants with ADHD had 13 years on average, and the children had attended primary school. Only 60% of the studies (n = 9) assessed the participants' intellectual quotient. Standardized instruments were used, and no impairment was found; the other studies did not provide such information.

ADHD was diagnosed or excluded mostly through clinical assessment performed by different mental health professionals (n = 11) or by consulting medical records (n = 03). The primary references used to verify and fulfill the diagnostic criteria were the DSM-IV-TR (n = 5) and DSM-5 (n = 7), often used together with other scales assessing the signs and symptoms of ADHD (n = 7). The ADHD subtype was specified in nine studies, with participants of the combined subtype predominating (n = 218 subjects). The severity of ADHD was seldom explored or reported (n = 6). Most studies (n = 13) investigated the presence of comorbidities with other neuropsychiatric conditions, but most participants did not present them. Note that only four studies addressed participants in the ADHD group who were medication-free or drug-naïve. The participants in 53% of the studies (n = 8) were using psychostimulants, which were interrupted 24 hours before the day of data collection; the other studies (n = 03) failed to report this information.

All studies, except Bigorra et al. (2016), adopted a cross-sectional observational design. Regarding methodological quality, only two of the cross-sectional studies achieved a quality percentage above 75% (Charman et al., 2001; Aydın et al., 2021). Half of the studies (n = 7) met between 56 and 67% of the quality criteria. The weakest points were in the items: a) "Exposure - Non-response rate," given that no study presented the rates of participant loss; b) "Selection - representativeness of the cases," since the samples in 80% of the studies were not representative or the information was not available; c) "Selection– definition controls," as only 50% of the studies (n = 7) ensured that the control participants were selected from the same population as the cases; d) "Exposure – validated instruments," given that less than half of the studies (n = 6) used instruments with adequate psychometric qualities to evaluate outcomes (EF and ToM). Further details are presented in SM3.

Regarding the outcomes of interest, EF was assessed through the following subdomains (non-exclusive categories): inhibitory control (N = 11; 73%), working memory (N = 8; 53%), cognitive

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flexibility (N = 5; 33%), attention processes (N = 4; 27%), planning (N = 3; 20%), and decision-making (N = 1; 7%). Different instruments were used to evaluate this outcome (Table 2); several studies adopted more than one instrument per subdomain (N = 12).

Likewise, various instruments assessed the ToM domain (see Table 2). As proposed by Castelli et al. (2011), all studies adopted at least one instrument classified as "ToM - Higher-order," which assesses the ability of an individual to understand the behavior of others in social situations involving complex mental states, such as gaffes, bluffs, and lies. The Reading the Mind in the Eyes Test (RMET; $N = 7$; 46%) and the Happé Strange Stories ($N = 3$; 20%) were the most frequently used. Six studies adopted more than one instrument to assess ToM (Table 2). Except for Miranda et al. (2017), which used a self-report measure to assess EF, all other studies relied on performance-based measures for evaluating EF or ToM.

Regarding the results, each study's data are described in detail in Table 2. All meta-analytic measurements are summarized in Table 3, Figures 2 and 3, and SM 4.

The meta-analytic correlation measures between ToM and EF were significant for all subdomains and presented a moderate magnitude in the ADHD groups. Subgroup analyses indicated the absence of significant differences between the correlations found between the samples of children and adults for the inhibitory control and working memory subdomains. Due to the restricted number of studies, such analysis cannot be performed for the other subdomains (cognitive flexibility, planning, and attention process). No heterogeneity was found between the studies for the planning and attention. However, moderate/high heterogeneity was found for the inhibitory, working memory, and cognitive flexibility subdomains and it did not decrease significantly in the subgroup analyses.

The correlations between ToM and EF in the healthy control groups were also significant. Although these correlations are of weak magnitude, they do not differ statistically from those observed in the ADHD group, as indicated by comparing confidence intervals in different analyses.

No indicators of potential publication bias were found for any of the study groups (Rank Correlation Test: $p > 0.08$; Regression Test: $p > 0.06$, Funnel Plot without indicators of asymmetry – see SM4A).

Discussion

The results of this systematic literature review with meta-analysis revealed significant and direct associations with moderate magnitudes between the different subdomains of EF and ToM among individuals with ADHD. No significant differences were found in the magnitudes of the correlations when comparing the children and adult samples. The correlations were also significant in the groups with healthy subjects. Despite a tendency for these magnitudes to be lower among the controls, no statistical differences were found from those presented by the ADHD group.

This study's results reinforce evidence in the literature that has already indicated an association between these two cognitive domains in other clinical samples, such as ASD (Jones et al., 2017) and Schizophrenia (Li et al., 2017), and also in non-clinical groups (Cho & Cohen, 2019; Wilson et al., 2018). However, researchers have differing views on the direction of the relationship between EF and ToM. This divergence can be partly attributed to methodological limitations in the field (Wade et al., 2018), as most studies, including those in this review, are correlational and do not allow for the establishment of cause-effect relationships.

Authors such as Russell (1996) argue that EF precedes and promotes the emergence of ToM, as a certain level of executive skills appears necessary to construct complex concepts of mental inferences. They consider that the ability to engage in goal-directed actions, inhibit responses, and overcome cognitive rigidity, among others, is necessary to reflect abstractly about the mental state of others and oneself. For Rowe et al. (2001), EF favors a pragmatic understanding of a narrative, which consequently facilitates understanding non-explicit meanings, grasping different perspectives, and obtaining a deeper understanding of other peoples' intentions, emotions, and mental states.

On the other hand, Perner & Lang (1999) consider that the relationship between these skills occurs in the opposite direction. They argue that a minimum level of understanding and representation of mental states (metarepresentation) is required to achieve better executive control. For Hughes & Ensor (2007), this association is explained by the fact that the two abilities share, at least in part, common aspects, such as the need for a conditional reasoning structure (Putko, 2009) or common or strongly related brain structures (Wade et al., 2018). However, studies with predictive analysis, such as that by Hughes & Ensor (2007), Müller et al. (2012), and Austin et al. (2014), showed greater support for the initial proposition that EF promotes performance in ToM tasks rather than to the proposition that ToM is a prerequisite for the development of EF.

Some studies indicate that the associations between EF and ToM are multifaceted and occur with specificities between the different subdomains (Hughes, 1998). For example, for Rowe et al. (2001), inhibitory control plays a central role in understanding false beliefs, as the individual needs to inhibit his/her context's knowledge to infer the other person's belief. Working memory and cognitive flexibility gains importance in the face of second-order or advanced ToM tasks, which require the individual to have the ability to gather relevant information from the context and the flexibility to switch between his/her mental states and those of others.

The correlations between the different subdomains of EF and ToM showed similar magnitudes in this study, with inhibition and working memory being the most frequently studied subdomains. However, specific correlations between the EF subdomains and the different levels of mental attributions of ToM tasks were not analyzed, given that these levels were mainly of advanced order. The previous review by Pineda-Alhucema et al. (2018), which exclusively addressed child samples, presented findings very similar to this study's, as all EF subdomains correlated with ToM. Based on a qualitative analysis of the study results, Pineda-Alhucema et al. (2018) also highlighted a stronger correlation between ToM and the inhibitory control subdomain.

It is also worth noting that the magnitudes of the correlations found in this study for samples with ADHD are very close to those evidenced in other meta-analyses that also intended to verify correlations between EF and ToM in other clinical groups. The meta-analytic correlation measure found by Joseph & Tager-Flusberg (2004) when addressing ASD samples was 0.59 ($p < 0.01$). The meta-analysis by Thibaudeau, Achim, Parent, Turcotte, & Cellard (2020) showed a measure of 0.30 (95%CI: .26 to .32, $p < 0.01$) for schizophrenia, while Devine & Hughes (2014) conducted a meta-analysis and found a value of 0.38 (95%CI: 0.35 to 0.41) for healthy controls. These findings are noteworthy, as EF is the cognitive domain most frequently impaired in ADHD, which suggest that more robust correlations with ToM might be expected in this clinical group, particularly in comparison to other

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Table 1. Main demographic and clinical characteristics of study samples included in the systematic review (N = 15)

	ADHD Group						Healthy Control Group		
Author (Year) / [Country]	N Sex	Age Years X̄ (SD) Range	Education X̄ (SD)	Diagnostic Resources (Criteria)	Comorbidity (N)	Medicines in use (N)	N Sex	Age Years X̄ (SD) Range	Education X̄ (SD)
Charman et al. (2001) [ENG]	22M	8.6 (1.0) 6 to 10	NI	Clinicians (DSM-IV/ ICD -10)	No ODD	PS (20)*	22M	9.0 (0.7) 6 to 10	NI
Dyck et al. (2012) [AUS]	42M 11F	10.9 (2.0) 7 to 12	NI	Medical Record + SWAN (NI)	LD (2) DD (4)	PS (9)*	42M 11F	10.9 (2.0) 7 to 12	NI
Caillies et al. (2014) [FRA]	10M 5F	9.0 (1.0) 6 to 10	Elementary School	Clinicians + Behavioral/ Neuropsychological Assessments (DSM-IV-TR)	Minor neurological signs	PS (15)*	10M 5F	9.0 (1.0) 6 to 10	Elementary School
Farahi et al. (2014) [IRA]	25MF	9.9 (1.3) 8 to 14	Primary School	(NI)	NI	NI	30MF	9.6 (1.45) 8 to 14	Primary School
Mary et al. (2015) [BEL]	17M 14F	10.3 (0.9) 8 to 12	Primary School	Clinicians + Questionnaires + Cognitive Assessment + DBRS-PV (DSM- IV-TR)	No	PS (14)*	14M 17F	10.0 (0.7) 8 to 12	Primary School
Bigorra et al. (2016) [SPA]	30M 36F	7 –12	Primary School	Medical Record (DSM-IV-TR)	ODD (18) ED (3)	No			
Miranda et al. (2017) [SPA]	33M 2F	9.1 (1.4) 7 to 11	Primary School	Clinicians + Medical Records + CPRS-R (DSM-5)	NI	PS (25)	39MF	8.4 (1.2) 7 to 11	Primary School
Abdel-Hamid et al. (2019) [GER]	15M 15F	34.5 (6.8) ≥18	11.1 years (1.5)	Medical Records + URS-K+ ADHS-SB (DSM-IV-TR)	No	Drug Naive	15 M 15F	35.8 (11.6) ≥18	12.0 years (1.5)
	ADHD Group						Healthy Control Group		
Author (Year) / [Country]	N Sex	Age Years X̄ (SD) Range	Education X̄ (SD)	Diagnostic Resources (Criteria)	Comorbidity (N)	Medicines in use (N)	N Sex	Age Years X̄ (SD) Range	Education X̄ (SD)
Yılmaz et al. (2019) [TUR]	16M 14F	25.6 (6.8) 18 to 65	14.4 years (3.2)	Clinicians + SCID-I (DSM-5)	No	No	15M 15F	25.4 (5.4) 18 to 65	14.8 years (1.9)
Lavigne et al. (2020) [SPA]	44MF	6 - 12	Primary School	Clinicians (DSM-IV-TR or DSM-5)	No	NI			
Thoma et al. (2020) [GER]	9M 10F	36.2 (10.0)	11.3 years (1.9)	Clinicians + WURS-K + SCID I/II (DSM-IV)	DD (7) SDr (1)	PS (12) APs (1) ADs (3)	10M 10F	36.7 (9.9)	11.5 years (1.3)
Tatar et al. (2020) [TUR]	22M 18F	21.7 (4.0)	14.2 years (2.0)	Clinicians + Self-rating scales + WURS + ASRS (DSM-5)	AD, DD, OCD, Phobia (8)	PS (NI)*	22M 18F	21.7 (3.5)	14.10 years (1.8)
Imanipour et al. (2021) [IRA]	11M 14F	9.9 (1.0) 7 to 12	NI	Clinicians (DSM-5)	No psychiatry disease	NI	11M 14F	9.7 (1.0) 7 to 12	NI
Şahin et al. (2018) [TUR]	55M 30F	9.4 (1.7) 7 to 12	NI	Clinicians (DSM-5)	ODD (21) LD (7) ED (6) Phobia (5) DD (5) GAD (5) SAD (4) Conduct (2) Tic (1)	Drug-naïve or no ADHD medications in the last 3 months			
Aydın et al. (2021) [TUR]	23M 17F	23.1 (3.5) 18 –40	15.8 years (1.5)	Clinicians (DSM-5)	No	PS (NI) *	22M 20F	21.7 (2.2) 18 – 40	14.6 years (1.5)

Note. AD = Anxiety Disorder; ADs = Antidepressant; ADHS-SB = Attention Deficit/Hyperactivity Disorder Scale – Self Assessment; ASRS = Adult Attention-Deficit/ Hyperactivity Disorder Self-Report Scale; Aps = Antipsychotics; AUS = Australia; BEL = Belgium; CPRS-R = Connor's Parents Rating Scale – Revised; DBRS-PV = Disruptive Behavior Rating Scale- Parent Version; DD = Depressive Disorder; DSM-5 = Diagnostic and Statistical Manual of Mental Disorders, 5th Edition; DSM-IV = Diagnostic and Statistical Manual of Mental Disorders, 4th Edition; DSM-IV-TR = Diagnostic and Statistical Manual of Mental Disorders, 4th Edition -Text Revision; ED = Elimination Disorder; ENG = England; *F* = Female; FRA = France; GAD = Generalized Anxiety Disorder; GER = Germany; ICD-10 = International Classification of Diseases, 10th Edition; IRA = Iran; LD = Learning Disorder; *M* = male; *N* = Number; NI = Not Informed; OCD = Obsessive Compulsive Disorder; ODD = Oppositional Defiant Disorder; PS = Psychostimulants; SAD = Social Anxiety Disorder; SCID-I/II = Structured Clinical Interview form for DSM-IV-TR axis I and II disorders; SD = Standard Deviation; SDr = Sleep Disorder; SPA = Spain; SWAN = Strengths and Weaknesses of ADHD-Symptoms and Normal Behavior Rating Scale based from DSM-IV; TUR = Turkey; WURS = Wender Utah Rating Scale; WURS-K = Wender Utah Rating Scale – Short Form.
$\bar{x}$ = average
*The authors indicated that medications were withdrawn at least 24 hours before the assessment.

Table 2. Methodological aspects and main results of the studies included in the systematic review (N = 15)

Studies		Instruments			Main results
Author (Year)	Design - Aim	EF Instruments	(Subdomains)	ToM (levels)	Results Descriptions
Charman et al. (2001)	O/CS - To investigate the associations between social competence, ToM, inhibition and planning aspects of executive function in boys with ADHD.	Tower of Hanoi Go/No-Go	(Planning) (Inhibitory Control)	Happé Strange Stories (higher-order)	EF (planning): ADHD = HC (adjusted age/IQ; $p > .10$) EF (inhibitory control): ADHD $<$ HC (adjusted age/IQ; $p < .05$) ToM: ADHD = HC ($p > .10$) ADHD EF (planning) X ToM: $r = .07$ ($p > .05$) EF (inhibitory control) x ToM: r = −.06 ($p > .05$) HC EF (planning) X ToM: $r = .29$ ($p > .05$) EF (inhibitory control) x ToM: $r = .43$ ($p < .01$)
Dyck et al., (2012)	O/CS - To estimate the abilities of children with ADHD in five domains: intelligence language, motor coordination, social cognition, and executive function.	Trial Making/ Updating Memory Goal Neglect Task Go/No-Go Modified Version	(Working Memory) (Working Memory) (Inhibitory Control)	"Sally Ann"; Smarties" and "Ella the Elephant" (1st order) "The Ice Cream Story" (2nd order) Happé Strange Stories (higher-order)	EF (working memory speed and response variability): ADHD $<$ HC ($p < .001$) EF (working memory accuracy average): ADHD = HC ($p > .05$) EF (inhibitory control): ADHD $<$ HC ($p > .05$) ToM (composite score): ADHD = HC ($p > .05$) ADHD EF (working memory speed) x ToM: $r = .32$ ($p < .05$) EF (working memory accuracy) x ToM: $r = .09$ ($p > .05$) EF (inhibitory control) x ToM: $r = .00$ ($p > .05$) HC EF (working memory speed) x ToM: $r = .08$ ($p > .05$) EF (working memory accuracy) x ToM: $r = .10$ ($p > .05$) EF (inhibitory control) x ToM: $r = .18$ ($p > .05$)
Caillies et al. (2014)	O/CS - To characterize the social cognition of children with ADHD, in terms of their understanding of people's recursive mental states and their irony comprehension.	Digit Span Forward/ Backward (WISC-IV) Sentence Repetition (NEPSY) Auditory Attention and Response Set, and Statue (NEPSY)	(Working Memory) (Working Memory) (Inhibitory Control)	"The Ice Cream Story"; "The Birthday Story" (2nd order) Task of Irony Comprehension (higher-order)	EF (working memory composite): ADHD $<$ HC ($p < .01$) EF (inhibitory control composite): ADHD $<$ HC ($p < .01$) ToM (composite score of 2nd order): ADHD $<$ HC ($p < .01$) ToM (Irony): ADHD $<$ HC ($p < .05$) ADHD EF (working memory) x ToM: $r = .27$ ($p > .05$) EF (working memory) x Irony: $r = .43$ ($p > .05$) EF (working memory) x Irony: r = −.06 ($p > .05$) EF (inhibitory control) x ToM: $r = .19$ ($p > .05$) EF (inhibitory control) x Irony: r = −.05 ($p > .05$) EF (inhibitory control) x Irony: r = −.06 ($p > .05$) HC EF (working memory) x ToM: $r = .42$ ($p > .05$) EF (working memory) x Irony: $r = .26$ ($p > .05$) EF (working memory) x Irony: $r = .41$ ($p > .05$) EF (inhibitory control) x ToM: $r = .31$($p > .05$) EF (inhibitory control) x Irony: $r = .62$ ($p < .05$) EF (inhibitory control) x Irony: $r = .82$ ($p < .01$)
Farahi et al. (2014)	O/CS - To compare the relationship between ToM and inhibitory responses in normal children and ADHD.	Stroop Test	(Inhibitory Control)	Theory of Mind Test (1st,2nd, higher-order)	EF (inhibitory control): ADHD $<$ HC ($p < .05$) ToM: ADHD $<$ HC ($p = .0001$) ADHD EF (inhibitory control) x ToM: $r = .60$ ($p = .01$) HC EF (inhibitory control) x ToM: $r = .40$ ($p = .01$) ToM Predicting EF: $R^2 = .46$
Mary et al., (2015)	O/CS: To investigate the hypothesis about potential	Alertness and Divided Attention (TAP Battery)	(Attention) (Inhibitory Control)	Reading the Mind in the Eyes Task (RMET;	EF (attention): ADHD $<$ HC ($p < .001$) EF (inhibitory control – Stroop): ADHD $<$ HC ($p = .003$)

(*Continued*)

Table 2. (*Continued*)

Studies		Instruments			Main results
Author (Year)	Design - Aim	EF Instruments	(Subdomains)	ToM (levels)	Results Descriptions
	ToM dysfunctions in children with ADHD may be attributed to attentional or executive deficits.	Stroop Test Go/No-Go (TAP Battery) Wisconsin Card Sorting Test - Adapted version Flexibility subtest (TAP Battery) Tower of London - Child Adapted version	(Inhibitory Control) (Cognitive Flexibility) (Cognitive flexibility) (Planning)	higher-order) “Faux Pas” Recognition Test (higher-order)	EF (inhibitory control – response time Stroop): ADHD > HC ($p < .001$) EF (inhibitory control) – Go/No-Go): ADHD < HC ($p = .03$) EF (cognitive flexibility – Wisconsin): ADHD < HC ($p < .001$) EF (cognitive flexibility –TAP): ADHD < HC ($p = .001$) EF (planning): ADHD < HC ($p < .001$) ToM (RMET – correct responses): ADHD < HC ($p = .002$) ToM (“Faux pax” – identification question accuracy): ADHD < HC ($p = .04$) ToM (“Faux pax” –false belief): ADHD = HC ($p = .31$) ToM (“Faux pax” – comprehension question): ADHD = HC ($p = .99$) <u>ADHD</u> EF (attention - alertness) x ToM (Faux-Pas): $r = .23$ (p > .05) EF (attention - divided attention) x ToM (Faux-Pas): $r = .39$ ($p < .05$) EF (inhibitory control - response time Stroop) x ToM (Faux-Pas): r = −.57 ($p < .01$) EF (inhibitory control - Stroop) x ToM (Faux-Pas): $r = .26$ (p > .05) EF (inhibitory control - Go/No-Go) x ToM (Faux-Pas): r= − .04 (p > .05) EF (planning) x ToM (Faux-Pas): $r = .043$ (p > .05) EF (cognitive flexibility - Wisconsin) x ToM (Faux-Pas): $r = .41$ ($p < .05$) EF (cognitive flexibility TAP) x ToM (Faux-Pas): $r = .32$ (p > .05) EF (attention - alertness) x ToM (RMET): $r = .31$ (p > .05) EF (attention - divided attention) x ToM (RMET): $r = .18$ (p > .05) EF (inhibitory control - response time – Stroop) x ToM (RMET): r = −.31 (p > .05) EF (inhibitory control - Stroop) x ToM (RMET): $r = .21$ (p > .05) EF (inhibitory control - Go/No-Go) x ToM (RMET): $r = .24$ (p > .05) EF (planning) x ToM (RMET): r = −.11 (p > .05) EF (cognitive flexibility - Wisconsin) x ToM (RMET): $r = .18$ (p > .05) EF (cognitive flexibility - TAP) x ToM (RMET): r = −.33 (p > .05) <u>HC</u>: Correlations were not performed for the HC group.
Bigorra et al. (2016)	RCT - To analyze the far-transfer effect of an intervention using the Robomemo® CWMT on decision-making and ToM in a sample of children with ADHD with or without comorbid disruptive behavior and control group. To analyze the relationship between working memory, decision-making and ToM.	Digit Span Forward/ Backwards (WISC-IV) Letter-Number Sequencing (WISC-IV) Backward Visuospatial Span (WMS-III) Iowa Gambling Taks	(Working Memory) (Working Memory) (Working Memory) (Decision-Making)	Happé’s Strange Stories (higher-order) Reading the Mind in the Eyes Task – children’s version (RMET; higher-order)	<u>ADHD</u> EF (working memory composite score) x ToM (composite score): $r = 0.47$ (p < .001) EF (working memory composite score) x ToM (Happé’s Strange Stories): $r = 0.36$ (p = 0.003) EF (working memory) x ToM (RMET): $r = 0.43$ (p < 0.001) EF (decision-making) x ToM: no correlation was made. EF (decision-making) x EF (composite score): ns (p = .96) <u>HC</u>: Correlations were not performed for the HC group.

Table 2. (*Continued*)

Studies		Instruments			Main results
Author (Year)	Design - Aim	EF Instruments	(Subdomains)	ToM (levels)	Results Descriptions
Miranda et al. (2017)	O/CS - To compare the affect recognition and ToM abilities in children with High-Functioning Autism Spectrum Disorder, ADHD, and Typical Development and to explore the interplay between affect recognition, ToM and Executive Function.	Behavioral Regulation Index (BRIEF) Metacognition Index (BRIEF)	(Inhibitory Control, Shift, Emotional Control and Behavioral Regulation) (Initiate, Working Memory, Planning, Organization of materials, Monitor and Metacognition)	Theory of Mind Subtest (NEPSY-II; 1^{st},2^{nd}, higher-order) Theory of Mind Inventory (ToMI; 1^{st},2^{nd}, higher-order)	ToM (total subscales): ADHD < HC (p < 0.001) ToMI (total subscales): ADHD < HC (p < 0.001) ADHD EF (inhibitory control) x ToM: *r* = .03 (p > .05) EF (shift) x ToM: *r* = .15 (p > .05) EF (emotional control) x ToM: r = −.08 (p > .05) EF (behavioral regulation) x ToM: *r* = .03 (p > .05) EF (initiate) x ToM: *r* = .15 (p > .05) EF (working memory) x ToM: *r* = .01 (p > .05) EF (planning) x ToM: *r* = .32 (p > .05) EF (organization materials) x ToM: *r* = .15 (p > .05) EF (monitor) x ToM: *r* = .08 (p > .05) EF (metacognition) x ToM: *r* = .17 (p > .05) EF (inhibitory control) x ToMI: *r* = .37 (p < .05) EF (shift) x ToMI: *r* = .13 (p > .05) EF (emotional control) x ToMI: *r* = .27 (p > .05) EF (behavioral regulation) x ToMI: *r* = .34 (p < .05) EF (initiate) x ToMI: *r* = .17 (p > .05) EF (working memory) x ToMI: *r* = .06 (p > .05) EF (planning) x ToMI: *r* = .06 (p > .05) EF (organization materials) x ToMI: *r* = .34 (p < .05) EF (monitor) x ToMI: *r* = .39 (p < .05) EF (metacognition) x ToMI: *r* = .21 (p > .05) HC: Correlations were not performed for the HC group.
Abdel-Hamid et al. (2019)	O/CS - To understand if social cognitive impairments in ADHD are selective or are connected to the executive dysfunction that is common these patients.	Trail Making Test - subtest A Trail Making Test - subtest B Stroop Test Go/No-Go	(Visual Attention) (Cognitive Flexibility) (Inhibitory Control) (Inhibitory Control)	Movie for Assessment of Social Cognition (MASC; higher-order)	EF (visual attention): ADHD = HC (p = .54) EF (cognitive flexibility): ADHD < HC (p < .01) EF (inhibitory control – response time): ADHD > HC (p = .01) EF (inhibitory control - Stroop): ADHD < HC (p = .018) EF (inhibitory control – response time Go/No-Go): ADHD = HC (p = .59) EF (inhibitory control – Go/No-Go): ADHD < HC (p < .05) ToM: ADHD = HC (p > 0.68) ADHD EF (cognitive flexibility) x ToM: *r* = 0.41 (p < 0.02) The authors did not show any other results of correlation. HC: Correlations were not performed for the HC group.
Yilmaz et al., (2019)	O/CS - To determine whether impulsivity, ToM, and neurocognitive functions differ in adult ADHD without psychiatric comorbidities compared to a control group. To identify the relationship between these constructs.	Digit Span Forward/ Backwards (WAIS-R) Auditory Silent Three-Letter Ordering Test Stroop Test	(Working Memory) (Working Memory) (Inhibitory Control)	Reading the Mind in the Eyes Task (RMET; higher-order)	EF (working memory – digit span forward/backward): ADHD = HC (p > .05) EF (working memory – auditory silent three letters): ADHD < HC (p = .04) EF (inhibitory control): ADHD < HC (p = .02) EF (inhibitory control – response time Stroop): ADHD = HC (p > .05) ToM: ADHD = HC (p = .78) ADHD EF (working memory – span forward) x ToM: r = −.03 (p = .85) EF (working memory – span backward) x ToM: *r* = .16 (p = .38) EF (working memory – auditory silent three letters) x ToM: *r* = .18 (p = .34) EF (inhibitory control) x ToM: *r* = .19 (p = .31) EF (inhibitory control – response time Stroop) x ToM: *r* = .06 (p = .74) HC: Correlations were not performed for the HC group.

(*Continued*)

Table 2. (*Continued*)

Studies		Instruments			Main results
Author (Year)	Design - Aim	EF Instruments	(Subdomains)	ToM (levels)	Results Descriptions
Lavigne et al. (2020)	O/CS -To investigate the relationships between ToM, working memory, and vocabulary in primary education students with ADHD	Digit Span Forward/ Backward (WISC-IV) Letter-Number Sequencing (WISC-IV)	(Working Memory) (Working Memory)	Theory of the Verbal Mind Subtest (NEPSY-II 1st,2nd, higher-order)	ADHD EF (working memory composite score) x ToM: $r = .51 (p < .001)$ EF predicting ToM: $R^2 = .29$ HC: Correlations were not performed for the HC group.
Tatar et al., (2020)	O/CS - To examine differences in ToM, attention, and executive function performances between adults with ADHD and healthy controls. To investigate the relationship between these constructs.	Trail Making Test - subtest A Trail Making Test - subtest B Continuous Performance Task	(Visual attention) (cognitive flexibility) (attention and inhibitory control)	Reading the mind in the eyes test (RMET; higher-order)	EF (visual attention – response time): ADHD > HC (p = .74) EF (cognitive flexibility -response time): ADHD > HC (*p = .00*) EF (attention): ADHD < HC (p < .001) EF (inhibitory control): ADHD < HC (p < .001) ToM: ADHD < HC (p = .003) ADHD EF (visual attention) x ToM: r = –.01 (p = 0.97) EF (cognitive flexibility) x ToM: $r = .38$ (p = .015) EF (attention) x ToM: $r = .21$ (p = .17) EF (inhibitory control) x ToM: $r = .11$ (p = .48) EF (cognitive flexibility) predicting ToM (RMET): $R^2 = 0.146$ (with the adjusted $R^2 = 0.123$). HC EF (visual attention) x ToM: r = - .038 (p = 0.81) EF (cogn itive flexibility) x ToM: r = - .013 (p = 0.94) EF (attention) x ToM: $r = .25$ (p = .12) EF (inhibitory control) x ToM: $r = .26$ (p = .10)
Thoma et al. (2020)	O/CS - To investigate social problem-solving strategies in adults with ADHD and to assess executive function and trait empathy.	Trail making test - subtest A trail making test - subtest B letter-number sequencing (WAIS) Color-Word-Interference Task	(Visual attention) (cognitive flexibility) (working memory) (inhibitory control)	mentalistic interpretation subscale (Task for the assessment of social cognition): judgment and generation (higher-order)	EF (visual attention - response time): ADHD = HC (p > .07) EF (cognitive flexibility - response time): ADHD = HC (p > .07) EF (working memory): ADHD = HC (p = .38) EF (inhibitory control): ADHD = HC (p = .59) ToM: ADHD = HC (p>. 20) ADHD EF (visual attention) X ToM (judgment): $r = .30$ (p = .21) EF (visual attention) X ToM (generation): $r = .06$ (p = .78) EF (cognitive flexibility) X ToM (judgment): $r = .06$ (p = .81) EF (cognitive flexibility) X ToM (generation): $r = .07$ (p = .78) EF (working memory) X ToM (judgment): $r = .04$ (p = .86) EF (working memory) X ToM (generation): $r = .16$ (p = .53) EF (inhibitory control) X ToM (judgment): $r = .04$ (p = 88) EF (inhibitory control) X ToM (generation): $r = .19$ (p = .44) HC EF (visual attention) X ToM (judgment): $r = .24$ (p = .31) EF (visual attention) X ToM (generation): $r = .21$ (p = .35) EF (cognitive flexibility) X ToM (judgment): $r = .08$ (p = .72) EF (cognitive flexibility) X ToM (generation): $r = .03$ (p = .90) EF (working memory) X ToM (judgment): $r = .08$ (p = .71) EF (working memory) X ToM (generation): $r = .20$ (p = .40) EF (inhibitory control) X ToM (judgment): $r = .22$ (p = .35) EF (inhibitory control) X ToM (generation): $r = .$ 16 (p = .49)
Imanipour et al. (2021)	O/CS - To explore the association between biological motion performance, emotion regulation, ToM, and working memory in children with ADHD.	Digit span forward/ backward (WISC-IV)	(Working memory)	Reading the mind in the eyes test (RMET) – child version (higher-order)	EF (working memory): ADHD < HC (p = .001) ToM: ADHD < HC (p = .01) ADHD EF (working memory) x ToM: $r = .60$ (p = .01) HC EF (working memory) x ToM: $r = .22$ (p = .36)

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Table 2. (*Continued*)

Studies		Instruments			Main results
Author (Year)	Design - Aim	EF Instruments (Subdomains)		ToM (levels)	Results Descriptions
Sahin et al., (2021)	O/CS - To support children with ADHD, who have ToM deficit, to find new approaches and intervention areas to improve their social cognitive skills.	Stroop test – basic sciences research group	(Inhibitory control)	Reading the mind in the eyes test (RMET; higher-order) Higher-order: "Faux Pas" Recognition Test (higher-order)	ADHD EF (inhibitory control – interference time) x ToM (RMET): r = – .30 (p = .006) EF (inhibitory control – interference time) x ToM (Faux Pas): r = – .34 (p = .001) HC: Correlations were not performed for the HC group.
Aydin et al., (2021)	O/CS - To examine whether cognitive flexibility, emotion recognition, and metacognitions differed between adult ADHD and healthy controls. To assess whether these variables have predictive value for ADHD symptoms.	Wisconsin card sorting test	(Cognitive flexibility)	Reading the mind in the eyes test (RMET; higher-order)	EF (cognitive flexibility): ADHD = HC (p > .93) TOM (RMET): ADHD = HC (p = 0.12) ADHD EF (cognitive flexibility) x ToM (RMET): *r* = .40 (p < .05) HC: Correlations were not performed for the HC group.

Note. ADHD = Attention Deficit Hyperactivity Disorder; BRIEF = Behavior Rating Inventory of Executive Function; EF = Executive Function; HC = Health Control; IQ = Intelligence Quotient; MASC = Movie for Assessment of Social Cognition; NEPSY = Neuropsychological Assessment Battery) ns = not significative; O/CS = Observational / Cross-Sectional; RCT = Randomized Controlled Trial; RMET = Reading the Mind in the Eyes Task; TAP = Test for Attention Performance; ToM = Theory of Mind; WAIS-R = Wechsler Adult Intelligence Scale, Revised; WISC-IV = Wechsler Intelligence Scale for Children, Fourth Edition; WMS-III = Wechsler Memory Scale, Third Edition.

* The levels of ToM were classified using Castelli et al. (2011) as a reference.

Table 3. Results of metanalytic measurements involving correlations between different domains of Executive Functions (EF) and Theory Of Mind (ToM)

			Metanalytic measures		Heterogeneity		Study		Publication bias			Subgroup analysis - age		
Correlation ToM vs	Group	N° of studies (C / A)	*r* (95%CI)	Classif.	I^2	Q-test p value[1]	Outlier	Influential	Rank correlation Test *p* (< .05)	Regression Test p (p < .05)	Funnel Plot	Children *r* (95% CI)	Adults *r* (95% CI)	*p* value
Response inhibition	ADHD	10 (6C / 4A)	.28 (.12 to .43)	Moderate	55.01%	.017	No	No	.38	.09	No	.31 (.07 to .54)	.21 (.04 to .38)	0.52
	HC	06 (4C / 2A)	.40 (.15 to .65)	Moderate	79.02%	.0002	Caillies et al. (2014)[a]		1.0	.06	No	.47 (.14 to .79)	.25 (.08 to .42)	0.41
Working memory	ADHD	08 (6C / 2A)	.38 (.26 to .51)	Moderate	35.2%	.14	No	No	.39	.06	No	.42 (.29 to .55)	.17 (–.02 to .53)	0.20
	HC	04 (3C / 1A)	.20 (.02 to .38)	Weak	0%	.67	No	No	.75	.32	No	.20 (.00 to .39)	–	–
Cognitive flexibility	ADHD	5 (1C / 4A)	.37 (.24 to .51)	Moderate	0%	.77	Thoma et al. (2020)[a]		.82	.22	No	–	.36 (.21 to .51)	–
	HC	2 (0C / 2A)	.02 (–.16 to .20)	NS	0%	.98	No	No	.08	.65	No	–	.02 (–.16 to .20)	–
Planning	ADHD	3 (3C / 0A)	.32 (.13 to .51)	Moderate	0%	.39	No	No	.33	.19	No	.32 (.13 to .51)	–	–
Attention process	ADHD	3 (1C / 2A)	.30 (.11 to .49)	Moderate	0%	.71	No	No	1.0	.98	No	–	.24 (.07 to .41)	–
	HC	2 (0C / 2A)	.25 (.08 to .42)	Weak	0%	1.0	No	No	.08	.96	No	–	.25 (.08 to .42)	–

Note. A = Adults samples; ADHD = Attention Deficit Hyperactivity Disorder samples; *C* = Children samples; CI = Confidence Interval; Classif. = classification of the magnitude of correlations based on Streiner & Norman (2003); HC = Healthy Controls samples; I^2 = I-squared; NS = Not Significant; *Q* = Cochran's Q test; ToM = Theory of Mind.

[a] This study, if excluded, would not significantly alter the metanalytic measure; therefore, it was retained in the analysis because there was no justification for its exclusion.

- The analysis was not conducted due to lack of studies or the presence of only one study.

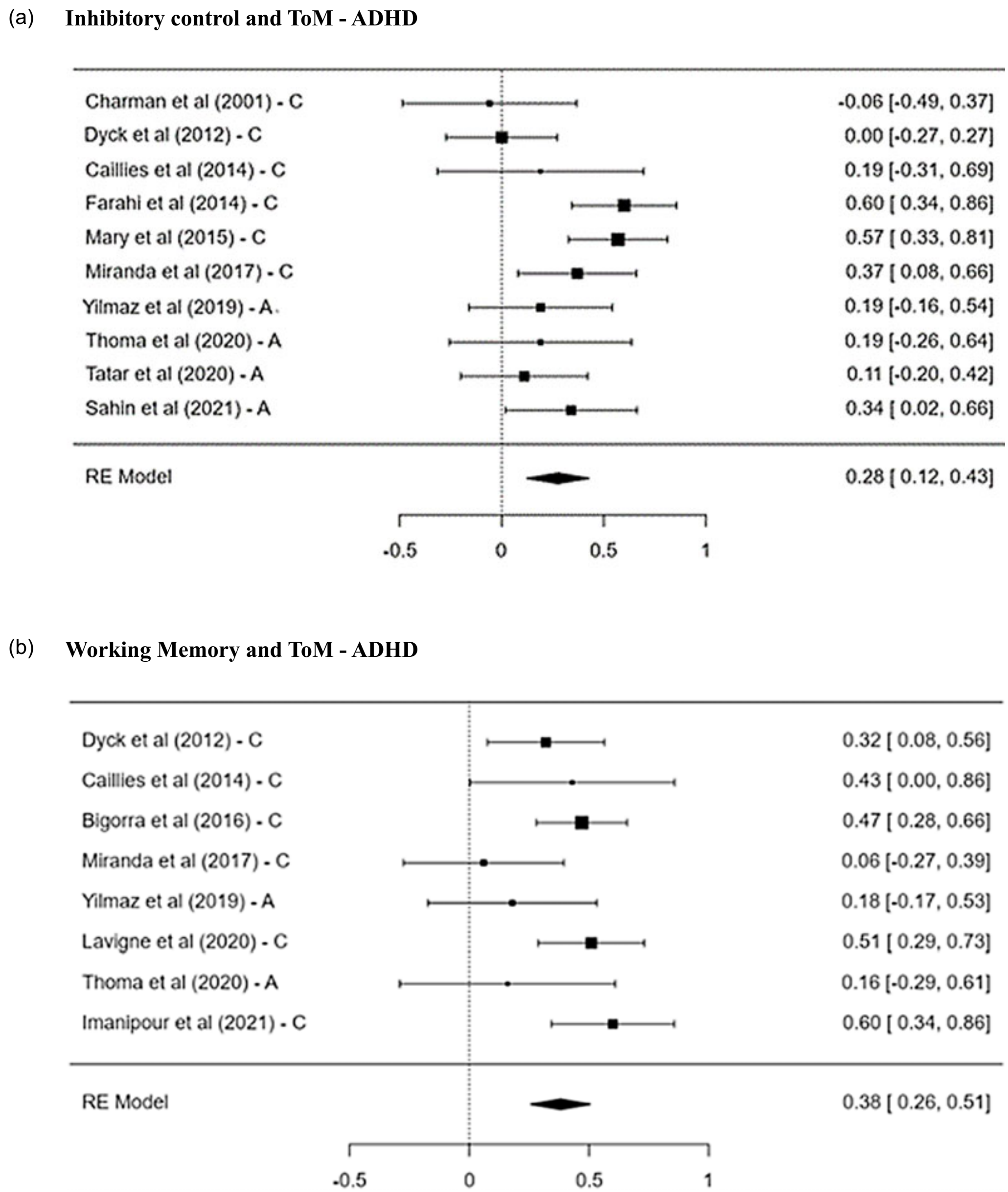

Figure 2. Metanalytic results of the correlations between Executive Functions (Subdomains of inhibitory control and working memory) and Theory of Mind (ToM) for ADHD group. *note*. A = adults≥18 years; C = children < 18 years; HC = healthy control; ADHD = attention deficit hyperactivity disorder. A - inhibitory control subdomain versus ToM in the total sample of ADHD; B - working memory subdomain versus ToM in the total sample of ADHD.

disorders where EF is not the primary area of impairment. Future studies are suggested to analyze in more depth whether this relationship suffers specific influences depending on the clinical group and the severity of the pathology.

Another aspect to be highlighted is that a moderate magnitude of the correlation between these two domains is found in most of the literature. Such a finding is supported by studies involving neuroimaging, which verified the same activations of specific brain regions (e.g., prefrontal cortex, temporoparietal junction) in both EF and ToM tasks, indicating the existence of neural network operations mediating both abilities (Molenberghs et al., 2016; Menon & D'Esposito, 2021). At the same time, findings regarding the activation of independent regions also indicated the existence of specific neural processes involved in each domain (Wade et al., 2018). Furthermore, other factors are known to directly or indirectly influence ToM skills, explaining part of the variability in the performance of tasks that assess them, such as language (Devine & Hughes, 2014; Wade et al., 2018), learning (Bora & Pantelis, 2015; Tucci & Easterbrooks, 2020), and cultural context (Sabbagh et al., 2006), among others.

The age variable might be another mediating factor of EF and ToM skills (Ferguson et al., 2021; Meinhardt-Injac et al., 2020), as maturational and developmental aspects are closely linked to the acquisition and impairment of these skills (Gigi & Papirovitz, 2022). Devine and Hughes (2014) consider it important to investigate whether the associations between EF and ToM become more specific with age as EF develops. For example, studies analyzing the associations between ToM, aging, and EF emphasize the role of inhibition (Bailey & Henry, 2008) and working memory (Phillips et al., 2011) in differences in the performance of ToM tasks, depending on age.

Therefore, this study tested whether age significantly influences the magnitude of correlations between these skills. This aspect could only be analyzed in the inhibitory control and working memory subdomains, and contrary to previous studies, no significant differences were found when comparing children and

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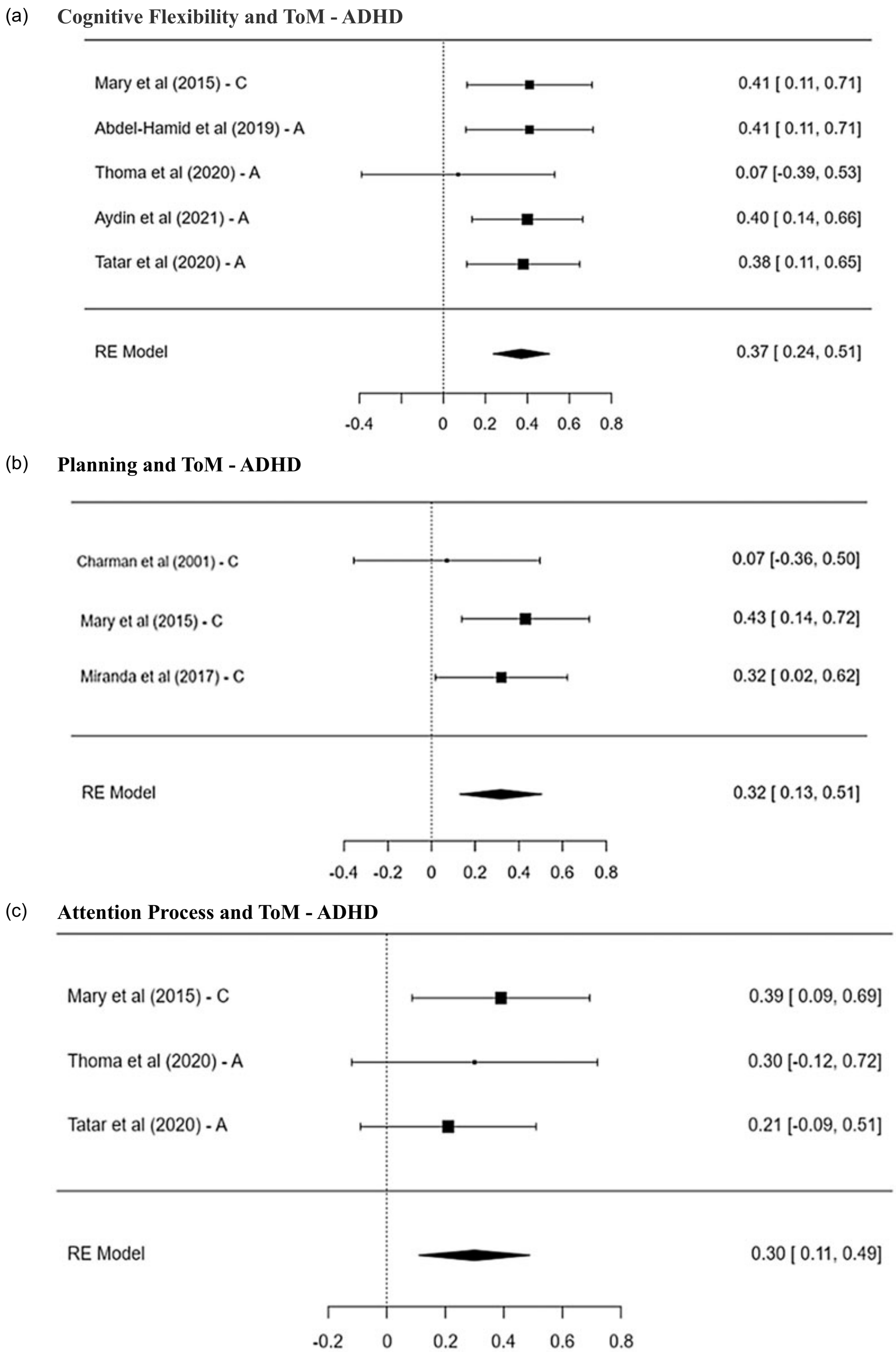

Figure 3. Metanalytic results of the correlations between executive functions (Subdomains of cognitive flexibility, planning and attention process) and Theory of Mind for attention deficit hyperactivity disorder group.

adult samples. Although this finding is not consensual in the literature (Bailey & Henry, 2008), such differences may not have been captured by the studies addressed here, as they predominantly assessed 9-10 years old and young adults aged 28 on average. There were no samples from more extreme age groups where specific developmental differences could be observed. Additionally, some samples included participants within age ranges that could exhibit differences, even if subtle, in EF development (e.g., Dyck & Piek, 2012; Imanipour et al., 2021; Sahin et al., 2021—groups aged 7-12). These aspects should be taken into account. According to Best and Miller (2010), EF develops rapidly during childhood, with the most pronounced age effects observed in children aged 5–7; moderate effects are found among those aged 8–15, and adolescents aged 15–17 show minor effects. Hence, future studies should investigate this aspect further.

The studies analyzed here presented some limitations that must be accounted for in the generalization of results. As previously mentioned, one limitation concerns the samples, which were poorly represented by children in the early stages of development and older adults. Moreover, clinical samples were poorly identified according to the subtype of ADHD and were predominantly composed of people on the continuous use of medication to control ADHD symptoms.

Another important limitation concerns the lack of consensus on the understanding and systematizing of the EF structure, subdomains, and their measurement instruments. According to Snyder et al. (2015), several neuropsychological instruments used to evaluate EF assess more than one of their subdomains, as well as non-EF-related skills. In their view, such a context favors inconsistency of responses and low reliability and sensitivity of the measure of interest, which can impact the evaluation of the construct and the level of correlation with other measures.

Furthermore, self-report and performance-based instruments may assess EF differently (individual perception *vs.* objective measures of executive skills), potentially leading to biased results. Previous studies have shown inconsistent relationships between these measures, ranging from no correlation to moderate correlations, suggesting that self-report measures have limited ability to assess EF cognitive performance (Heilmann, 2022). Nevertheless, since the analyses did not indicate Miranda et al. (2017) - the only study using self-report measures - as an outlier, it was retained in the dataset. However, researchers should consider this variable in future studies.

This framework hinders more robust analyses, such as meta-regressions, due to the considerable variability of instruments and the scarcity of studies accounting for these measurement specificities. Future research should further explore and systematize these aspects.

Other limitations relate the instruments used to assess ToM, as many of them contain verbally demanding tasks. Given that verbal difficulties are relatively common in ADHD, verbal assessments may introduce bias. Furthermore, Quesque & Rossetti (2020) point out that not all of ToM instruments require the participants to engage in mental representation or distinguish between their mental states and those of others. These instruments fail to meet the two main criteria characteristic of ToM measures: "mentalization" and "nonmerging." In this sense, it is worth highlighting the instrument most frequently used in the studies reviewed—the RMET. We argue that the RMET cannot be considered a ToM instrument, as it does not meet either of the previously mentioned criteria; rather, it is regarded as a measure of visual discrimination and state identification (Quesque & Rossetti, 2020). However, other researchers contend that the RMET enables individuals to make mental inferences through the direct reading of facial expressions, and for this reason, it serves as a ToM index (Baron-Cohen et al., 2001; Putko, 2009).

It should also be noted that many of the instruments used to assess both outcomes, especially ToM, lacked adequate psychometric indicators, which affects the methodological quality of the studies. These observations highlight the need to strengthen the theoretical foundation of the concepts, terminologies, and instruments related to EF and ToM. Addressing these challenges remains a key priority for researchers in the field.

The conclusion is that this study's hypotheses were partially confirmed, as the association between EF and ToM was significant with a moderate effect size. However, no significant differences were found based on age, ADHD, or the specific executive function domain assessed. Future studies should focus on expanding the age groups and addressing the previously mentioned limitations and confounding variables regarding the constructs and instruments to achieve more robust conclusions.

Supplementary material. The supplementary material for this article can be found at http://dx.doi.org/10.1017/S1355617725000190.

Availability of data and materials. This metanalysis includes detailed search parameters and *MeSH* terms to ensure replicability of the search and findings. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Authors contributions. All authors contributed to the study's conception and design. DAF and FLO prepared the material, collected data, and analyzed it. All authors read and approved the final manuscript.

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